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Functional components and consumption frequency of "chapulines" fed on alfalfa vs. corn in the Sierra Sur region of Oaxaca

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Abstract

Aim: To explore the potential contribution of ω-3 fatty acids and fiber from traditionally cooked adult chapulines (*Sphenarium purpurascens*) to the diet of consumers in the Sierra Sur region of Oaxaca.

Methods: Exploratory study in two phases. In the first stage, preliminary interviews were conducted with retailers of the edible insect *S. purpurascens* at the traveling market in the city of Miahuatlán de Porfirio Díaz, Oaxaca. Proximate analyses were also performed in triplicate and fatty acid profiles were determined by gas chromatography on samples of cooked adult *S. purpurascens* fed on alfalfa and corn (Mesoamerican polyculture), collected at the same market. The information was analyzed using descriptive statistics, confidence interval comparisons, and Welch's *t*-test. The second phase consisted of a survey (n = 144) to estimate the average intake (g/day) and frequency of consumption of *S. purpurascens* by its buyers in the aforementioned market. The information was analyzed using descriptive statistics and the Kruskal-Wallis test.

Results: Alfalfa-fed *S. purpurascens* had 6.4 times more fiber (57.80% vs. 8.96%) than their corn-fed counterpart ($p < 0.001$), with the ω-6:ω-3 ratios being 0.60 and 0.59 in the corn- and alfalfa-fed samples, respectively. The most frequent consumption of *S. purpurascens* reported by buyers was 1–2 days per week (51%), and the average intake of all respondents was 27.5 g/day. This amount would provide 12.4% of the average daily requirement of omega-3 for adults and 39.7% of fiber if the alfalfa-fed insect is considered.

Conclusions: Alfalfa-fed adult *S. purpurascens* provide a high fiber content to the diet of their consumers, and those fed alfalfa or corn provide a moderate amount of ω-3 fatty acids, which can help balance the ω-6:ω-3 ratio.

Keywords

edible insects, sustainable food system, functional food, nutrition surveys

Introduction

Humans have been eating insects since prehistoric times [1] and, to a greater or lesser extent, this has occurred in most cultures [2]. Thus, in the 21st century, around two million people worldwide consume insects as part of their diet, mainly in regions of Asia, Africa, and Latin America [3].

In Mexico, approximately 549 species of insects are incorporated into culinary traditions [4]. In addition, approximately 85 species of edible insects have been identified in Oaxaca, Mexico [5]. One of these species, *Sphenarium purpurascens* (Charpentier, 1845), is particularly significant in the state's culinary heritage and is commonly referred to as the "*chapulin*" [6].

In Oaxaca, the harvesting of *S. purpurascens* traditionally begins with the June rains and lasts until December. It is mainly carried out in alfalfa pastures (*Medicago sativa*) and cornfields (Mesoamerican polyculture centered around *Zea mays*). However, the expansion of urban land has led to less local harvesting and more importation of the insect [6]. Thus, most of the *S. purpurascens* sold commercially comes from the Mexican states of Puebla and Tlaxcala, although a minority still comes from the Central Valleys region of Oaxaca [6]. Under these circumstances, the price per gram of protein from *S. purpurascens* is higher than that of eggs, meat, and dairy products [7], and 30% of the supply is perennial [6].

In nutritional terms, *S. purpurascens* contains between 50–75% protein and 6–11% fat [8]. Its fiber content has been reported to range from 3.9% to 32.2% [9–12], and *S. purpurascens* raised on a corn diet contains 20–25% less fiber than those fed alfalfa [11] or soybean [12] diets.

As for the fatty acid profile, *S. purpurascens* has been analyzed in only two studies, which identify 20% [12] and 69% [10] of polyunsaturated fatty acids, a difference that could be due to the insect's diet [9]. However, only one of the studies specifies the diet of *S. purpurascens* and how, depending on whether it is based on corn or soy, it significantly changes the fatty acid profile and the ω-6:ω-3 ratio [12].

Furthermore, *S. purpurascens* is a functional food, a classification attributed to its fiber and polyunsaturated fatty acid content. These biomolecules, in addition to their nutritional value, have the capacity to modulate one or more metabolic processes that contribute to the promotion of health [13]. The fiber is primarily composed of chitin, a substance found in the exoskeleton of the insect [14, 15]. Insoluble chitin has been shown to assist in the treatment of constipation [16], possess anti-inflammatory properties [17], and promotes colonic eubiosis [17]. Conversely, polyunsaturated fatty acids have demonstrated the capacity to mitigate the risk of disorders and diseases associated with inflammatory processes, including cardiovascular disease [18].

