# Especies de insectos con potencial para la entomofagia a nivel mundial: una revisión

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## Resumen

**Fundamentos:** Una de las tendencias en la nutrición humana es el consumo de insectos, conocido como entomofagia, que se está volviendo cada vez más popular como una alternativa sostenible y segura. Los insectos representan una fuente importante de proteínas de alta calidad, comparable a las fuentes proteicas convencionales, además de ser ricos en grasas, minerales y vitaminas. La cría de insectos es considerada una actividad sostenible que requiere un menor consumo de recursos en comparación con la ganadería tradicional.
**Métodos:** Se realizó mediante la búsqueda de información en cinco bases de datos: ScienceDirect, Elsevier, Springer, SciELO, MDPI y Brill. Como criterio general, se revisaron artículos científicos relacionados con las especies seleccionadas desde el año 1927, excepto en el caso de la sección de taxonomía, en la que se consultaron documentos anteriores.
**Resultados:** El artículo presenta una síntesis de las cinco especies de insectos con potencial para el consumo humano: *Tenebrio molitor, Acheta domesticus, Zophobas morio, Gryllus assimilis* y *Rhynchophorus palmarum*. Para cada especie se describen su taxonomía, características biológicas y perfil nutricional, tanto en macro como micronutrientes. Además, se examinan los usos actuales de estas especies en la industria alimentaria, destacando su valor como ingredientes funcionales y su potencial para ser incorporadas en nuevos productos alimenticios.
**Conclusiones:** La entomofagia representa una alternativa viable y sostenible para contribuir a la seguridad alimentaria y nutricional ante el crecimiento de la población mundial. La entomocultura, entendida como la cría de insectos para consumo humano, surge como un sistema agroalimentario sostenible, capaz de ofrecer proteínas de calidad con un impacto ambiental reducido, posicionándose como una opción prometedora dentro de las estrategias de alimentación futura.

**Palabras clave:** Alimento; Entomocultura; Insectos comestibles; Nutrición; Sostenibilidad ambiental.

## Insect species with potential for entomophagy worldwide: a review

## Summary

**Background:** One of the current trends in human nutrition is the consumption of insects, known as entomophagy, which is becoming increasingly popular as a sustainable and safe alternative. Insects represent an important source of high-quality protein, comparable to conventional protein sources, and are also rich in fats, minerals, and vitamins. Insect farming is considered a sustainable activity that requires fewer resources compared to traditional livestock production.
**Methods:** The review was carried out through an information search in five databases: ScienceDirect, Elsevier, Springer, SciELO, MDPI, and Brill. As a general criterion, scientific articles related to the selected species were reviewed from 1927, except for the taxonomy section, in which earlier documents were consulted.
**Results:** The article presents a synthesis of five insect species with potential for human consumption: *Tenebrio molitor*, *Acheta domesticus*, *Zophobas morio*, *Gryllus assimilis*, and *Rhynchophorus palmarum*. For each species, its taxonomy, biological characteristics, and nutritional profile including both macro and micronutrients are described. In addition, the current uses of these species in the food industry are examined, highlighting their value as functional ingredients and their potential to be incorporated into new food products.
**Conclusions:** Entomophagy represents a viable and sustainable alternative to contribute to food and nutrition security in the face of global population growth. Entomoculture, understood as the farming of insects for human consumption, emerges as a sustainable agri-food system capable of providing high-quality proteins with a reduced environmental impact, positioning itself as a promising option within future food strategies.

**Key words:** Food; Entomoculture; Edible insects; Nutrition; Environmental sustainability.

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## Introduction

Entomoculture refers to the rearing and cultivation of insects for various purposes. One of the most important applications is the consumption of insects as food for humans, known as entomophagy. Currently, this is traditionally practiced in 113 countries around the world (1). Africa, Asia, and the Americas are the regions where insects are mainly consumed, they harbor a variety of more than 2300 species of edible insects (2). The most popular edible insects are beetles, caterpillars, bees, wasps, ants, grasshoppers, locusts, crickets, royal bugs, dragonflies, termites, flies and cockroaches, which belong to the orders Isoptera, Lepidoptera, Orthoptera and Hymenoptera (3). Traditionally, it is common to use natural or wild sources of edible insects, known as traditional entomophagy; however, in recent years, several insect species such as mealworms, locusts and crickets have been cultivated on a large scale in entomoculture systems, the consumption of which is known as non-traditional entomophagy (4).

