COLLECTING PUPAE (*ESCAMOLES*) OF *Liometopum apiculatum* (HYMENOPTERA, FORMICIDAE, DOLICHODERINAE) IN THE SAN LUIS POTOSÍ HIGH PLAIN, MEXICO

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SUMMARY

The pupae (locally known as escamoles*) of the reproductive caste of the ant* Liometopum apiculatum *are eaten. Fertilized eggs and larvae are tended in the trabecula by ant workers into the ant nest, but trabecula must be destroyed by collectors to obtain the escamoles and the ants must rebuild their trabecula. The objectives were to characterize how escamoles are obtained in two sites in the San Luis Potosí High Plain (SLP) and two sites in the state of Hidalgo (HGO), Mexico, and to test two artificial trabecula prototypes. Regarding size, 76% of the ant nests were classified as large and 18% as medium. Sound escamoles extraction practices in SLP include excavation from the side to avoid damaging the royal chamber and to access the trabecula chamber. In HGO, sound practices involve the partial extraction of the trabecula. In both regions, it is understood that the death of an ant nest is usually the result of improper management. Between 57,5 and 62,5% of the volume of the trabecula prototypes was used by the ants. These prototypes are easier to place in ant nests on sites with deep, friable soil. Collectors acknowledged the ease of separating the escamoles that developed on the prototypes.*

Introduction

Myrmecophagy was probably practiced by *Australopithecus robustus*, given that utensils appropriate for getting ants out of the nest were found with its fossil remains (Costa and Ramos-Elorduy, 2006). It is currently estimated that there are more than 1783 species of edible insects in the world (Costa and Ramos-Elorduy, 2006; Ramos-Elorduy, 2009). In Mexico, there are five edible ants: *Atta cephalotes*, *A. mexicana*, *Liometopum apiculatum*, *Myrmecosistus melliger* and *M. mexicanus* (Ramos-Elorduy *et al*., 1984; Ramos-Elorduy and Pino, 1989; Ramos-Elorduy and Levieux, 1992; Viesca and Romero, 2009; Ramos-Elorduy, 2009). The pupae of the reproductive caste of *L. apiculatum*, popularly known as *escamol* (plural, *escamoles*) (Viesca and Romero, 2009; Lara-Juárez *et al.,* 2015), are eaten in several parts of Central Mexico (Cuadriello, 1980; Ramos-Elorduy *et al*., 1998, 2006, 2007) by mestizos and indigenous people (Ramos-Elorduy, 2009). Escamoles are appreciated for their exquisiteness and outstanding nutritional value. By dry weight, escamoles are 67% protein, 12,08% ether extract, 5,05% mineral salts, and 0,99% raw fiber (Ramos-Elorduy *et al.,* 1988; Ladrón *et al.,* 1995). On the San Luis Potosí Highlands (SLP), escamoles were first collected around 2004, at the urging of sheep traders from the Hidalgo State who saw a lucrative business opportunity: to buy escamoles in San Luis Potosi State, a new source where they are not eaten, and to sell them in Hidalgo, the main region for sales and consumption. The SLP collectors lacked basic knowledge about the biology and appropriate ways to collected escamoles while preserving the populations of the insects, and the middlemen of Central Mexico either did not know or were not interested in explaining the details of the traditional ways in which this resource was used in their states of origin. It is likely that this likely led to premature loss of ant nests and a decrease in their re-population. Studying the collection of escamoles in a way that preserves the insect population is necessary, specifically in SLP, in order to offer training to collectors. Escamoles are currently collected in SLP, with an annual collection of 9t in ~4500ha (Castillo and Aguirre, 2008; Esparza *et al.,* 2008).

