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Are Insects a Good Alternative in Human Food?. Nutritional Value

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Abstract

Entomophagy refers to the dietary intake of insects and supplements practiced by millions of people worldwide. It has always been present in the eating behaviours of regions in Asia, Africa, and Latin America. Entomophagy is on the rise both in the feeding of humans and in animal feed. Insects are powerful bio converters that can transform the low quality biomass of nature into proteins of high nutritional value. The recent introduction of the consumption of insects in new types of restaurants and supermarket chains in Western cultures has led us to conduct a review of the subject to see if the myths our Western conceptions can be overcome.

Keywords: Insects; food; nutritional value

Introduction

The continuous increase in demand for all types of food, both meat and fish, vegetables, etc. for human consumption, the production of high-quality proteins from livestock (beef, pork and lamb), fish, poultry, eggs, and milk is not sufficient for an adequate supply. The limited available sources drive a relentless search for protein sources that can be an alternative to proteins derived from animal meat [1]. There are an immense number of insects that inhabit the earth. It is believed that there are between 200 and 2 billion insects per human being. Therefore it is logical that both health authorities and the food industry regard insects as possible foods for their nutritional properties [2]. Insects are an important source of food for both animals and humans, and for this reason there are various nutritional reports in articles from various disciplines, from anthropology to zoology. Nowadays, very few insects are eaten in Western societies, in the rest of the world they are an important part of the daily diet and many are considered a real delicacy. The variety of insects that man eats is very large, but most of the nutritional analyzes have been carried out with butterfly larvae, beetle larvae, grasshoppers, termites, etc.

The nutritional value of insects becomes evident when we see in nature that birds feed both seeds and insects and also feed their young. Therefore, the key to raising birds is therefore a varied diet with insects, seeds, herbs, etc. Insects are already used as traditional food in many parts of the world. There are more than 2.000 species of edible insects, mainly in tropical regions [3]. African, Asian and diverse South American cultures are big consumers of insects [4]. However, in almost all human societies there are a large number of taboos related to food [5]. Insects are no exception, so there are still taboos about their consumption by humans, as well as the possibility of toxicity and allergic risks of when ingested.

Insects are an important source of protein and their nutritional value is so high that they would provide the essential amino acids for human consumption [6]. The use of insects as food and for the manufacture of feed would provide great benefits, both environmental and sanitary. There are already more than 2.000 species of insects that can be consumed, and this figure increases as more studies are carried out. Therefore the use of edible insects in human food is an interesting challenge [7,8]. The majority of these species are collected from the natural environment. The insects mostly consumed are beetles (31%), caterpillars (18%) and bees, wasps and ants (14%), followed by grasshoppers, locusts and crickets (13%), cicadas, woodlice. and bugs (10%), termites (3%), dragonflies (3%) and flies (2%) [6] (Figure 1 and 2).

Entomofagia is the science that studies the consumption of insects by humans. Since ancient times, perhaps before tools for hunting and agriculture were developed, insects have been consumed in Africa, Asia and Latin America [3]. Regulations recently

enacted by the European Union (EU) authorize and facilitate the commercialization of insects for human consumption, thereby expanding markets worldwide, as with prawns, barnacles or eels many of its inhabitants are reluctant and reject the consumption of other insects such as ants, grasshoppers and worms [7]. In Korea silkworm pupae are boiled and eaten as snacks, and in Africa termites are prepared in various ways. In Asia, grasshoppers are very common. An insect that is very common in Japanese diets is the “aza-mushi”, or "hachi-no-ko" (wasp larvae). In Indonesia one of the most appreciated specialties is the dragonfly. In African cuisine caterpillars are often preferred to meat.