Beliefs point to traditional entomophagy as a more nutritious and health-promoting food source compared to non-traditional entomophagy, but this is not exactly true. One of the reasons that strongly encourages insect farming is the fact that wild insects can be dangerous because of the high concentrations of minerals they contain. In one study it was found that the concentration of manganese in wild termites was 50-100 times higher than in other insects. One possible factor could be that wild insects have excessive levels of heavy metals due to the complex environment in which they are found (5). On the other hand, wild insects are quite susceptible to accumulating residues of insecticides, herbicides, and fungicides (6). One way to prevent these risks is to opt for non-traditional entomophagy, cultivating insects under controlled conditions. With human intervention, insects are homogenous, of higher quality and provide high levels of nutrients of interest depending on the diet (7).

Harvesting wild insects can be considered an invasion of natural resources, which is why the cultivation of edible insects is a more sustainable option. Each insect species has its peculiarities (size, life cycles, cultivation, reproduction, feeding, management) making it difficult to elaborate a general protocol on sustainable insect farming (8).

This does not rule out the potential of edible insects to offset the increasing demand for animal protein in a sustainable way. There are several advantages of farming insects on a large scale, most of which benefit the environment, but there are also economic benefits (9). The ability of insects to convert plant protein to insect protein is more efficient than that of mammals, as for every 2 kg of feed, insects gain 1 kg of weight with approximately 65% protein (10). Poultry, pigs and cattle require 2,5, 5 and 10 kg of feed respectively to gain 1 kg of weight. Insects produce more protein per unit of feed; in addition to this, 80% of a cricket can be consumed and digested (11). Compared to cattle, pigs and poultry there is a significant difference in resource use efficiency (12). Edible insect farming is more environmentally friendly because it requires less land, energy, and water. Studies show that to produce one kg of insect biomass 0,36-3,6 $m^2$ of land is needed, while the average for cattle is 23,1, pigs 6,28 and poultry 4,64 $m^2$ land/kg meat. In terms of energy, 0,36-21,2 MJ are required per kg of insects produced while for cattle, pigs and poultry 104, 28,3 and 23,8 MJ are required respectively (13).The amount of water to produce one kg of insect ranges between 8,5-11 $m^3$ (14),while the production of 1 kg of beef requires 2300 L, for poultry 3500 L and for pigs 22000 L (15). The cost of insect production can be 3 times lower than that of cattle. The cost of production is influenced by the following 4 factors: feed composition and consistency, species selection, cultivation parameters and conditions, and regulatory guidelines for optimal production (16). There is the option of feeding edible insects with food waste, however it is not known how safe and efficient this practice is. Food waste is rich in nutrients and water content but is prone to putrefaction leading to foul odors and possible proliferation of moulds, pathogens, and toxins (17). The potential of rearing insects for human consumption from food waste in the future is not ruled out, but is not currently permitted in Europe as oversight and legislative structures are underdeveloped (18).

The objective of this review was to investigate and summarize the five insect species that have potential for human consumption in Latin America as a sustainable food alternative. The article discusses general aspects of the species, such as habits, feeding, behaviour, as well as the nutritional content. It also details examples of the use of these insects in the food industry.

## Materials and methods

Initially, a selection of inclusion terms was made, identifying the topics of interest. The parameters selected were entomophagy, human nutrition, food products, food application, insect consumption and insect-based products as the basis for the search. The most common species in entomophagy in Latin America were used as inclusion parameters: *Tenebrio molitor, Acheta dosmesticus, Zophobas morio, Gryllus assimilis, Rhynchophorus palmarum*. As a general criterion, articles from the year 1927 onwards were considered, except for those used in the taxonomy section, for which older papers were used.

The repositories used to identify the scientific articles were the following: Science Direct, Elsevier, Springer, SciELO, MDPI and Brill. Once it was decided that the article met the inclusion criteria, analysis and synthesis of the literature was performed, carrying out a critical evaluation of the article, extracting relevant data and scientific evidence, identifying trends, discrepancies and relevant information on the species selected for description. A basic structure was established for the distribution of information on each species, including taxonomy, ethological characteristics, nutritional content and their contribution to human nutrition, to facilitate the potential and to clarify their individual contributions to human nutrition.

Two hundred and fifty-eight records were identified through a database search and then screened, of which one hundred and forty-five records were excluded for not meeting the eligibility criteria. One hundred and thirteen studies were excluded for the following reasons: out of scope, duplicate content, did not specify research methodology, did not describe any of the species of interest for the review, did not include in-formation on the biological characteristics, breeding potential, nutritional content or use in the food industry of the species of interest. In the end, sixty-three studies categorized into the nine species of interest in this study were included.