Worker ants stick soil particles and organic matter, together with their effluvia, in a special chamber of *L. apiculatum* ant nests, to make a structure known as 'trabecula', where they place the eggs laid by the queen ant and raise the larvae that emerge

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RECOLECCIÓN DE PUPAS (*ESCAMOLES*) DE *Liometopum apiculatum* (HYMENOPTERA, FORMICIDAE, DOLICHODERINAE) EN EL ALTIPLANO DE SAN LUIS POTOSÍ, MÉXICO

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RESUMEN

Las pupas (localmente conocidas como escamoles) de la casta reproductora de la hormiga Liometopum apiculatum *son alimenticias. Los huevos fertilizados y las larvas son colocados por las hormigas obreras en la trabécula dentro del nido; los recolectores deben extraer y destruir la trabécula para obtener los escamoles y posteriormente las hormigas la reconstruyen. Los objetivos fueron caracterizar cómo se obtienen los escamoles en el altiplano de San Luis Potosí (SLP) y en el estado de Hidalgo (HGO), México, y probar dos prototipos de trabéculas artificiales. En cuanto al tamaño, el 76% de los nidos de hormigas fueron clasificados como grandes y el 18% como medios. Las buenas prácticas en SLP incluyen la excavación lateral del nido para acceder a la trabécula; en HGO las buenas prácticas de recolecta implican la extracción parcial de la trabécula. En ambas regiones la desaparición de un hormiguero es generalmente el resultado de su manejo incorrecto. El 57,5 y 62,5% del volumen de los prototipos de trabécula artificiales fue utilizado por las hormigas. Estos prototipos son más fáciles de colocar en hormigueros en los sitios con suelo friable y profundo. Los recolectores reconocieron la mayor facilidad de separar los escamoles que se desarrollaron en los prototipos.*

COLHEITA DAS PUPAS (*ESCAMOLES*) DE *Liometopum apiculatum* (HYMENOPTERA, FORMICIDAE, DOLICHODERINAE) NO PLANALTO DE SAN LUIS POTOSÍ, MÉXICO

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RESUMO

As pupas (escamoles) *da casta reprodutora da formiga* Liometopum apiculatum *são alimentares. Os ovos fertilizados e as larvas são colocados pelas formigas operárias na trabécula dentro do ninho; os coletores têm que extrair e destruir a trabécula para obtê-los, e posteriormente as formigas a reconstroem. Os objetivos foram caracterizar como se obtém os escamoles no planalto de San Luís Potosí (SLP) e no estado de Hidalgo (HGO), México, e testar dois protótipos de trabéculas artificiais. No tocante ao tamanho, 76% dos ninhos de formigas se classificaram como grandes e 18% como médios. As boas práticas em SLP incluem a escavação lateral do ninho para chegar à trabécula; em HGO as boas práticas de coleta implicam a extração parcial da trabécula. Em ambas as regiões, o desaparecimento de um formigueiro é, em geral, resultado de seu manejo incorreto. Entre 57,5 e 62,5% do volume dos protótipos da trabécula artificial foi utilizado pelas formigas. Esses protótipos são mais fáceis de colocar em formigueiros que se encontram em lugares com solo profundo e quebradiço. Os coletores reconheceram a maior facilidade de separar os escamoles que se desenvolveram nos protótipos.*

thereof. Collectors destroy the trabecula to extract the escamoles, and place rolls of dry or fresh plant branches in the chamber to function as a structural base upon which the ants can rebuild it (Lara-Juárez *et al.,* 2015). At the time this study was proposed, collectors did not have any other devices to either facilitate the reconstruction of the trabecula by the ants or make easier and sustainable to extract the escamoles. The objectives of this study were to characterize the way escamoles are currently exploited on the SLP Highlands and to compare this with the traditional pre-Hispanic practice in two *Hñähñu* locations (generically known as *Otomí*) in the state of Hidalgo (HGO), and to test two semi-permanent prototypes of trabeculae.

Materials and Methods

The study was carried out in the municipality of Charcas, in the northern part of the of San Luis Potosí State, in two areas of escamoles collection: the Laguna Seca private ranch (LSR) and the Pocitos *ejido* (PE), where the use of their rangeland is communal. The *ejido* is a peasant communal type of land tenure. To provide a context for what happens in SLP we also worked in the indigenous *Hñähñu* region, where collecting escamoles is a prehispanic tradition, with key informants known for their expertise in handling them in Chicavasco, Actopan municipality, and in San Andrés Daboxtha, Cardonal municipality, both in HGO, in Central Mexico, about 343km southeast of SLP.

