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Nutritional quality of the white worm (*Agathymus remingtoni* Stallings & Turner Lepidoptera: Hesperiidae) of maguey lechuguilla (*Agave lechuguilla* Torrey)

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ABSTRACT

Objective: to evaluate the nutritional quality of white worm larvae (*Agathymus remingtoni*) of the maguey lechuguilla plant (*Agave lechuguilla*).

Design/Methodology/Approach: samples of *A. remingtoni* larvae were collected from the stems and leaves of wild maguey lechuguilla that grows in the hills of the community of San Francisco, Municipality of Epazoyucan, in the state of Hidalgo, Mexico. Proximate analysis was performed and the calcium and phosphorus contents were determined in larvae samples.

Results: larvae of *A. remingtoni* had a protein content of 33.69% on a dry basis, and 12.05% on a wet basis. Other results obtained were as follows: ethereal extract 15.97%, dry matter 35.76%, moisture 64.24%, ash 0.82%, crude fiber 0.85%, free nitrogen extract 6.07, calcium 0.40%, and phosphorus 0.56%.

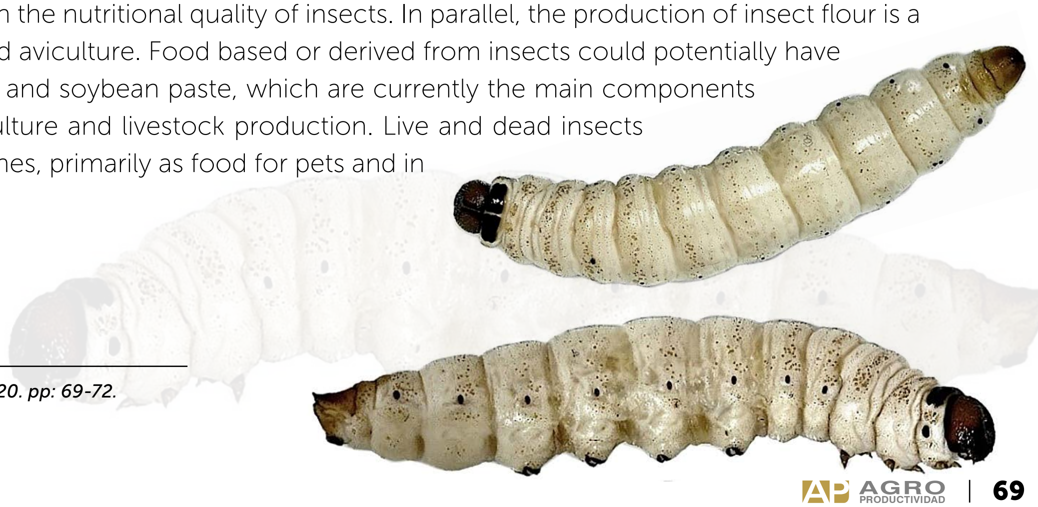
Limitations/Implications: During: in the literature review carried out, no reports were found on the nutritional quality of the white worm (*Agathymus remingtoni*) of maguey lechuguilla (*Agave lechuguilla*).

Findings/Conclusions: *Agathymus remingtoni* larvae have excellent nutritional content, which makes them an alternative source of protein, fat, calcium, and phosphorus for human consumption and livestock feed.

Keywords: maguey, white worm, food, nutritional composition.

INTRODUCTION

Insects have played an important role in the history of human nutrition. Hundreds of hexapod species have been used for human consumption, the most important among them including grasshoppers, caterpillars, beetle larvae and sometimes adults, termites, bees, wasps, ant larvae and pupa as well as winged ants, cicadas, and a great variety of aquatic insects. Insects are included in human diets when they are seasonally available or during a particular time of year (Banjo *et al*. 2006). The nutritional value of edible insects is highly variable due to the wide range of edible species; even within the same group of hexapods, nutritional value can differ depending on their metamorphic phase, their habitat, and their diet. Human population growth and the rise in poverty have driven new research on the nutritional quality of insects. In parallel, the production of insect flour is a viable alternative for aquaculture and aviculture. Food based or derived from insects could potentially have a market similar to that of fish meal and soybean paste, which are currently the main components utilized in feed formulas for aquaculture and livestock production. Live and dead insects have already established market niches, primarily as food for pets and in zoos (van Huis *et al*., 2013).