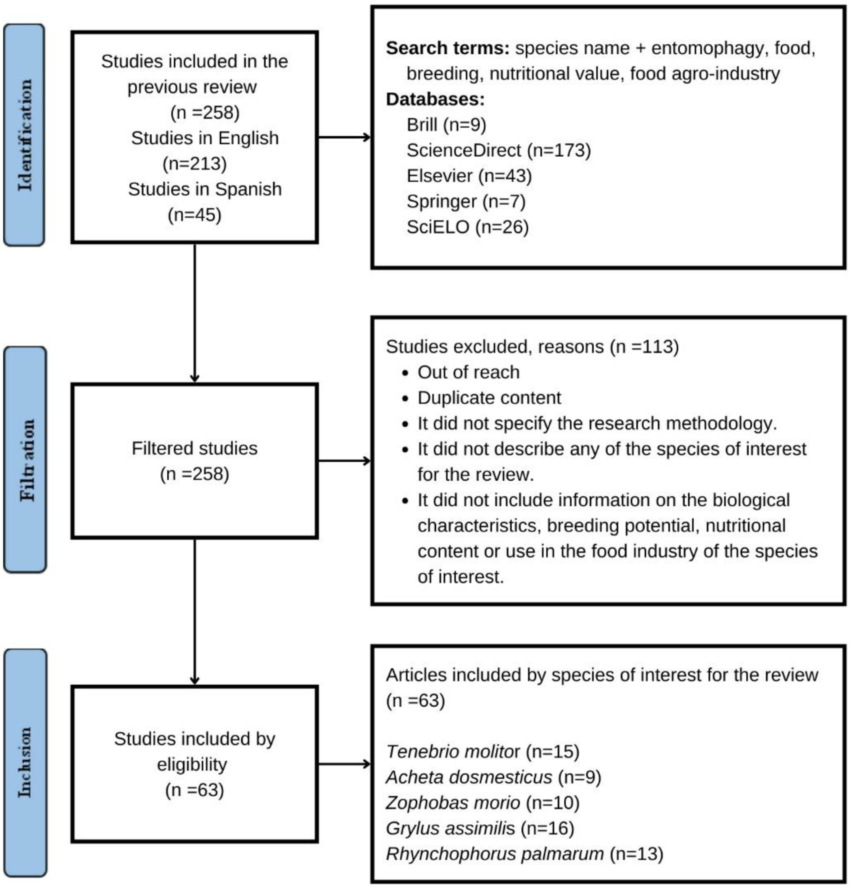


**Figure 1.** PRISMA flowchart for this review.

## Results and discussion

### Description of insects with potential in the food industry

### Description of *Tenebrio molitor*

The mealworm (*Tenebrio molitor* L., Coleoptera: Tenebrionidae) feeds mainly on floury materials, such as stored grains, flours, or semolina (Figure 1). It is considered a pest in stored grain handling. Females produce about 500 eggs per clutch, which are laid singly or in small groups; they adhere to the substrate, walls, or floor of containers, where the females oviposit (19,20). The hatching period of the eggs can take 4 days under optimal conditions (26-30 °C) but can be delayed up to 34 days at low temperatures (less than 15 °C). The larval stage can reach 57 days under controlled conditions and a maximum of 629 days under outdoor environmental conditions (20–22). An average of approximately 112 to 203 days (23).

The larval stage has multiple moults, which may be between 9 (20), and 23 moults although an average of 11 to 19 instars is most common (24). This factor greatly influences the total duration of the mealworm life cycle (25). As the larva approaches the pupal stage, it undergoes a brief period of dormancy where it acquires a characteristic "C" shape. The pupal stage lasts between 6 to 20 (20,26). In the adult stage they develop into whitish beetles with whitish exoskeletons, which gradually harden and darken (25). Mating and subsequent oviposition occur approximately 3 days after hatching (27). While the adult stage lasts approximately 16 to 173 days with an average of 31,8 to 62 days (28,29).

**Figure 1.** *Tenebrio molitor.*

**Breeding potential of *Tenebrio molitor***

Temperatures between 25 and 28 °C are used for rearing with the extreme parameters being a minimum of 10 °C and a maximum of 35 °C (24). Temperatures below 17 °C cause inhibition of embryonic development and temperatures above 30 °C increase mortality rates (24,30). The pupal stage is more resistant to changes in temperature and humidity, while the egg to larval stages is more sensitive (25). Oviposition does not occur at temperatures below 14 °C, and low relative humidity can significantly reduce oviposition (20%) (19).