The documentation about traditional knowledge, current use and characterization was based on Aguirre's (1983) methodological proposal, which consists of preparing a list of the phenomena of interest, explaining them, organizing the information and preparing the final report. The most intensive work was done in SLP, where 13 mestizo peasants were selected as informants: 12 men and one woman, five of them in LSR (these were neighboring *ejidatarios* paid by the landowner based on the quantity of escamoles collected) and eight in PE, whom we accompanied when they collected and cleaned the escamoles in order to simultaneously record their answers and make direct observations. A total of 400 ant nests were visited, 200 in LSR and 200 in PE. In HGO, three informants from Chicavasco and four from San Andrés Daboxtha, all of them *Hñähñu*, were interviewed (three men and four women). In order to select informants we used the criteria suggested by Aguirre (1983): informants with high level of knowledge about the phenomena to study, but also to include informants with a medium level of knowledge, in order to know the true status of knowledge among the informants.

Two prototypes, designed to facilitate the reconstruction of the trabecula by the worker ants were tested: one uses a dry, fibrous weave obtained from mature cladodes of the cactus pear (*Opuntia streptacantha*), and the other uses a plastic mesh. The first prototype (Figure 1a) used old cladodes, after removal of the

epidermis, the parenchyma and the mucilage in a process called retting. The design places the sheets of fibers, once dry, in 14 layers separated by perforated pieces of wood (1,5'3,0'3,0cm), which in turn were connected at their centers with the spokes of a motorcycle wheel (3,5mm bore and 30cm long). The second prototype (Figure 1b) consisted of squares of semirigid 25,0' 25,0cm plastic 1,0cm mesh. Both devices appear cubic in shape with each side measuring 25cm (Figure 1). With the guidance of expert collectors, in June 18th and 19th 2013, eight cactus and eight plastic devices were placed in 16 ant nests in LSR, paired with another 16 ant nests that were nearby and similar in size, located also in LSR. The prototypes were located only in LSR, where, it was assumed, they would be safe and easier to keep an eye on. We evaluated the effectiveness of these trabeculae devices in September 2013 and removed them in March 2014.

Results

Escamoles collection

Collection and handling procedures used by collectors on the private ranch (LSR) and the *ejido* (PE) in SLP were similar, so they are described together and contrasted with those recorded in HGO. In SLP, escamoles are collected during the warm dry season, beginning the last week in February, and in HGO collection begins the first Sunday after Ash Wednesday (between February 4 and March 10, depending on the Catholic liturgical calendar). In both states, the collecting season ends the first week in May, though sometimes, when the rains are delayed, it continues until the beginning of June. In HGO, because so many of the men have emigrated to urban and rural areas in Mexico or USA, a notable portion of the collectors are women, while in SLP, collection is mainly a male activity and is done by pairs of relatives (cousins, brothers, brothers in-laws, or father and son) or friends. In HGO, collectors refrain from sexual relations the day before collecting, because they believe it will prevent the escamoles from turning yellow or dying. Collectors in SLP ignore this practice.

In SLP escamoles are collected between 07:00 and 18:00, using the following tools: an iron bar 1,5m long, with both ends sharpened and a 1,8m long iron bar with one end sharpened and the other flattened into a spatula, a pickaxe, hedge clippers (50cm long blades), a kitchen spoon attached to a long handle (1,0m), a shovel, two 50'60cm screens with a wood frame, one of 5,0mm and the other of 3,0mm mesh size, a reed basket or a plastic bucket, a kitchen sieve and a broom. In HGO, instead of the shovel or spoon, half of a maguey *Agave salmiana* leaf is used. To this end, the upper part of a leaf from the apex to the lower part of the wings, where it is widest, is cut transversally to separate it from the rest of the plant. The lateral spines as well as the apical spine are cut off, and the corners are rounded by cutting the leaf. The apex is used as a handle and the wide part as a shovel or spoon. In HGO, the sieve is a square of mesh (*ayate*) 1,25m on a side, made from the fiber of maguey (*A. salmiana* and/or *A. mapisaga*) with a 5,0mm mesh; more recently, industrial mesh made from plastic thread is used.