Figure 1: Sale of insects from a well-known supermarket chain in Spain

Figure 2: Sale of insects in an Asian market

In American countries like Mexico there is already a general entomophagic. Consumption of insects is common, with more than 57 different species eaten both as larvae and as adults, usually roasted. Consumption of insects is usually seasonal. They are marketed in both small and large markets. The most consumed species are three: a cockroach (*Periplaneta australassiae Fabricius*), and two moths (*Latebraria amphipyroides Guenée* and *Arsenura amida Cramer*) [8]. Grasshoppers are a specialty of Mexican gastronomy; they are usually eaten marinated in lemon juice. In Colombia consumption of the culona ant is traditional.

In Australia, the consumption of insects occurs only as a novelty, but Australians do not include them in their daily diet. A study was carried out in the Australian population in which the acceptance of insects as food was evaluated by their population. The sample of study was formed by 820 consumers. The results were that 68% of the participants were familiar with entomophagy, but only 21% had eaten insects. Taste, appearance, food safety and quality were factors that most influenced to participate in the survey. The most consumed insects were ants, grasshoppers and crickets. Among the conclusions it was deduced that there was still a too high percentage of reluctant population to consume new food products such as insects [3].

The daily consumption of insects as food in China has existed for more than 2000 years. Scientific studies on the consumption of insects in China have been conducted for 20 years. 324 species belonging to 11 different families are consumed as food. In addition to food use, there are insects used for medicinal purposes, such as the eggs of the praying mantis, or the red cicada, and the beetle [9,10]. The centipede is used mainly to treat arthritis, and the fungus of the silk moth, which infects silk moth larvae and is used mainly to treat blows [11]. However, only 20 or 30 insects are consumed regularly, although there are studies on the nutritional value of about 174 different species, the nutritional value of insects vary among species and are ingested by different ethnic groups, including directly as food products, the consumption of products from cattle fed with insects is also common. There are also data on the food safety of insect consumption, although these data are limited, there are also data on the existence of allergic reactions caused by its ingestion. In China there are already farms dedicated to industrially breeding of insects for human consumption. Agriculture in China is also directed towards the breeding of edible insects [12].

Entomophagy is also practiced in India. Some insects are consumed in the diet only temporarily, others throughout the year. Generally insects are roasted, fried, or simply boiled [13]. Due to the impossibility of introducing insects radically into the human food chain, insects are already present in some foods without consumers knowing it, such as cereal grains. Some varieties of rice contain numerous insects among their grains. Health authorities know it and consider it as an important source of vitamins [3,7].

Insects can be an important source of proteins, fats, vitamins and minerals such as calcium, iron and zinc, they are very nutritious, however there are doubts about whether their large-scale production can be more or less sustainable than other protein sources, more conventional. Proteins from insects are in an intermediate state between animal and vegetable proteins, not being as harmful as non-beneficial animals such as plants. One of its main advantages is that they can be consumed whole or ground, in the form of paste or powder and incorporated into other foods. Its use as a raw material for aquaculture and poultry feeding will be much more common in the next decade (Table 1) [1,2,14].

	Protein(g)/100 g	Fat (g)/ 100 g	Carbohydrate (mg)/ 100 g	Calcium (mg) 100 g	Iron (mg) 100 g
Cricket	12,9	5,5	5,1	75,8	9,5
Grasshopper (little ones)	14,3	3,3	2,2	27,7	3,0
Ants red	13,9	3,5	2,9	47,8	5,7
Chrysalis of worms of silk	9,6	5,6	2,3	41,7	1,8
Bedbugs of water giants	19,8	8,3	2,1	43,5	13,6

Summarizes the nutritional analysis of some of the insects used in human nutrition today
Table 1: Nutritional analysis of some insects [18]

Nutritional Value

The use of insects as food, as well as for the elaboration with them of feed provides great advantages both of environmental type, as for human health, for the social environment and the livelihoods. Currently more than two million people in the world assiduously consume insects, however there is a very high percentage of consumers reluctant to try new foods such as insects, they even express their rejection when they consume foods that are contaminated by insects, However, if there is a relatively interesting percentage of consumers who are receptive to introducing them into their diet, it is easy that the way they do so is to insert them into home-made products such as making biscuits for family consumption [3,14]. Insects like the cricket contain high doses of proteins, calcium, selenium, zinc, iron, magnesium, omega 3 and 6 acids and other essential minerals and vitamins such as riboflavin (vitamin B12), in some cases they also contain folic acid; even some they have five times more magnesium than meat, three times more iron than spinach, twice as much calcium as milk, twice as much fiber as rice and ten times more vitamin B12 than salmon, compared with 100g of insect dry weight.