In the case of stock densities Ribeiro et al. (25), indicate that they vary from 1 larva/dm$^2$ (1 larva / Petri dish 10 cm) to a maximum of 750 larvae/dm$^2$. Similarly, Morales et al. (31), found that the optimal population density is around 8,4 adults/dm$^2$ for mass production. The density factor influences the number and duration of larval moults, as well as reduction in length or increase in factors such as moult inhibition and cannibalism associated with overcrowding in these species (31,32). Overcrowding generates incomplete transformations, reduced growth rate and high conspecific competition, leading to a decrease in the efficiency of the conversion of ingested and digested foods (32). Due to its habits, *T. molitor* is phototropic and negatively phototactic, with adults and later larval stages found beneath the substrate surface during the day and preferring to move about in darkness (25). Although the period affects the growth and development of the life cycle, the response to this factor tends to disappear under constant conditions (22). It is worth noting that studies reveal that a lengthening of light time benefits growth rates and egg hatching rates (25).

**Nutritional composition *Tenebrio molitor***

*T. molitor* larvae have a high protein content between 43,4 and 66,8% on a dry basis, with a robust amino acid profile containing almost all the amino acids essential for human consumption (25,33). Detailed as follows (Table 1).

**Table 1.** Macro and micronutrient composition of *T. molitor*.

| Amino acids | % | Lipids | % | minerals | mg/g |
|---|---|---|---|---|---|
| Isoleucine | 1,39±4,8 | Fats | 17 | Ca | 0,32±0,75 |
| Leucine | 2,81±8,65 | dry matter | 42,48 | Mg | 1,45±3,4 |
| Lysine | 1,6±6,6 | palmitic acid | 9,33±23,7 | P | 5,37±13,45 |
| Methionine + cysteine | 0,64±7,6 | oleic acid | 36,5±52,94 | K | 6,7±13,8 |
| Phenylalanine + Tyrosine | 3,99±13,6 | linoleic acid | 3,8±33,58 | Na | 0,025±1,76 |
| Threonine | 0,93±4,43 | | | Faith | 0,032±0,13 |
| Valina | 3,14±7,61 | | | Cu | 0,012±0,04 |
| Histidine | 1,61±3,64 | | | Zn | 0,082±0,145 |
| Tryptophan | 0±1,8 | | | | |

The mealworm (*T. molitor*) is one of the first species to receive positive approval from the European Food Safety Authority (EFSA) as a novel food for human consumption (37). The larvae can be consumed whole, thermally dried, in powder form and in various preparations such as snacks, pasta or biscuits. The cooking methodology influences the final nutritional quality by modifying their nutritional value and volatile compounds related to Maillard reactions. Likewise, this process significantly reduces their microbiological load and increases preservation. The best results are obtained by combining boiling with vacuum cooking, which guarantees biosafety without altering the macronutrient composition (38,39).

Regarding its organoleptic characteristics, the insect has a mild and slightly nutty flavor, with a crispy texture when roasted or dehydrated. These properties make it attractive for the formulation of functional foods, such as energy bars, enriched flours, and snacks. Several products have been generated, for example, Roncolini et al. (40), reported that flour from this insect (5 to 10% of inclusion) could be used to fortify bread, improving characteristics such as softness, volume and protein content. Even so Kröger et al. (41), showed that the acceptance of products with visible insects has a negative impact compared to flour products or crushed larvae. Similarly, factors such as familiarity and culture influence consumer judgement. In relation to current consumption, *T. molitor* is widely used in processed food products across regions of Europe, Asia, and Latin America.

**Description of *Acheta dosmesticus***

*Acheta dosmesticus* is native to Southeast Asia but is widely distributed throughout the world (Figure 2). This species has an incomplete metamorphosis consisting of 3 stages egg, nymph and adult. The development of the adult has a series of 7 to 10 moults, depending on the time it takes to reach physiological maturity, which usually takes approximately 6 to 8 weeks. Within 24 to 48 hours after mating, *A. domestica* females oviposit their eggs. At optimum temperature, the eggs will hatch 11 to 15 days after oviposition, initiating their nymphal cycle (42,43).

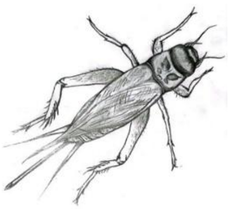

**Figure 2.** *Acheta domesticus.*

**Breeding potential for *Acheta dosmesticus***

*A. dosmesticus* is highly dependent on ambient temperature because its metabolism is not able to produce sufficient heat. At a temperature of 29°C, the growth rate is faster in the nymphal and early adult stage, compared to a temperature of 27°C or less; the optimal humidity for the breeding habitat lies between 50 and 60% (44). These habitats can be constructed from plastic containers, filled with egg cartons and plain paper. However, females prefer a topsoil substrate for oviposition (38).

