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BENEFITS OF INSECT CONSUMPTION AS A FOOD SOURCE ON HUMAN HEALTH: A LITERATURE REVIEW

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Summary. The exponential demographic increase and the lack of resources are forcing the population to look for healthier and more appealing alternatives for their diet. The objective of this review is to demonstrate that the consumption of insects, as a food supplement in the regular diet of humans, provides health benefits. A bibliographic review of articles with a consolidated scientific basis was carried out by consulting the databases "Cochraine", "Pubmed", "Science direct", "Dialnet" and "Medline plus", with a date restriction of 5-10 years, in Spanish and English. Gray literature such as dissertations, projects, master's theses, among others, has also been included. As for the study, no limitations have been made. Insects have the capacity to offer health benefits to people due to their high nutritional value, the bioactivity of their components and even to increase environmental sustainability. The type of insect, its diet, its habitat... They will determine its composition and, consequently, its nutritional benefits. As a result, there is a great deal of research demonstrating such benefits to a greater or lesser extent, although, due to their novelty and precariousness, much research is needed.

Key words: Edible insects. Entomophagy. Nutritional value. Bioactive compounds. Human health.

BENEFICIOS DEL CONSUMO DE INSECTOS COMO FUENTE DE ALIMENTO EN LA SALUD HUMANA: UNA REVISIÓN BIBLIOGRÁFICA

Resumen. El aumento demográfico de forma exponencial y la falta de recursos obliga a la población a buscar alternativas más saludables y sugerentes para su alimentación. El objetivo de esta revisión es demostrar que el consumo de insectos, como complemento alimenticio en la dieta habitual de los seres humanos, aporta beneficios a la salud. Se realizó una revisión bibliográfica de artículos con base científica consolidada consultando las bases de datos "Cochraine", "Pubmed", "Science direct", "Dialnet" y "Medline plus", con restricción de fecha de 5-10 años, en español y en inglés. También se ha incluido literatura gris como tesinas, proyectos, trabajos de fin de máster, entre otros. En cuanto al estudio, no se han hecho ningún tipo de limitaciones. Los insectos tienen la capacidad de ofrecer beneficios a la salud de las personas por su alto valor nutricional, la bioactividad de sus componentes e inclusive, por aumentar la sostenibilidad medioambiental. El tipo de insecto, su alimentación, su hábitat... Van a determinar su composición y, por consiguiente, sus beneficios nutricionales. A consecuencia de esto, existen numerosas investigaciones en las que se demuestran tales beneficios en mayor o menor medida aunque, debido a su novedad y a su precariedad, se necesita mucha investigación al respecto.

Palabras clave: Insectos comestibles. Entomofagia. Valor nutricional. Compuestos bioactivos. Salud humana.

Introduction

Food consumption and demand is increasing unlimitedly worldwide. Due to a lack of resources, people are increasingly forced to opt for highly processed alternatives whose safety is not assured. Due to the exponential growth of the human population and the lack of extensions such as agricultural areas, it is necessary to introduce another type of food to complement the dietary pattern of the population, insects. This type of invertebrate animal is one of the most diverse groups of animals found on the planet. With more than 1 million described species, they can be considered the most abundant animal population, accounting for about 90% of the existing life forms (1).

Edible insects are found in countless habitats, however, some species are in danger of extinction due to deforestation, anthropogenic factors, pollution, etc. Both their distribution and availability are affected by climate change (2).

Resources are limited and, with it, food, feed and fuel. Insects are an important and interesting food source due to their high content of macro and micronutrients, and their capacity to be used as an ingredient in other products, increasing their nutritional value and collaborating in more ecological productions. The Food and Agriculture Organization of the United Nations (FAO) states that it is necessary to increase food production in order to avoid nutritional problems such as malnutrition and undernutrition, among others (3).

The use of insects as a food source is an interesting and innovative strategy because, among the many benefits they can offer us, these animals have a high feed conversion rate (for 2kg of feed, insects gain 1 kg of weight; on the other hand, cattle would need 8 kg of insects to gain 1 kg of weight), they give off less greenhouse gas (GHG) and ammonia than cattle, they are pollinating animals, they need less water to survive, they improve soil fertility, contribute to pest control and even act as aids to the subsistence of certain populations, improving the health of both favored and disadvantaged people (4).