Currently, human beings consume more than 2.000 species of insects in the world. The most eaten are beetles (31%), caterpillars (18%), bees, wasps and ants (14%) and grasshoppers, locusts and crickets (13%).

While their interest lies in the fact that beef contains 6 mg/100 g of dry weight, the iron content of locusts is between 8 and 20 mg/100 g of dry weight. However eating 150 gr or 200 gr of beef is easy, eating the same amount of insects is not so much.

It cannot be said from the dietary point of view if the insects are hypercaloric or hypocaloric, what we do know is that the larvae contain more fats than the adult state. It is not easy to substitute a steak for a plate of crickets and insects are not more appetizing than healthy foods such as avocados, nuts or blue fish, but there are already in the market today energetic bars made with insects how the crickets are. The preferred insects on the plate are the beetles. After studying the content of amino acids and fatty acids that most of the different edible insects found in the literature have, and after a study on the beneficial and harmful effects of their consumption, although the data obtained are subject to multiple variations, can conclude that many of the edible insects provide enough energy and proteins to provide adequate food for humans, are rich in several micronutrients such as copper, iron, magnesium, manganese, phosphorus, selenium and zinc, as well as riboflavin, acid pantothenic, biotin and in some cases folic acid.

It is very interesting to study the diet of insects that are going to be used in human nutrition, to take care of their diet by providing them with nutrients rich in proteins and fats, they would make their nutritional value could be modified and their consumption would be more interesting, if their diet is adequate its use as food can be as acceptable as poultry, at least as far as nutritional value is concerned. They would make insects a sustainable alternative to conventional production animals as a source of food [15]. Edible insects are an important source of long-chain polyunsaturated fatty acids, their content is different in terrestrial insects of aquatic, Terrestrial are richer in omega 6, as these are much more numerous are more attractive to human food terrestrial insects, discarding in many cases the use of aquatic insects as far as human consumption is concerned [16]. However, after studying five potentially edible aquatic insects, after analysing its composition it was found that its protein and mineral content: calcium and magnesium were very high, some even had strong antioxidant properties, therefore these insects can be considered aquatic as referents in a for its high nutritional value, benefits for health and the environment [17].

Analyzed the content of iron, zinc and calcium in five different insect species: 1 species of ant, 3 different species of termites (ogawo, oyala and agaor) and one species of cricket, it was found that the content in dry matter the iron ranged from 18 to 1562 mg/100 g of dry matter, the zinc content ranged from 8 to 25 mg/100 g of dry matter and the calcium content varied between 33 to 341mg/100 g; all these values are considered quite high so the insects reaffirm with it the idea that insects are a very important source of minerals [18] (Table 1).

What can not be ruled out is the existence of possible allergenic and toxic substances, Of which is beginning to be reported in the literature, as well as pathogens. More exhaustive studies on the nutritional value of edible insects and their processing, as the development of methods to eliminate pathogenic substances would be necessary that guarantee their innocuousness for their consumption [19]; since insects in nature have a high microbiological risk and would have to be treated later before their human consumption, in the preparation chains.

As well, the use of insect larvae as a new source of animal feed due to its high composition in high quality proteins for feeding both livestock and aquaculture is very interesting, however in many cases it is not possible to advance in its study due to the regulatory obstacles they face [20].