For its diet, *A. dosmesticus* requires food rich in proteins, vitamins, and minerals, being beneficial for its development the access to vegetables such as carrots, though, some organic waste from vegetables or cereals can also be used as a food source (38,45). For harvesting, the adult insect is exposed to low temperatures, which causes dormancy or a phase of low activity. *A. dosmesticus* is subjected to two days of freezing to kill and preserve the structure for human consumption (46).

**Nutritional composition of *Acheta dosmesticus***

Differences in nutritional content are observed depending on whether the species undergoes incomplete or complete metamorphosis. Nevertheless, it has a high content of protein, vitamins and minerals, as well as a considerable amount of high-quality lipids (omega 3 and 6) and fibre, which are listed in the table below (Table 2).

**Table 2.** Nutritional composition of *A. dosmesticus*.

| Amino acids | % | Lipids | % | minerals | mg/g |
|---|---|---|---|---|---|
| isoleucine | 3,64 | Fats | 82±92 | Ca | 1,32±2,10 |
| leucine | 6,67 | dry matter | 66,6 | Mg | 1,09±4,2 |
| lysine | 5,11 | palmitic acid | 24±30 | P | 1,1±2,66 |
| Methionine + cysteine | 2,49 | oleic acid | 23±27 | K | - |
| Phenylalanine + tyrosine | 8,75 | linoleic acid | 30±40 | Na | 4,35 |
| threonine | 3,11 | | | Faith | 11,23 |
| valine | 4,84 | | | Cu | 2,01 |
| histidine | 2,34 | | | Zn | 21,79 |
| tryptophan | 0,63 | | | | |

*A. dosmesticus* has been accepted as a food on the grinding surface, which can take longer to process. Similarly, due to the high protein content of *A. dosmesticus*, protein extraction for direct consumption is an opportunity, which can be incorporated into gelling agents or texturizing agents for foodstuffs (50). alternative by consumers, especially in recent years, recognizing that it can serve as an alternative source of protein. The most accepted meal presentation by consumers is flour. In addition, it is possible to isolate natural proteins, fats, chitins, vitamins and minerals from this material (12,48). In the processing of some *A. dosmesticus* species, spore-forming bacteria species were identified, so it must be processed and stored in a suitable way for consumption. As well as if its physicochemical properties (nutrients, digestibility, texture, color, size and flavor) are to be preserved (12,46).

For conditioning, freeze-drying or drying processes, where a water content of less than 10% must be maintained, provide a safe alternative to deal with the problems associated with bacteria (49). Depending on the requirements of the final product, grinding can be carried out, although due to the fatty content of the insect, spots can be generated

Concerning its nutritional characteristics, *A. domesticus* has a high protein content with a balanced profile of essential amino acids, as well as unsaturated fats and minerals such as magnesium, copper, sodium, zinc, and calcium (46,47). It has a mild, slightly nutty flavor and a crunchy texture when roasted or dehydrated. Currently, it is consumed in processed food products such as protein powders, flours, energy bars, and snacks, mainly in Europe, Asia, and Latin America.

**Description of *Zophobas morio***

The taxonomy of *Zophobas morio* (formerly *Tenebrio morio*, F., 1778) is controversial and somewhat unclear (51,52). *Z. morio* belongs to the beetle family Tenebrionidae, where stored grain pest species such as *T. molitor*, previously mentioned in this review, belong. *Z. morio* has only been associated with one stored product, wheat flour, and is a pest of little importance (Figure 3). Its life cycle begins with eggs, round-edged, white, approximately 1,7 mm long and 0,7 mm wide. Each female can lay up to 2200 eggs during her life cycle, this value is negatively correlated with the age of the insect and positively correlated with the density of adults (53).

**Figure 3.** *Zophobas morio.*

**Breeding potential of *Zophobas morio***

The larval stage has an initial yellowish coloring and a later dark brown color, consisting of a cylindrical, sclerotized exoskeleton, and can reach up to 55 mm in length. Eggs hatch in 8 to 25 days under optimal conditions (25°C), the number and duration of larval instars is influenced by density and varies whether larvae are reared in isolated or grouped environments (22,53). If an isolated state is maintained, larvae reach 11 to 18 instars, while the pupal stage is reached after 16 to 17 moults on average. This behavior is suppressed under crowded conditions, moulting occurs until death is reached (51,54).