Collectors in SLP and HGO are familiar with established nests and discover new nests in the course of collecting the escamoles from the established nests. The majority (60%) of the people interviewed in both states found ant nests guided by signs or by the behavior of the ants, such as the accumulation of sand, garbage, dead ants and the fine gravel accumulated at the ant hill. Other collectors (40%) search for the confluence of four or five ant trails, because the entrance to the ant nests is typically adjacent. Following these trails requires expertise, because some of their sections are underground, pass between rocky crevices, and burrow under the litter layer or below the tillers of grasses and other herbs. Additionally, experience is required to distinguish between the feeding sites, resting places and the entrance to the ant nest. The former are the places on the trail where the ants pile up during the hottest hours of the day, which looks similar to ant piles at the entrance of the ant nests at other times. Another indication of the nearness of the ant nest is the presence of the mite *Trombidium holosericeum*, known locally as the red spider or anthill fire; in HGO, it is also called *rä me'yuhi* in *Hñähñu*. Collectors also use the presence of the *maguey verde* (*A. salmiana*) with hemipterans on its leaves as indicator. Once an ant nest has been located, to find the exact location of the nursery chamber with its trabecula, the SLP collectors use the metal bar with pointed ends, which they repeatedly push carefully into the soil until a strong odor of rancid butter is released when they pull it out. Collectors harvest escamoles from both previously harvested nests and new nests. They use the shovel and the pickaxe when collecting escamoles from an ant nest from which they have previously collected, so as to remove the branches of spiny plants that were placed *ex profeso* over the lid of the mouth of the ant nest to protect it from mammal predators. The ridge of soil that was formed to keep runoff out of the nest is also removed, as is the dry *A. salmiana* plant or the flagstone used to cover the ant nest.

In HGO, once the ant nest has been opened, the collector lights a cigarette and blows the smoke inside the nest to drive out any snakes that are inside. The soil is then removed using the shovel until the tunnel is found. The collector continues removing soil, but now using his hands to avoid destroying the nest. Using hedge clippers, the live roots limiting access to the nursing chamber are cut and removed. The shovel or the flat end of the bar (in SLP) or the shaped maguey leaf (in HGO) are pushed into the base of the trabecula to allow for a careful extraction.

Analogous to the bee hive built by worker bees, the trabecula is the structure where worker ants place the eggs laid by the queen and from which the larvae hatch and are fed until they transform into pupae or escamoles. In colloquial Spanish this structure is called *huacal* or *panal de tierra* and in *Hñähñu*, it is called *xit'a yä yuhi* or *'bafi yuhi*. The trabecula is a spongiform structure attached to the walls of the nest. It is very fragile, round or polyhedral and asymmetric, 40 to 50cm in diameter (Figure 2). When dealing with a new ant nest on the outer edge of the area delimited with the bar, but on the other side of the ant nest, the collector digs to make an opening and gain access from the side to the chamber where the trabecula is located. This way, according to the informants, the collector avoids collapsing the royal chamber, which is above the trabecula. The trabecula is then extracted as explained

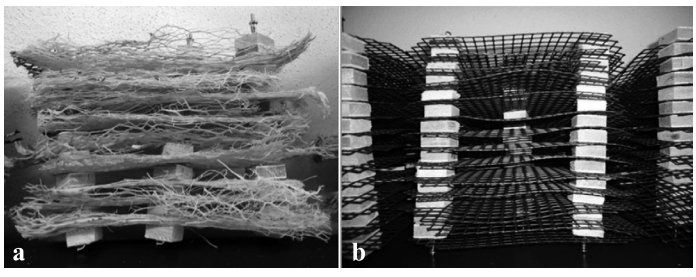

Figure 1. Trabecula device, a: made with the fibrous tissue of nopal cactus cladodes (*Opuntia streptacantha*), b: made from a rigid plastic mesh.

Figure 2. *Liometopum apiculatum* trabecula.

above. Eighty percent of the collectors in SLP extract the trabecula almost entirely, and only leave the escamoles that fall during the maneuver and that the worker ants energetically manage to rescue and take into the deepest part of the ant nest. The other collectors use the spoon with the extended handle and a small broom to extract as many escamoles as possible. In HGO, only about 80% of the trabecula is extracted. During extraction, many ants attack the collector, bite him and spread formic acid on him. The collector or his companion use the branches of a species with soft leaves, such as *Schinus molle*, to brush the ants from his body without harming them.