However, despite the existence of nutritional composition analyses, no study has examined the contribution of *S. purpurascens* to the human diet under real culinary processing conditions or the amount ingested by consumers. Thus, there is a research gap regarding its effectiveness as a functional food since effectiveness is the extent to which a treatment works under real-world conditions [19].

It is imperative to address the issue of culinary processing, as it invariably results in a modification of the nutritional value of foods [20]. In the case of *S. purpurascens*, the physical and chemical factors intrinsic to cooking have the potential to influence the oxidative stability of polyunsaturated fatty acids [18].

The other significant condition that may influence the effectiveness of *S. purpurascens* as a functional food is the amount ingested, given that the favorable effect of a functional food is contingent not only on its bioactive compounds but also on the dose-response curve according to the physiological context of the consumer [21].

Indeed, although the therapeutic efficacy of bioactive components such as ω-3 fatty acids [22] and fiber [17] is well known, their effectiveness as components of *S. purpurascens* cooked and consumed in normal

quantities in real-life contexts is unknown. Thus, the aim of this report is to explore the potential contribution of ω-3 fatty acids and fiber from traditionally cooked adult *S. purpurascens* to the diet of consumers in the Sierra Sur region of Oaxaca.

Materials and methods

This is a two-phase exploratory study. The first phase examined the nutritional content of *S. purpurascens* available at the weekly traveling market in the city of Miahuatlán de Porfirio Díaz (CMPD), located in the Sierra Sur region of the Mexican state of Oaxaca. The second phase determined the quantity and frequency of consumption of *S. purpurascens* among adults who purchase this food at the market. This report is part of a research project approved by the Research Ethics Committee of the Universidad de la Sierra Sur under number CEI-02 and registration number SPN/02/25042019.

Phase I

In January 2019, six consistent points of sale for *S. purpurascens* were identified, where a social scientist interviewed vendors about the origin and processing of the insect prior to its retail sale. At the point where the vendor provided sufficient information, samples of adult *S. purpurascens* (with visible vestigial wings and a length greater than 1.8 cm) were collected for analysis. These had been cooked and fed on two diets: alfalfa and corn, both collected in November and stored for a month and a half prior to retail sale, according to the vendor's testimony.

For each type of *S. purpurascens* (alfalfa and corn-fed), a proximate analyses were performed in triplicate using the methods listed in Table 1, and a fatty acid profile was obtained by gas chromatography using the AACCI 58-18.01 method [23], in the agri-food technology laboratory of the CIIDIR Oaxaca Polytechnic Unit for Social Integration. The fatty acid profile was performed in a single run due to budgetary constraints of the study, so it was not possible to estimate analytical variability or establish precision limits for this profile.

Table 1. Methods employed for the proximate analysis of *Sphenarium purpurascens*.

Parameter	Method
Moisture	AOAC (13.002) [24]
Ash	AOAC (13.005) [24]
Protein	AOAC (13.011) [24]
Fiber	NMX F 613 NORMEX 2003※ [25]
Fat	AOAC (13.031) [24]

※: Crude fiber was determined according to NMX-F-613-NORMEX-2003, a Mexican standard adapted from ISO 5498:1981 to suit local conditions. NMX: Mexican Standard; NORMEX: Mexican Society for Standardization and Certification.

The results of the proximate analyses of alfalfa and corn-fed *S. purpurascens* were compared by mean difference and Cohen's d, as well as 95% confidence intervals (CI), and Welch's *t*-test. The fatty acid profiles were compared descriptively.

Phase II

The number of survey participants was calculated using the formula for estimating population parameters (means) in infinite populations [26], using data from a previous survey. Thus, during January 2019, the questionnaire was administered to 144 people who purchased *S. purpurascens* at two locations in the CMPD traveling market; although the selection was by consecutive sampling, when people met the following criteria: a) 18 years of age or older; b) regular consumers of adult *S. purpurascens*; c) willingness to participate in the study.

The questionnaire administered by a nutritionist inquired about the frequency of consumption of adult *S. purpurascens* during the week or month prior to the interview. In addition, the amount eaten (grams) per meal was measured using a digital kitchen scale on which the respondent—observed by the nutritionist—

placed the portion they reported eating with their own hands. This was done to activate sensory memory and improve the accuracy of the response.

Using Jamovi version 2.3.28, consumption data were analyzed using descriptive statistics (percentages, medians, and quartiles). Likewise, the average intake ratios of *S. purpurascens* (g/day) (number of times per week or per month) were compared using the nonparametric Kruskal-Wallis test as they showed abnormal distributions and heteroscedasticity.