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Assessment of the nutritional composition of insects allows identifying the proportion of the elements and macromolecules that constitute them (Rodríguez-Ortega *et al*., 2016). In the present analysis, no reports were found on the nutritional value of the maguey lechuguilla white worm (*Agathymus remingtoni*); therefore, the objective was to evaluate the nutritional quality of white worm larvae (*A. remintoni*) of maguey lechuguilla (*Agave lechuguilla*).

MATERIALS AND METHODOLOGY

In the spring of 2017, *A. Remingtoni* larvae were collected from the stalks and leaves of *Agave lechuguilla* plants that grow in the hills of the San Francisco community within the Municipality of Epazoyucan (19° 59' 47.922" N and 98° 40' 40.9512" W), at an elevation of 2419 m in Hidalgo, Mexico (Rodríguez *et al*., 2017). In this ecosystem, maguey lechuguilla (Figure 1A) is naturally distributed associated to grasses, sweet acacias (*Acacias* spp.), nopal (*Opuntia* spp.), and other small maguey-like plants such as guapilla bromeliads. The white worm larvae were extracted from the cavities that they create during their development, mainly in the plant's basal leaves (Figure 1, C, D, E). In the damaged part of the leaf's shaft, an entrance hole can be observed through which the recently-hatched larva burrowed. This opening also serves as an exit point for its excrement and is from where the adult emerges (Figure 1B). The specimens were deposited in a plastic jar and placed in a freezer for their preservation and transportation to the Department of Animal Nutrition and Biochemistry in the School of Veterinary Medicine and Zootechnics of the National Autonomous University of Mexico (UNAM), for their determination. To analyze nutritional content using proximate analysis, as well as the calcium and phosphorous content, 250 g of completely developed larvae measuring 4 cm in length and 1 cm in diameter, with an average weight of 1.2 g, were used. Each analysis was tripled and the averages were recorded.

The results are on a wet basis, where moisture was determined by stove-drying at 50 °C for 72 h and dry matter content was calculated with the difference (Helrich, 1990). Raw protein was measured using the Kjeldahl method (Helrich, 1990); ethereal extract was obtained using a Soxhlet extractor; ash content was measured using the calcination method with a Linbert TZ45T model muffle furnace; crude fiber was determined using two digestors, one acid and the other alkaline (Helrich, 1990), in an ANKOM 200/220 model fiber analyzer; and the nitrogen-free extract was calculated differentially, in which the percentages of protein, fats, mineral salts, and crude fiber were subtracted from 100% of the dry matter. To determine gross energy, the methodology described in Standards for Bomb Calorimetry and Combustion Methods was used (Tejada, 1992). Calcium (Ca) was determined using the precipitation method, forming calcium oxalate (Helrich, 1990), and phosphorous concentration was measured using the UV visible ammonium phosphomolybdate method (Helrich, 1990).

RESULTS AND DISCUSSION

The white worm is associated with leaves of the maguey lechuguilla, also known in Mexico as the mountain maguey (*Agave lechuguilla*) (Figure 1 and 2). These plants provide a strong reservoir of high nutritional value for the life cycle of *Agathymus remingtoni*. These insects are harvested every year by regional collectors and consumers in April for the most part, and the larvae are part of the regional diet.

The proximate analysis results were compared with data from two Lepidoptera species associated with the pulque maguey plant: another white worm (*Aegiale hesperiaris*) and the red chinicuil worm (*Comadia redtenbacheri*) (Table 1). It was observed that crude protein content on a dry basis was very similar in the three species: *C. redtenbacheri* (32.23%), *A. remingtoni* (33.69%), and *A. hesperiaris* (37.79%). These results indicate that *A. remingtoni* larvae are an excellent source of protein, a highly important macronutrient in the human diet. Concerning the ethereal extract, the highest value was reported in the chinicuil larvae (23.43%), most probably due to their source of food, since these larvae feed on the maguey stalk or trunk, where the plant's nutrients are more concentrated and in movement. The second-highest concentration of ethereal extract (15.97%) was found in *A. remingtoni*, followed by *A. hesperiaris* (7.98 %) (Ramos *et al*., 2012). These two larvae feed on the central part of the host's leaves. It is important to highlight that *A. remingtoni* larvae present a notable fat content (ethereal extract), which may be beneficial for human health, as it probably constitutes unsaturated fatty acids. Ramos (2000) reported that insects harbor a large quantity of monounsaturated and polyunsaturated fatty acids.