For controlled rearing of *Z. morio*, temperatures of approximately 25 to 28°C and average relative humidity of 60 to 70% are needed. The common cannibalism that occurs with this species must be monitored because it affects production and biomass increase yields (55,56). Likewise, when talking about commercial production, care must be taken to avoid the proliferation of diseases, there are few reports of the occurrence of infectious microbial agents in *Z. morio* (57,58).

**Nutritional composition of *Zophobas morio***

Studies of the nutritional composition of *Z. morio* show that it presents a great alternative for human nutrition due to its high nitrogen content ranging from 6,2 to 8,6%, which is not affected by its development (59). The nutritional composition is detailed in table 3.

**Table 3.** Nutritional composition of *Zophoba morio.*

| Amino acids | % | Lipids | % | minerals | mg/100g DM |
|---|---|---|---|---|---|
| **isoleucine** | 2,2±2,4 | Fats | 2,1±32,4 | Ca | 31,9±70,8 |
| **leucine** | 3,4±4,5 | dry matter | 38,2 | Mg | 39,2±118,3 |
| **lysine** | 2,4±2,9 | palmitic acid | 9,7±12,5 | P | 562,9±564,9 |
| **Methionine + cysteine** | 0,5±1,0 | oleic acid | 11,6±15,7 | K | 750,6±773,0 |
| **Phenylalanine + tyrosine** | 1,6±2,2 | linoleic acid | 7,1±7,8 | Na | 104,1±112,8 |
| **threonine** | 1,9±2,0 | | | Faith | 2,3±5,4 |
| **valine** | 2,4±3,4 | | | Cu | 0,5±1,0 |
| **histidine** | 1,4±2,3 | | | Zn | 2,5±8,2 |
| **tryptophan** | 0,4±0,5 | | | | |

**Description of *Gryllus assimilis***

The field cricket (*Gryllus assimilis*) is widely distributed in the Americas, from the southern United States to parts of South America (60,61). Its life cycle comprises three crucial stages: egg, nymph and adult, with different nymphal stages. The cycle begins when females deposit eggs on the ground, approximately one centimeter beneath the surface for protection. These eggs are light-colored and measure approximately 2,5 mm long by 0,5 mm in diameter. Newly hatched nymphs are soft-textured and light-colored, but their exoskeleton quickly hardens, acquiring the characteristic color of their species. During their nymphal stage, crickets moult their exoskeleton seven to ten times before reaching adulthood. In the last moult, females fully develop their ovipositor, while males unfold their wings to produce their distinctive song by rubbing them against each other, a process known as stridulation that attracts females (62).

Adult *Gryllus assimilis* can reach a size of 25-28 mm (Figure 4). All adults have long hind wings, adult females are slightly larger, with a prominent ovipositor protruding from the abdomen. The life cycle of the Jamaican field cricket (*G. assimilis*), from egg to adult, can last around 138 days. Egg incubation lasts approximately 11 days and the nymph stage lasts 62 days. Adult longevity varies according to living conditions, with an average lifespan of 76 days (63). This species, like other species of the same family, is relatively resistant to environmental conditions and can be productive in massive crops, although under high population density, it may show a tendency to cannibalism. Its diet is omnivorous, as it feeds on leaves, stems, fruits, vegetables and other insects (64).

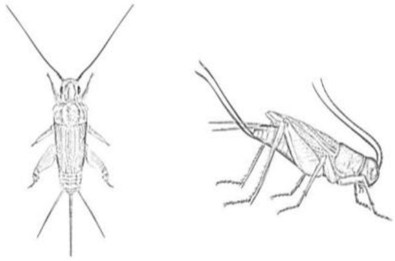

**Figure 4.** *Gryllus assimillis.*

**Breeding potential of *Gryllus assimilis***

According to the results obtained by Alfaro et al. (61), cricket farming has a high nutritional value, low production cost and environmental sustainability, which makes it a promising alternative for human food (49). Crickets are extremely efficient in feed conversion, requiring only 1,7 kg of feed to produce 1 kg of body weight, compared to cattle, which require 8 kg of feed to achieve the same conversion. This makes crickets approximately twice as efficient as chickens, three times as efficient as pigs and four times as efficient as cattle in feed conversion (65). Furthermore, cricket farming has been shown to be a way to increase cricket consumption without endangering wild insect populations by taking advantage of their small size and the possibility of rearing them at higher densities (66).