The Insects and New Foods in the Western World

There are reviews that evaluate the content and digestibility of insect proteins, their composition in amino acids, their quality, considering them as an alternative source of proteins for human consumption [6].

Among the environmental advantages of the use of insects for food we find the ease that insects have for the conversion of food, since they are cold-blooded species. The gases produced by the so-called greenhouse effect, by most insects are generally lower than those produced by the usual livestock. They feed on biological waste as well as food waste or human origin, fertilizer and manure, and can transform these residues into high quality proteins, which in turn can be used as animal feed. Insects use much less water than regular livestock, they are therefore much more resistant to drought. Insects report great health benefits, since they generally provide high quality proteins and nutrients when compared to meat and fish.

Por lo tanto son muy beneficiosos en la alimentación del niño desnutrido ya que la mayoría

Therefore, they are very beneficial in feeding malnourished children since most of the insect species contain high levels of fatty acids, similar to those of fish. They are also rich in fibers and micronutrients such as iron, copper, magnesium, phosphorus, manganese, selenium and zinc. The risk of transmission of zoonotic diseases is very small.

The quality of a protein depends on the combination of amino acids and their digestibility. Digestibility is a way of measuring the use of a food, that is, the ease with which it is converted in the digestive system into substances useful for nutrition. Amino acids are very small particles that bind together to form proteins. They can bind from 2 to hundreds of amino acids and this is what determines the formation from small enzymes to complex tissues and organs.

The type of amino acids that make up a protein are what determine its function and since we are born, in our genetic code, it is written what combination of amino acids each of the proteins that make up our body must have. It is the information stored by our cells and how vital is the need we have for these amino acids. Because of this, our body manufactures some of them known as non-essential amino acids. There are others that we can not manufacture and we have to obtain them from the diet, these are the so-called essential amino acids, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, histidine and arginine.

For a protein to be of good quality, it must provide all the essential amino acids, because if it lacks one, it becomes a protein of poor quality. Vegetable proteins such as legumes, which include lentils, chickpeas, beans, etc., and cereals such as corn, rice, wheat, etc., are considered poor quality because some are missing some essential amino acids that others have more and vice versa. That is why they complement and consume together to raise their nutritional quality.

On the other hand, animal proteins are of good quality because they provide all the essential amino acids, but there are levels within them depending also their level of digestibility, since the correct absorption of their amino acids and nutrients in general will depend. Within the animal proteins with the highest biological value because it has the most balanced proportions of the ten essential amino acids and because its digestibility is very good, like cow's milk.

Regarding the social environment and livelihoods, insects report enormous advantages because they can be collected directly from the environment in a simple way, without the need for complex technological processes, which suppose a significant economic outlay, and it can be done by disadvantaged people from rural areas, they are also really important for the economic progress of developing countries. In addition to serving as food for humans, they can also be used for animals, they can be eaten whole or turned into pasta or ground into flour, and they can even be extracted from their proteins and used as such.

The breeding of insects for human consumption is cheap, as well as nutritious and sustainable, since it consumes less resources of the environment than those that use mass production of animal feed. For what is presented as a good alternative to combat poverty and pollution in an increasingly populated world.

If more research were financed, it would be clearer if eating insects fully guarantees food safety or if there is a potential problem that has not yet been investigated, and that it asks to accumulate too many pesticides from the plants from which they feed or threaten with the extinction of some species in case that eating insects becomes fashionable in the west.

The problem of the Mediterranean diet is the price, since the little it costs to buy junk food like industrial bakery makes it difficult to opt for olive oil and fruit. Although insects are also a cheaper option than products considered healthy. In addition you have to

take into account the rations, that is, on a plate you can eat a steak of 150 g of meat or 200 g of fish but you could 200 g of insects, since they are animals that weigh little and bulge a lot.