Collectors in SLP place the extracted trabecula on top of the two screens, with the coarser-mesh screen (5,0 mm) on top of the finer mesh screen. They shake the screens until the trabecula's soil particles and organic remains separate, revealing the escamoles inside. The first screen retains the sand, small gravel and organic debris, allowing the escamoles to pass through to the second (3,0 mm) screen, where they are retained along with similarly particle sized screen that are partially separated as the material is winnowed. The collector moves the screens lightly up and down, with quick, short but firm movements to expose the contents to the wind. In HGO, this process is done using an *ayate*, a piece of woven maguey fiber that functions as a screen and also allows the material to be winnowed. In spite of this process, the escamoles are still covered in dust and there are small soil particles among them. It is worth mentioning that because the escamoles are almost always collected by two people; one is in charge of opening the ant nest and removing the trabecula, while the other sifts the trabecula and separates out the escamoles. In SLP the collectors noted that only some of them are good at sieving the escamoles.

Escamoles were extracted from 34% of the 400 ant nests evaluated in SLP, for the first time in 2012, when the field work for this study was done. In contrast, only 1% of the ant nests had been exploited in the previous 11 years, with most of the nests having been exploited in the previous 4 to 9 years. The collectors consider that ant nests in SLP are generally in 'good conditions', their main criteria being the degree of activity that they observe around the nest. We could confirm their observations: of the 400 ant nests observed, 80,5% exhibited considerable ant activity, 6,5% only little activity (possibly because they were declining or recovering after being exploited) and 13% had been abandoned by the ants, probably as a result of errors in the collection process, attacks by mammal predators or death of the queen.

Collectors estimate the size of an ant nest based on the abundance of ants and the depth and width of their trails. Thus, 76% of the 400 ant nests observed were classified as large, 18% as medium-sized and 6% as small. In SLP, 40% of the collectors agree that from the largest ant nest it is possible to obtain 1000 to 2000g of escamoles, 500g from a medium-sized one, and only 50g from a small one. Once the trabecula has been removed, and before the nest has been covered, the collectors replace the trabecula with rolled green or dried branches or rolled up, dried plant remains. The process is similar in SLP and HGO and depends on the availability of material. In SLP, the branches of *Juniperus monosperma* and *Salvia ballotiflora* are used, or the fibrous tissue of the dead cladodes of the nopal cactus (*Opuntia* spp.) or maguey (*A. salmiana*). This plant material is used to fill the gap left by removing the trabecula and is compressed with a shovel. In HGO, the pupae that have fallen from the trabecula when it is removed are rescued and quickly taken back by the worker ants back to the nest and placed on the part of the trabecula that was left intact in its chamber.

After the collectors have properly opened and harvested the escamoles they must close the ant nest properly to ensure its persistence. If the ant nest is in a field wall, the same rocks that make it up are used to cover it once again, and it is sealed with soil around the rocks; if the ant nest is located on soil, a flagstone or a dead maguey plant whose base fits the ant nest opening and prevents soil or water from entering is used. This is reinforced with two or three shovelfuls of soil to finish sealing it. In SLP, the surface is invariably covered with *Cylindropuntia imbricata* or *C. tunicata* branches, while this practice is only carried out in 25% of the ant nests used in HGO.

The sieved escamoles collected in SLP are carried in a plastic bucket or a reed basket. Those who use reed baskets (<10%) say that they do so to keep the escamoles fresh throughout the workday in the field. In HGO, the escamoles are transported in the same *ayate* or woven maguey fiber used to sieve them; this allows any worker ants that were trapped with the escamoles to escape and return to the nest.

Post-collection and commercialization

Once at home, the collectors clean and wash out the escamoles. In both SLP and HGO, the cleaning process is a family affair. In SLP, the day's harvest is put into a big bucket with water and the undesired materials that float to the surface are skimmed off with a kitchen sieve. The escamoles are then rinsed in clean water at least four times. Cleaning the day's harvest requires at least 80 liters of clean water. In HGO, the final cleaning is dry: the escamoles are spread out on a table and with a small stick and much patience, the remaining little bits of debris are separated, and then the escamoles are rinsed once again. In SLP, most of the informants (85%) discard the escamoles when are in the final developmental stage (between pupae and adults) since the well-defined body of the adult ant can be distinguished and, when these escamoles are frozen, the whitish color of the pupa changes to black, like that of the adult ant, which makes them less appealing to consumers.