Cricket farming is presented as a cost-effective alternative, especially in areas where land costs are high, and space is limited. *G. assimilis* is reared in rectangular containers, usually 1,2 to 3,0 m wide, 2,4 to 5,0 m long and with 0,6 m high walls. These containers are filled with egg cartons or other material to increase the surface area and provide shelter for individuals. Brood containers can be made of different materials such as cement, brick, clay, wood, cardboard, metal, high-density polyethylene or fiberglass, with preferably smooth surfaces to avoid leakage. It has been reported that in a container of 1,5 m x 1,5 m x 0,6 m high, approximately 10 kg of crickets can be produced in fresh weight (67).

Rearing area and environmental temperature influence the production of a cricket farm. Under mass rearing conditions with an average temperature of 21°C, one container has the capacity to produce approximately 4 kg of fresh insects. A 60 $m^2$ farm can accommodate up to 90 rearing containers. Consequently, a small farm of this size can produce 360 kg of fresh insects per cycle, equivalent to 1,08 tons per year. A feasibility study carried out by Chong & Cribillero (68) has shown that the cost of production per cycle is only $27,44 US dollars, generating a profit of $82,32 US dollars, highlighting its promising potential. According to Araújo et al. (69), to maintain a *G. assimilis* brood optimally, the temperature should be in the range of 25 to 32°C and the relative humidity between 45 and 60%.

It is important to know that the growth rate of crickets is closely linked to their feeding, water availability and environmental temperature. It is recommended to avoid excessive humidity levels, as this can encourage the growth of harmful fungi and bacteria. Under optimal temperature conditions, the growth process of crickets lasts between four and six weeks.

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**Nutritional content of *Gryllus assimilis***

*G. assimilis* meal has a nutritional composition with a content of 65,52% protein, 21,80% lipids, 8,6% carbohydrates and 4,8% ashes (70). In another research conducted by Mlček et al. (71), found the following values: crude protein 55,6%, dry matter content 22,6%, and fat content 11%. In addition, the insects exhibit significant levels of palmitic, oleic, and linoleic acid. As for minerals, they are present in notable amounts, including 0,74% phosphorus, 1,02% potassium, 0,38% calcium, 0,11% magnesium, 0,43% sodium, 203 ppm zinc, 55 ppm copper, 43 ppm manganese, and 654 ppm iron. The presence of essential amino acids such as Isoleucine with 21 $g/kg^{-1}$, Leucine with 49 $g/kg^{-1}$, Lysine with 79 $g/kg^{-1}$, Methionine with 6 $g/kg^{-1}$, Phenylalanine with 7 $g/kg^{-1}$, Threonine with 35 $g/kg^{-1}$, Tryptophan with 9 $g/kg^{-1}$ (70). Compared to other commonly used food sources, edible insects offer significant amounts of protein, lipids and minerals, providing an adequate nutritional supply to meet biological needs (72).

*G. assimilis* flour has great potential for use in the food industry. Many products can be created from this raw material in the baking industry. Da Rosa Machado and Thys (73) characterized *G. assimilis* flour as a protein source for gluten-free breads. The result was not only a gluten-free product with high protein content, but also the properties of the cricket flour improved physical characteristics while maintaining microbiological properties suitable for human consumption. Another potential product with potential economic, nutritional, and environmental benefits is the barbecue sauce made by Fernandez et al. (74), whose physicochemical properties were evaluated by adding *G. assimilis* flour. Other researchers such as Aleman, et al. (48), used *G.* assimilis y *A. domesticus* as an alternative for the development of new symbiotic ingredients with potential for the food industry (48).

**Description of *Rhynchophorus palmarum***

*Rhynchophorus palmarum* (Coleoptera: Curculionidae) is known to be an important pest in palm monoculture (Figure 5). This species causes economic losses due to the physical damage caused by the larvae feeding on the meristems and for being a vector of the red ring disease (red ring disease) (75). However, this perspective changes in certain places, such as in South America, where the weevil has long been seen as a source of edible protein and is not only collected from the wild but also cultivated by natives using ancestral practices (70). The palm weevil is native to Mexico, Central America, South America and the Caribbean and has now been reported in parts of North America (76).

Adult palm weevils are black in color and can vary in size from 2 to 5 cm. They are sexually dimorphic, with the female having a smooth, curved beak, longer than the male, and lacking the presence of setae on the dorsal part of the beak. Its life cycle is one of complete metamorphosis and lasts at least 122 days under optimal conditions. In the egg stage it lasts 3,5 days, in the larval stage 60,5 days and in the pupal stage 16 days until it reaches adulthood. The adult female has an oviposition period of 43 days in which she lays an average of 900 eggs (77). There are many species of weevils that are very similar to each other, however in their ethology they can be different. Such is the case of *Dynamis borassi*, which is very similar to *R. palmarum* but feeds only on living palm tissue while *R. palmarum* feeds on dead tissue (78).