A. remingtoni had the lowest crude fiber content (0.85%), while the chinicuil worm (*C. redtenbancheri*) had the highest fiber concentration

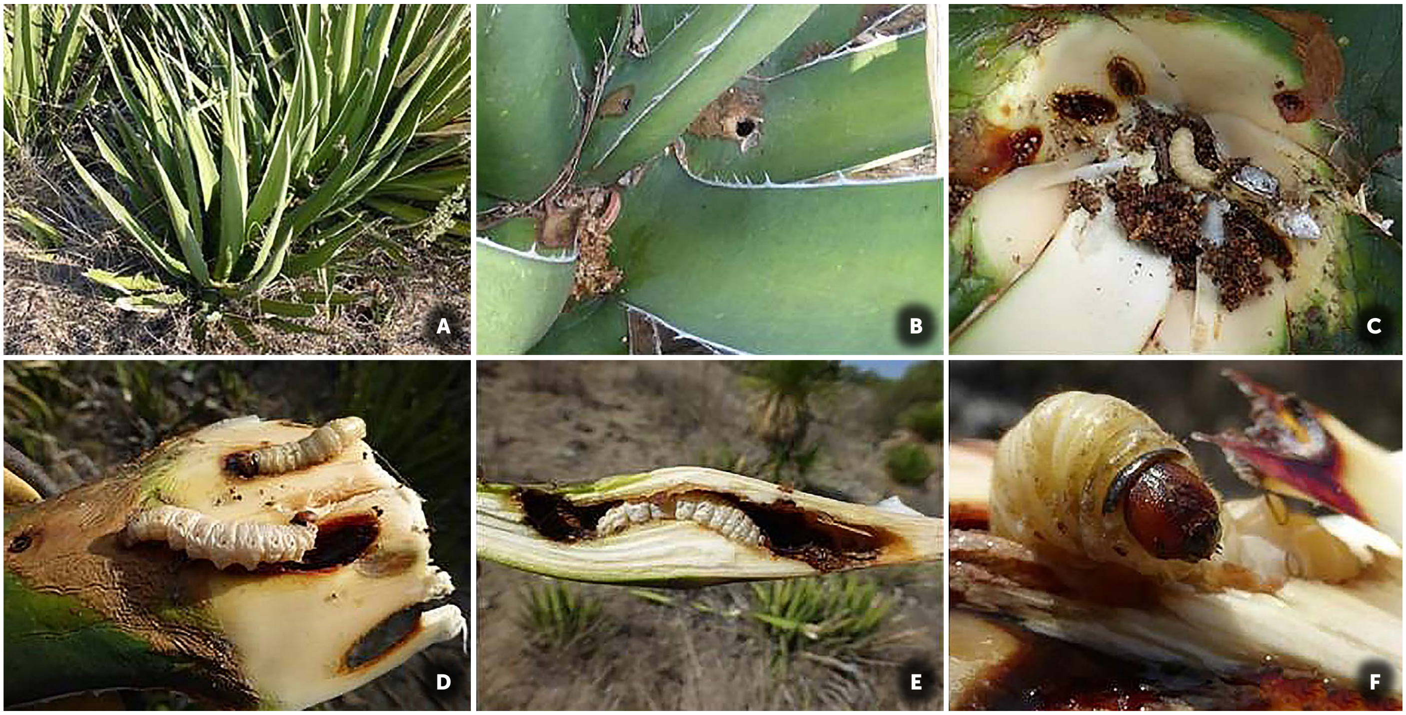

Figure 1. Mountain maguey plant *Agave lechuguilla* (A), larval burrow opening and exit point for excrement (B), leaf extraction to collect worms (C), white specimens per leaf (D), cavity form made by larva (E), and front section of *A. remingtoni* head (F).

(1.85%). These insects' fiber could be considered healthy, as it is fundamental for intestinal function (Almeida *et al*., 2014). On the other hand, the larvae of *A. remingtoni* and *C. redtenbacheri* had similar ash content (0.82 *vs*. 0.87); ash content is correlated to the amount of minerals present.