The clean escamoles in the PE are packed into heat-sealed plastic bags of 1000, 500 and 250g. In the LSR, only 1000g bags are packed. In both cases the escamoles are kept frozen until sold. In HGO, escamoles are collected to be eaten by the family or to be sold in the family's community. In general, they are cooked and eaten soon after being collected and are frozen only occasionally.

The escamoles that are sold locally to neighbors or intermediaries are sold fresh, by weight and on a small scale in cups, cans or cones made of rolled maguey *pencas*.

In the PE, the escamoles are taken to the collection center where they are bagged, frozen and stored. This center and its equipment belong to the *ejido*'s organization of collectors and was remodeled with government subsidies for that purpose. During the 2012 season collectors were paid MXN 250/kg. In turn, the escamoles were sold in the collection center to intermediaries for MXN 350/kg; the difference of MXN 100 is invested in furniture and equipment, materials, the operational and maintenance costs of the center, and in tools and fees paid to the collectors. Each afternoon or the next day in the morning, the *campesinos* hired to collect escamoles in the LSR deliver them and are paid. In 2012, they were paid MXN 300/kg, and of this they were required to pay MXN 30 to the *ejido* to which they belong, even if the escamoles were collected somewhere else. This money is used for the *ejido*'s collection center or to attend to other needs in the *ejido*. The escamoles collected in HGO were sold fresh in the same community for MXN 250/kg, or MXN 50 per glass (~150g). However, in the municipal market of Actopan, Hidalgo, they are sold for MXN 450 to 550/kg. Roadside vendors sell escamoles for 450/kg. In SLP, the escamoles collected by organized groups of *campesinos* are sold in the collection center to intermediaries from the Hidalgo and Mexico states.

Comparative analysis of collection in HGO and SLP.

The following stand out as good practices for obtaining escamoles: (1) from SLP, digging into the ant nest from the side to gain access to the trabecula chamber without damaging the royal chamber; (2) from HGO, extracting only 80% of the trabecula, allowing a portion of the reproductive pupae to complete their development, in order to encourage repopulation of the ant nest; (3) HGO, avoiding damage to the ants that attack the collector; (4) HGO and SLP, putting plant material into the chamber to facilitate reconstruction of the trabecula; and (5) HGO, transporting the escamoles in the *ayate* so the ants can get out and return to the nest.

Practices that threaten the continued availability of this resource are, in SLP: (1) extraction of all the escamoles from the nest; (2) premature collection, almost two months early (in January), when only worker ant pupae are available, which are of inferior quality and results in the ant population's capacity to feed the larvae of the reproductive castes; in SLP and HGO: (3) threat of the continued availability of this resource by repeated extraction of escamoles from a given nest in the same collecting season. The informants from both states recognize that most of the nests that have been abandoned by the ants can be attributed to unsustainable practices by collectors, such as inappropriate opening the nest the first time, inadequate removal of the trabecula, poor closure of the nest (generally altering the nest when first opening it) and totally and repeatedly extracting escamoles in the same season.

Trials with different prototypes for trabecula reconstruction

Of the 16 devices installed in order to facilitate reconstruction of the trabeculae in the ant nests, four made from nopal cactus fiber and four of the plastic ones were removed from the nests by unauthorized third parties, as were several natural trabeculae in the similar ant nests we selected as controls. Thus, it was only possible to record the following data as provisional or tentative information. Eight months after the devices had been put into the ant nests, they were well accepted by the ants. In the remaining four nopal devices ants had built trabeculae on 57,5% (50-80%) of the volume of the device, and in the plastic ones, on 62,5% (20-90%).

Regarding the difficulty in removing these devices from the ant nests, 60% of the collectors said it was no more difficult to remove them than to remove the natural trabeculae, and the majority of them (75%) said the devices were very easy to put back into the trabecula chamber when the ant nest had been built on deep, friable soil, while the rigidity of the devices made it difficult or impossible to fit them into the gaps of nests built in stony or rocky soils.

A majority (75%) of collectors acknowledged that the main advantage of the devices is the greater easiness in separating the escamoles from the trabecula, as there is no need to dismantle them and they need to be struck or shaken firmly and the escamoles fall right off (Figure 3). All of the collectors agreed that the characteristics of these escamoles are identical to those obtained from natural trabeculae, but they are cleaner.