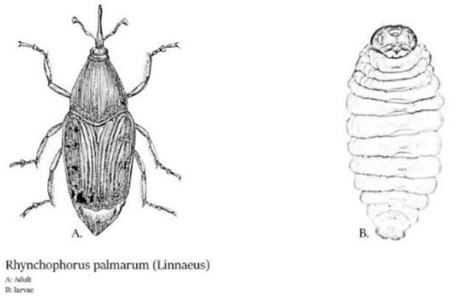


**Figure 5.** *Rhynchophorus palmarum*.

**Breeding potential of *Rhynchophorus palmarum***

Captive production of the palm weevil is debatable where hosts are endangered. Hoddle et al. (76), report that in California, USA, *R. palmarum* is invasive and responsible for killing four species of palm hosts. Rearing this insect could be a threat to the spread of the pest. However, from another point of view, the cost of producing a larva of this insect is USD $0,25-0,50. In tourist sites inhabited by the Sionas, an indigenous people living in Colombia and Ecuador, the best price achieved per pound was USD $6,00. This price can change based on whether the larvae are cooked or live and depending on their size (79).

**Nutritional content of *Rhynchophorus palmarum***

In general, the total fat content of dehydrated *R. palmarum* is 30% to 60%. This fat content is mostly composed of monounsaturated fatty acids, which account for 40% to 60% of the total. In addition, it contains saturated fats, which vary between 36% and 55%, and polyunsaturated fats, which make up approximately 1% to 3%. In terms of protein content, *R. palmarum* has a protein content ranging from 19% to 26%. These proteins are rich in essential amino acids, the specific concentrations of which depend on the insect's diet. In addition to its fat and protein content, the weevil is also a carrier of vitamins and minerals that contribute to its nutritional value (80).

In South America, the Kichwa and Shuars indigenous groups consume *R. palmarum* in the form of grilled or roasted larvae. The process begins with the collection of live larvae from the shells of the palm trunks, to be consumed or marketed (81,82). The adult stage weevil is mainly consumed in roasted form, but no products or by-products from its processing are reported (70). Research reports the consumption of 6 kg/per capita of *R. palmarum,* and it is estimated that this is equivalent to consuming 50 larvae per person/month (83).

In the Peruvian Amazon, the palm weevil is consumed not only for its protein content, but also for the health benefits it provides; it is useful for treating respiratory diseases such as asthma, tuberculosis and rheumatism. This can possibly be explained by the high content of fatty acids in the palm kernels, mainly the precursors of essential fatty acids, such as linoleic acid. Ethnic groups that consume the larvae of *R. palmarum* claim that consuming the larvae on an empty stomach can cause diarrhea or headache and even make a person sluggish (84). Due to its potential functional ingredient, *R, palmarum* was used in combination with other endemic plants from Honduras to evaluate its symbiotic effect with *Lactobacillus acidophilus* LA-K for the development of nutritionally enhanced products such as yogurt and other functional beverages (48).

## Conclusions

Latin America has a wide variety of insects that have the potential to be used in human diets. From the commonly known mealworms and house crickets to the palm weevils, these insects offer generous flavors, textures, and nutritional profiles in terms of fatty acid concentration, protein, minerals and vitamins. These insects offer generous flavors, textures and nutritional profiles in terms of fatty acid concentration, protein, minerals and vitamins. The adoption of insect species as sustainable food sources represents an alternative for Latin America in the face of food security and sustainability challenges. Similarly, entomophagy promotes the conservation of the cultural heritage and culinary diversity of indigenous peoples.

There are major challenges that need to be addressed for entomoculture to thrive in Latin America. One of them is the lack of awareness and acceptance among consumers. In many Latin American countries, insects are traditionally viewed as pests rather than food. Overcoming this cultural bias and educating the public about the benefits of entomoculture is crucial to its success. Another challenge is the need for supportive regulations and policies. Currently, there is a lack of clear guidelines for insect farming and processing in Latin America. Establishing regulations that guarantee quality and food safety standards and at the same time promote innovation will be essential for the growth of the entomoculture industry.

Despite the challenges, there are promising signs of progress in the field of entomoculture in Latin America. Several start-ups and research institutions have begun to explore insect farming as a viable business opportunity. These companies are experimenting with different insect species, developing innovative farming techniques and creating value-added products from insects.

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