The calcium value of the *A. remingtoni* larvae was lower compared to the silk worm (*B. mori* 0.52 *vs*. 0.40%; Rodríguez *et al*. 2016). The amount of calcium in *A. remingtoni* is beneficial to the consumer since this element is essential for human nutrition and its requirements are not always totally met, possibly due to many people being lactose intolerant or allergic to calcium-containing products (Aámková *et al*., 2014). Phosphorus content was similar in larvae of *A. remingtoni* and *A. hesperiaris* (0.56 *vs*. 0.57%); silk worm larvae contain a lower phosphorous concentration than those of lechuguilla worms (0.56 *vs*. 0.30) (Rodríguez *et al*. 2016). Phosphorous is an essential mineral that forms part of the ATP (adenosine triphosphate) molecule, which is fundamental for energy production.

The moisture percentage was higher in the larvae of *A. hesperiaris* (77.15%), followed by *A. remingtoni* (64.24%), and lastly by *C. redtenbacheri* (58.3%). This can probably be attributed to the larvae size. Moisture plays an important role in insects' life cycle and larvae in this study are found in succulent plants with high moisture in their leaves and stalks, from which the insects obtain the nutrients and water they need, in addition to being protected from dehydration.

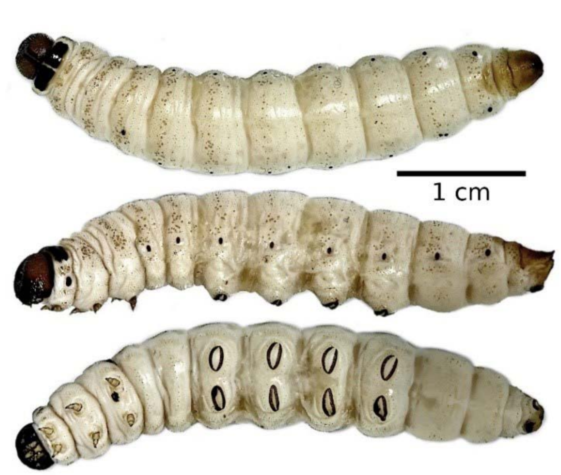

Figure 2. Edible *A. remingtoni* larvae in their last instar. The dorsal, pleural and ventral sections are shown.

Regarding protein digestibility in 0.2% of pepsin, *A. remingtoni* larvae showed a value of 30.84%, similar to the silk worm (34.19%). Digestibility is an indicator of protein quality because it is not enough for the protein content or that of another element to have a high percentage in food, but rather, it should be digestible so that it can be assimilated and thus utilized by the organism that ingests it

(Gutiérrez *et al*. 2011). The nutritional values of the *A. remingtoni* larvae (Figure 2) confirm the fact that they are an excellent source of nutrients. Therefore, the consumption of this larva can be promoted not just in Mexico, but also worldwide.

CONCLUSION

Larvae of *Agathymus remingtoni* offer excellent nutritional content, making them an alternative source of protein, fat, calcium, and phosphorous in diets. In addition, the *Agave lechuguilla* plant in the state of Hidalgo is sparsely exploited, making it an economic opportunity for local residents and the object of new scientific studies to demonstrate its nutritional significance.

Table 1. Proximal chemical analysis values for three Lepidoptera larvae associated with the *Agave genus* (*Agathymus remingtoni*, *Aefiale hesperiaris* and *Comadia redtenbacheri*) on a wet basis.

Variable	*A. remingtoni* (%)	*A. hesperiaris* (Ramos *et al*. 2012; %)	*C. redtenbacheri* (Ramos *et al*. 2012; %)
Dry material	35.76	-	-
Humidity	64.24	77.15	58.30
Crude protein	12.05	8.64	10.09
Ethereal extract	15.97	7.98	23.43
Ashes	0.82	1.05	0.87
Crude Fiber	0.85	0.96	1.85
N-Free Extract	6.07	4.21	5.46
Calcium	0.40	223.7 $\mu g\ g^{-1}$	126.9 $\mu g\ g^{-1}$
Match	0.56	0.57	0.33
PC (Dry basis) **	33.69	37.79	31.23
Digestible Protein in pepsin 0.2%	30.84	-	-

**CP: Crude protein on a dry basis.

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