Over their first year of use the average yield of the nopal devices was 236,7g (130-325g) of escamoles, and for the plastic devices it was 418,4g (255-645g). The advantage of the plastic devices with respect to yield appears to be consistent given that later, yields of up to 1200g were recorded for them, while the natural trabeculae in similar ant nests only produced 400g. This might be due to a more regular, less chaotic structure of the plastic device that facilitates the movement and work of the worker ants.

Discussion

Escamoles collection

Escamoles are collected during the warm dry season in both SLP and HGO, a period also mentioned by Miranda *et al.* (2011) and Ramos-Elorduy (2006) for central Mexico. According to Cuadriello (1980), a biological indicator used by collectors in central Mexico to start the season is the size of the abdomen of the worker ants. Most of the year their abdomen is bulky, but it begins to shrink between March and April. This decrease is thought to result from the worker ants feeding the larvae of the reproductive castes. This indicator was not confirmed by the informants consulted in SLP nor by those in HGO.

Collection in SLP is done by relatives or friends and according to Miranda *et al.* (2011); locating ant nests is a skill that parents pass to their children. The confluence of four or five ant trails is a signal that the entrance to one ant nests is typically adjacent; also, a good indicator of an ant nest proximity is an increase in the depth and width of the ant trails, as indicated by Cuadriello (1980), who reports that following ant trails requires expertise. To use the presence of the *maguey verde* with hemiptera on its leaves as an indicator was shown by Cruz-Labana *et al.* (2014), who found that the density of *A. salmiana* was greater (1298 plants/ha) in sites with *L. apiculatum* nests than in sites without ant nests (433 plants/ha), and that 61% of the magueys in areas with ants had

Figure 3. Sifting using the prototypes, a: from the nopal cactus, b: from plastic.

colonies of hemiptera. Velasco *et al.* (2007) mentions *Cinara* spp., *Dysmicoccus brevipes* and *Saissetia oleae* as the main taxa of hemipteran that *L. apiculatum* feeds on by trophobiosis.

When the ants detect foreign organisms or objects inside the nest, in this case the bar that collectors introduce to find the exact location of the nursery chamber with its trabecula, the ants attack *en masse*. *Liometopum apiculatum* worker ants attach to the intruder with their mandibles, smearing it with formic acid and releasing compounds with a strong odor of butyric acid from their anal glands (Del Toro *et al.*, 2009; Hoey *et al.,* 2013). Also, the ants attack the body of the collector during extraction, they raise their abdomen to a 90° angle and violently shake their antennae (Cuadriello, 1980). In HGO, the collector blows cigarette smoke inside the nest to drive out any snakes that are inside. According to Cuadriello (1980) *Conopsis lineata*, a myrmecophagous snake, is often found inside ant nests, especially in HGO.

The natural trabecula is polyhedral and asymmetric, its mesh is broad and somewhat flattened (Cuadriello, 1980; Gulmahamad, 1995; Lara-Juárez *et al.*, 2015). It is made from sand (50-70%), silt (10-35%), clay (15-20%), and plant detritus brought into the nest, and all of this material is glued together with the saliva of the ants. The organic matter content of the trabecula is between 26 and 31% (Lara-Juárez *et al.*, 2015).

The partial extraction of the trabecula performed in HGO is favorable for the persistence of the ant nests (Esparza *et al.*, 2008), but more than anything it makes viable, in operational and biological terms, the continued exploitation of this resource through repopulating the nest (Lara-Juárez *et al.*, 2015). The procedure to obtain escamoles by shaking the screens was also documented by Miranda *et al.* (2011) and Gulmahamad (1995).

Ramos-Elorduy and Levieux (1992) mentioned that the time of exploitation of ant nests in central Mexico is most commonly of 4 to 12 years, but a well-managed nest can be used for up to 40 years. Ideally, nests are only harvested once a year, but in SLP ant nests are occasionally opened up to four times during one collecting season. Comparing the yield of escamoles in SLP from the largest ant nests (1-2kg), it is lower than in central Mexico, where Ramos-Elorduy and Levieux (1992) reported that the annual yield from a large nest was 3 to 3,6kg.