Insect breeding is viable, although initially it is more expensive than the production of traditional sources of food and feed, however recent studies suggest that taking into account the result of the total cost of the production of insects could be cheaper than traditional foods and foods. This would require the development of insect breeding facilities that were made in a massive and automated way, which would be more profitable as long as they provided a stable and safe product for human consumption. Mechanization is a key issue for the growth of the industry in terms of insect breeding. Providing tropical countries, where the number of insects is much higher, adequate financing to ensure production that is sustainable and provide the necessary means to make it possible to raise and care for the most edible species would be essential to make their use profitable [5]. In addition, appropriate regulatory frameworks should be developed to regulate the production and trade of insects such as food and feed.

A key point is to get more funding for research on insects and their safety for human consumption, it is necessary to be clear that if eating insects fully guarantees food safety, we must also know if there is any potential problem in their safety not yet investigated, such as the excessive accumulation of pesticides of the plants from which they have been able to feed. The Mediterranean diet has always had an enemy and is the price, insects are a much cheaper option.

In addition to being useful as food, insects have other useful functions such as:

• Are providers of ecosystem services; its role in pollination is very important, as well as in the biological control and decomposition of organic waste.
Its ability to reduce manure, such as that generated by pigs and reduces their bad smell; the larvae of flies can be used to convert manure into fertilizer and consumable proteins.
• Insects have inspired human innovation for many years.
• They have been part of human medicine for thousands of years; fly larvae are used to clean dead tissue in wounds, and royal jelly, propolis and honey, bee products, are used for their healing properties.
• The natural color of insects, such as the red color produced by the cochineal (carmine), was already used by the Aztecs, and is currently used as a natural colorant in foods and dyes.
• The use of silk as tissue obtained from the silkworm.
• Insects could be not only bioquivalent for their protein content in wild meat but also other food products such as some seafood, fruits and vegetables, their culinary use would also be very attractive [21].

Entomophagy has many advantages, however in western countries there is still reluctance to practice, the low price, taste and availability are positive factors that will affect their consumption, and antecedents such as sushi, currently widely accepted in the current western world, it does weigh that western diet models can be changed quickly [7].

Although countries like Mexico have been using them as a natural resource in food for more than 25 years, many restaurants currently demand it in considerable quantities, this makes their natural exploitation grow. In Tulancalco, a small town in the state of Hidalgo uses approximately 30 edible insect species, its exploitation being an important source of income. However, overexploitation by unqualified collectors threatens the subsistence of numerous species. Therefore, the establishment at the same time that insect exploitations of actions and legislation are created to preserve the stocks of the most consumed species of insects, is fundamental and necessary [8].

It is important to create a culture or an "Education of the entomophagy", beginning to use the insects as an appetizer or tapa or as an additive to a dish or dressing, in exotic salads [22].

More and more restaurants create menus and new recipes of which the insects are part, experimenting with their flavor, it is necessary to make them appetizing, the problem that currently exists is to obtain the necessary and continuous supplies of insects in the quantity and quality necessary , for its use and that there is no shortage [1].

It is also necessary to guarantee the food safety of insects by means of a precise and safe regulation, there is still not enough scientific knowledge to guarantee their safety especially when their breeding and handling are carried out on an industrial scale [23]. The lack of sufficient and contrasted data on the composition of insects and a reliable database that clearly specifies their analytical composition and their nutritional value limits their widespread use as food in different countries, especially in the western world [24]. The study of insects will have a place within these congresses and their repercussion and conclusions would surely be favorable in their use as food.

The creation of societies and the realization of congresses whose objectives are the study of the relationships between human societies and the natural environment in order to study new means for human consumption are increasingly frequent [25].

For what will be necessary and key to its research and development:

1. Improve the innovation of mechanization, automation, processing and logistics in order to reduce production costs.
2. To develop feeding tables for insects, the study of the diets of the different insects in captivity is basic to achieve a greater number

of species with a higher nutritional value and that are therefore more accepted and more valued for the human consumption [15,26].