Lastly, based on the median and interquartile range (IQR) of the regular consumption of *S. purpurascens* identified and its nutritional content on a wet basis, the percentages of adequacy of its fiber and ω-3 fatty acid content were calculated in relation to the recommended daily intake for adults according to international references [27, 28].

Results

According to the testimony of the vendor interviewed who provided the samples of *S. purpurascens* that were analyzed, the origin of these samples was the municipality of Ocotlán de Morelos (16.79151° N, 96.67455° W, and an altitude of 1,644 meters based on WGS84), Oaxaca, where this insect is a pest of green alfalfa pastures and cornfields; however, the organized social response to control it is sustainable extraction. This is mainly done with nets and occasionally by hand, by people who collect, purge (store the insects in plastic bags for 24 hours), and sell the raw insects wholesale by the sack.

The vendor interviewed said that he buys the insect in bulk and cooks it at home. Culinary processing consists of placing *S. purpurascens* in a pot with previously boiled water, washing them, and draining them manually to remove impurities (soil, plants, and others). They are then poached (70°C–85°C) for 10–12 minutes. Once drained using a manual strainer, cooking continues on a griddle over low heat (around 90°C) for one hour, stirring and mixing the food constantly with a wooden spoon (to avoid damaging the insects). At the 45-minute mark, garlic blended with lemon juice is added, along with salt to taste.

Among the results of the proximate analysis, it is noteworthy that alfalfa-fed adult insects cooked as described contain on average 6.4 times more dietary fiber than those that were corn-fed, and this difference is not attributable to chance (Table 2). In contrast, differences in other nutritional parameters are attributable to chance, due to the bilateral nature of the CI and the *t*-test results.

Table 2. Comparison of bromatological parameters on a dry basis between adult alfalfa and corn-fed *Sphenarium purpurascens*.

Parameter	Alfalfa (A) (%)	Corn (C) (%)	Difference in means A–C	95% CI of the difference in means	*t*※	*d*	*p*-value
Moisture	21.4 ± 0.5	21.0 ± 0.4	0.40	–0.7 to 1.5	1.08	0.88	0.343
Ash	14.36 ± 0.45	13.75 ± 0.13	0.61	–1.36 to 0.14	2.26	1.84	0.131
Protein	52.8 ± 1.27	52.49 ± 1.27	0.31	–3.19 to 2.57	0.30	0.78	0.780
Fiber	57.8 ± 0.46	8.96 ± 0.18	48.84	–49.63 to –48.05	171.25	139.83	< 0.001※
Fat	6.04 ± 0.37	5.13 ± 0.58	0.91	–3.19 to 2.57	2.29	1.87	0.093

※: Only fiber showed a significant difference according to Welch's *t*-test at the 95% confidence level. Note: values expressed on a dry basis, except for moisture. The sums do not add up to 100% due to the independent nature of each analysis.

The proportions of fatty acids are similar in both types of *S. purpurascens* (Table 3). They provide fewer a lower proportion of ω-6 polyunsaturated fatty acids (linoleic C18:2) and a higher proportion of ω-3 polyunsaturated fatty acids (linolenic C18:3 *n*-3). The latter is the most deficient in the diets of modern industrial societies, which are characterized by a pro-inflammatory imbalance associated with a higher proportion of ω-6 [29]. Thus, ingesting *S. purpurascens* could contribute to balancing the ω-6:ω-3 ratio, which, the closer it is to 1:1, would favor the modulation of inflammatory responses associated with various diseases and their complications [30, 31].

Table 3. Fatty acid profile in adult alfalfa and corn-fed *Sphenarium purpurascens*.

Fatty acids	Alfalfa (%)	Corn (%)
Saturated	**66.45**	**70.13**
Caprylic C8:0	0.04	0.03
Lauric C12:0	50.32	55.84
Miristic C14:0	0.57	0.49
Pentadecylic C15:0	0.06	0.08
Palmitic C16:0	9.32	7.80
Heptadecanoic C17:0	0.46	0.41
Estearic C18:0	5.20	4.39
Araquidic C20:0	0.34	0.93
Behenic C22:0	0.09	0.16
Monounsaturated	**11.25**	**9.21**
Myristoleic C14:1	0.05	0.04
Palmitoleic C16:1	2.19	1.73
Elaidic C18:1 *trans*-9	0.15	0.18
Oleic C18:1 *cis*-9	8.78	7.21
Erucic C22:1	0.08	0.05
Polyunsaturated	**22.29**	**20.57**
Linoleic C18:2	8.40	7.64
Linolenic C18:3 *n*-3	13.89	12.93

Around 50% of respondents consume ready-to-eat adult *S. purpurascens* 1–2 times per week (Table 4); however, there is no significant relationship between the frequency of consumption and the amount of *S. purpurascens* ingested on each day of consumption.