Post-collection and commercialization

Together with the sale of escamoles in collection center (SLP), or in the municipal market and roadside (HGO), Ramos-Elorduy *et al.* (2006) also reported door-to-door sales, and orders placed in temporary and permanent stalls in the market, among others. It is possible that both a recent increase in the demand for escamoles and also a decrease in supply, owing to the deterioration of the maguey plantations in the states of central Mexico resulting from changes in agricultural practices, have created a demand in the states of SLP and Zacatecas. However, it could also be the result of the recently identified trend of eating escamoles as part of the new appreciation of these insects as food, especially in gourmet restaurants. This, in turn, could be causing the overexploitation and poor management of the resource in areas where it is traditionally collected, and in new collection areas as well.

The practices that threaten the availability of escamoles (total extraction from the nest, beginning collecting earlier, repeated extraction from a given nest during the same collecting season) jeopardize the chances of the ant nests to repopulate, and the increased intensity of disturbance may decrease the span of time over which the ant nest can be exploited. Amateur collectors on their own *ejidos* and people who clandestinely cause the same kind of damage to ant nests on nearby, private land, also pose threats by inappropriately opening the nest, inadequate removal of the trabecula, poor closure of the nest and totally and repeatedly extracting escamoles in a given season. Land deterioration by overgrazing also includes a drastic reduction of ant nest density (Whitford and Steinberger, 2010; Lara-Juárez *et al.*, 2016).

Currently, the most important differences between HGO and SLP trade is the way the escamoles are used. In HGO the collection and commercialization is a family affair and the escamoles are sold fresh, whether to neighbors, intermediaries or in the nearest market. In SLP the collectors belong to an organization that is officially recognized and authorized for collecting, packaging, freezing and commercializing the escamoles, for which purposes they have a building set up as an office, meeting hall, warehouse and freezer room that belongs to the collectors' organization and was acquired with contributions from the group and government subsidies. In SLP, the escamoles are sold frozen in packages of different weights and mostly to intermediaries from central Mexico, so that their sales have the advantage of volume and a longer period of availability.

Concerning the devices for facilitating the reconstruction of the trabecula, the devices built of nopal deteriorated rapidly and it was only possible to use them for two years, while the plastic ones could last four, five or more years, although their metal components should be anti-rust to facilitate their separation and nest reconstruction. The replacement of the spokes with flexible plastic bars could make it easier to use them in ant nests on rocky soils. The lack of control over the exploitation of ant nests and related resources, especially on communal land (Lara-Juárez *et al.*, 2016), is a limiting factor in the use of these prototypes because they are stolen during clandestine collection. It can be postulated that the widespread use of these prototypes, particularly the plastic ones, may help collectors obtain escamoles that are cleaner, with the concomitant savings in water and cleaning effort, in addition to a greater yield; the ants will spend less energy rebuilding the trabecula and it will be possible to more easily return an intact part of the trabecula to the nest to facilitate the repopulation of the ant nest.

Conclusions

Escamoles are collected during the dry season. In terms of size, 76% of the ant nests are classified as large, 18% as medium-sized and the rest as small. Each season, 1-2kg of escamoles can be extracted from each large ant nest, 500 g from a medium-sized one and only 50g from a small one.

Good harvesting practices in SLP include digging in from the side to gain access to the trabecula chamber, and in HGO, the partial removal of the trabecula, and the placement of appropriate plant material for trabecula reconstruction into the nest. The transportation of the escamoles in an *ayate* makes it easy for ants to escape and return to the nest. In SLP, the practices that threaten the continued availability of the resource are the total extraction of escamoles from the nest and starting to collect in January during the cold season. In both SLP and in HGO the worst practice is the repeated extraction of escamoles from the same nest during a given collecting season.

The ants accepted both artificial devices well, particularly those made of plastic, and the yield of escamoles was greater than from natural trabeculae.

The devices are easily rearranged in the ant nest when the soil is deep and friable, although it is difficult or im-

possible to accommodate them in the gaps in stony or rocky soils. They make it easier to separate the escamoles from the trabecula, thus contributing to obtain more and cleaner escamoles, saving materials and energy in cleaning them. They also make it possible to put a portion of the trabecula back into the nest intact to maintain and facilitate ant nest repopulation.

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