3. Carry out more precise studies on the life cycles of insects and their genetic diversity.
4. Research on the safety of its uses as food and feed, possible allergies to insects in humans and the ability to digest chitin.
5. Expand the information that is available about the nutritional value of edible insects
6. Research on possible zoonoses.
7. Develop means for its conservation.
8. Develop legislative frameworks that regulate the condition of insects such as food and feed.
9. Develop the risk assessment methodology for the prevention of edible insect hazards associated with mass rearing and wild collection. There are already scientific reviews that focus on safety aspects that have to be considered when splitting insects for the production of food products and food ingredients at an industrial level [23].
10. Support the entomophagy in those cultures that already exist, through the creation of education campaigns and the formation of gastronomic events in which the gastronomic values of insects are enhanced [22,27].
11. Educate consumers about the advantages of entomophagy such as:

- Its low price,
- The environmental benefits caused by its consumption,
- The high protein content of the food products made with them [5].

12. Creation of new products based on insects for human consumption, for example, the energy-based insecticide bars (Figure 3).
13. Promotion of insects as a food supplement.

Figure 3: New products based on insects

Different species of insects have different food composition, cannot be considered as more nutritious food than those from meat, fish or poultry, but after studying the composition of several insect species with different analytical methods for the identification of amino acids among which high performance liquid chromatography and ion exchange chromatography can be said that insects are in no case less nutritious than meat, are therefore considered an excellent alternative to avoid combat malnutrition in the world [28,29]. There are some 805 million undernourished people according to data offered by the United Nations for Agriculture and Food, by using insects in human nutrition this deficit in nutrition in people (about 84 Kcal / day / person) it could be reduced considerably [30]. Its consumption could be used as a strategy to address malnutrition, although even its inclusion in the diets of consumers is still very limited because some consumers are very skeptical [31]. It is an excellent alternative for the nutrition of the aging population that continues to grow in all cultures of the world, being in many cases much more accepted by this type of population, much more spoiled than by the young population that in many cases express disgust and dislike for its consumption [32]. Several studies describe the main factors that influence the acceptance of entomophagy by consumers, with nutrition education being fundamental in its acceptance [22]. Although its consumption varies according to ethnicity, consumer's residence and the season of the year, the development of insect breeding is still very precarious, however it could greatly increase the availability of edible insects [31].

Conclusion

Increasingly there is a growing interest in entomophagy by health administrations, consumers and the food industry. And the exploitation of insects as food causes the creation of farms for the cultivation of insects dedicated to human consumption.

There are new restaurants interested in having menus containing insects in their menus, creating more and more specific books with entomophage cookbooks.

The nutritive contribution of insects is not questioned at any time, the main problem of their consumption is the rejection that the consumer presents mainly from Western countries, however, are considered as a possible solution to the problem of hunger in the world due to the high number of insects that exist and their low economic cost.

Insects are a good alternative for all those people who refuse to consume animals due to ethical problems due to the rejection that causes them to cause pain, insects do not have the neurological structures that serve to transmit negative stimuli in an emotional experience, they lack the sense of pain. A relative increase in entomophagy could have environmental benefits. Insects represent a great nutritional opportunity, since the growing world population needs sustainable food sources. And the consumption of insects could be a very valuable measure to combat deficiencies especially iron and zinc in developing countries.

In western countries the acceptance of insects by the consumer will be related to their price, the environmental benefits they provide and the development of food products rich in proteins based on insects whose taste is pleasant for consumption. And the breeding, cultivation and care of edible insects is essential to maintain their demographic sustainability. A larger number of studies are needed to support the nutritional value of insects and ensure the absence of pathogens and their safety for human consumption. A greater number of scientific studies and reviews that describe in detail what are the key points in the food industry of insects that ensure their safety in human nutrition are necessary. The entomophagy could be a solution to avoid malnutrition and hunger in the world, it provides enough proteins, mineral fats and fiber, so that an aging population, such as currently exists, can be perfectly fed and nourished without great costs economic.

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