Table 4. Frequency and quantity of consumption of *Sphenarium purpurascens* by regular buyers at the traveling market in Miahuatlán de Porfirio Díaz, Oaxaca.

Consumption frequency days (*n*)/period	Individuals (*n*)	Range (g/day)	Median (g/day)	IQR (g/day)	IQR (%)
1/month	20	10.0–136.0	35.5	19.8–79.0	47.0
1/two weeks	35	6.0–138.0	28.0	12.5–55.5	32.6
1–2/week	73	9.0–136.0	24.0	16.0–35.0	15.0
3–4/week	8	14.0–136.0	30.5	21.3–79.5	47.7
5–7/week	8	10.0–76.0	34.0	22.0–42.5	34.1
All groups※	144	6.0–138.0	27.5	16.0–51.0	26.5

※: There were no significant differences in the amount (g/day) of *S. purpurascens* between the consumption frequency groups, since according to the Kruskal-Wallis test the effect size was $\varepsilon^2 = 0.0354$ with a p value = 0.409.

According to the average ω-3 content of *S. purpurascens* (Table 2), the median daily consumption of all groups (Table 4) would provide 12.4% of the average daily ω-3 requirement for adults according to references [27] and between 7.3% and 23.2% if the interquartile range is considered. Likewise, with the fiber contribution from alfalfa-fed *S. purpurascens*, the median consumption of all groups surveyed (Table 4) would cover 39.7% of the daily fiber requirement for adults according to references [28] and between 23.1% and 73.6% if the interquartile range is considered.

Discussion

This exploratory study confirms a previous report in which alfalfa-fed *S. purpurascens* had a higher fiber content than corn-fed ones [6]. However, the fiber content identified here was, on average, 81.7% higher than that reported. This difference could be due to the fact that in the adult stage of the insect, the exoskeleton is larger than that of the nymphs [32] and therefore has a higher fiber content [33]; however, this must be verified with further studies that specify the stage of development of the samples analyzed, as this aspect is omitted in most previous studies.

The proportion of saturated fatty acids in the *S. purpurascens* samples analyzed here is just over double that previously reported [10, 12], implying a lower proportion of polyunsaturated fatty acids, which could be due to thermal degradation resulting from the temperatures [34] inherent in the cooking processes described here for *S. purpurascens*; but this finding should be treated with caution as the fatty acid profile was not performed in triplicate. It is evident that subsequent studies are required to substantiate or refute these proportions, while accounting for variables such as the insect's developmental stage and the extent of its culinary processing.

This research provides preliminary guidance for establishing recommended amounts of regular consumption of *S. purpurascens* that may be useful for testing the effectiveness of its functional components. In this regard, it is imperative to acknowledge that overall diet composition constitutes a system, comprising a set of interdependent variables. Consequently, the functional effectiveness of a specific food can be augmented or neutralized, contingent on the quantity and quality of other foods regularly consumed.

However, among the main limitations of this study are its cross-sectional design (a single point in time, January 2019), its implementation in a single market, and the lack of replication in the fatty acid profile. Nevertheless, the evidence presented possesses heuristic value for future research on the effectiveness of the functional components of *S. purpurascens*.

Ultimately, the consumption of *S. purpurascens* harvested through sustainable extraction complements a production process in line with the 12th goal of the 2030 Agenda, which is to "Ensure sustainable consumption and production patterns" [35]. This is because it is a production-consumption system that involves avoiding the use of conventional chemical pesticides, which pose health risks, as well as obtaining nutrients—especially proteins—with a lower environmental impact compared to livestock farming [3].

Abbreviations

CMPD: city of Miahuatlán de Porfirio Díaz

Declarations

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Author contributions

JCHR: Funding acquisition, Project administration, Supervision, Conceptualization, Methodology, Investigation, Data curation, Validation, Visualization, Writing—original draft, Writing—review & editing. SML: Conceptualization, Methodology, Investigation, Validation, Writing—original draft, Writing—review & editing. Both authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical approval

This report is part of a research project approved by the Research Ethics Committee of the Universidad de la Sierra Sur under approval number CEI-02 and registration number SPN/02/25042019, within the Instituto de Investigación sobre la Salud Pública at the same university.

Consent to participate

Informed consent to participate in the study was obtained from all participants.

Consent to publication

Not applicable.

Availability of data and materials

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

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Publisher's note

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