We can affirm that insects, apart from being sustainable, have a positive influence on people's health (3,4). New studies and research advocate the consumption of edible insects, as long as they are regulated by law, as they offer high nutritional quality and numerous health benefits (5).

The main objective of this review is to demonstrate through their composition, bioactive compounds, food safety and consumer acceptability, among others, that the consumption of insects provides benefits to human health.

Method

In order to carry out the bibliographic search, several studies were analyzed, which were mainly focused on insects as a new food to be incorporated to enrich the Western diet, as long as they are safe for human consumption and are legally permitted in Europe. Clinical studies, review articles, online books, guides, dictionaries... were included. Among many other scientific sources. Gray literature such as dissertations, projects, master's theses, among others, has also been included. The search began in November 2021 and ended in April 2022.

The following is a more detailed explanation of how this literature search was carried out using some key words in the following open access databases (Cochrane, Pubmed, Science direct, Dialnet, Medline plus): ("Edible Insects" [in title and abstract] or "Entomophagy" [in title and abstract]), ("Insect Nutritional Value" [in title and abstract] or "Insect Proteins" [in title and abstract] or "Insect Lipids" [in title and abstract]), ("Edible Insect Ecology" [in title and abstract] or "Insect Sustainability" [in title and abstract]) and ("Insect Food Safety" [in title and abstract] or "Insect Allergies" [in title and abstract]).

Once the search had been carried out and the titles and abstracts of each article had been obtained, the following inclusion criteria were applied: the articles should be articles on insects suitable for human consumption, especially those that are safe for consumption and permitted in Europe; the articles should be in indexed journals with an IF≥1.5; and the articles should be from the last 5-10 years.

As for the exclusion criteria, they are simply those that do not meet the inclusion criteria without any other type of limitation. Consequently, 86 articles were selected and included in the review.

Results

Nutritional value

The nutritional value of these invertebrates is highly variable, since it depends on the species, the metamorphic stage in which it is found, its habitat, its diet, its processing and preparation, and even the analytical techniques and methods used in its measurement (2). Broadly speaking, all food-grade insects are a valuable source of energy, protein, fat, fiber and micronutrients, according to the nutritional quality index (NQI) (6)and we can therefore consider them as an interesting food to incorporate into our diet (7).

Focusing on the insects legally permitted by the European Union, we will divide them into two orders; coleoptera (*Tenebrio molitor*) and orthoptera (*Locusta migratoria and Acheta domesticus*).

The mealworm (*Tenebrio molitor*) is a beetle that is usually consumed in its larval stage. It is used as food for reptiles and birds, although it is becoming increasingly popular for human consumption due to the high protein and lipid content needed for energy production during the metamorphic process (8).

The domestic cricket (*Acheta domesticus*) and the migratory locust (*Locusta migratoria*) are Orthoptera whose breeding is mainly intended as animal feed, although their interest in human consumption is increasingly being encouraged due to their high nutritional value, their low fat content compared to the *Tenebrio molitor* and their high fiber (chitin) content thanks to their exoskeleton (9, 10) (9, 10).

As far as nutritional composition is concerned, the 3 species are rich in proteins and fats, although the mineral and vitamin content differs among them (11-13) (Table 1).

Table 1

Nutritional composition of Tenebrio molitor, Acheta domesticus and Locusta migratoria (6, 11-13). Own elaboration.

Species dried of insects	**Value energy (Kcal/100g)**	**Proteins (g/100g of dry matter)**	**Fats (g/100g of subject dry)**	**Carbohydrates carbon (g/100g of dry matter)**	**Minerals (mg/100g of dry matter)**	**Vitamins (µg or mg /100g of dry matter)**
Acheta domesticus (adult common cricket)	153	20,5	TOTALS (5.06) PUFA (2.43) SFA (2.28)	1-4	Ca (99.6) Cu (0.62) Faith (5,46-8,83) Mg (55.1) P (299,3) Na (163-178) K (347-390) Zn (6.71-11) Mn (1.15)	A (6.53 µg) E (2.26 mg) B1 (0.04 mg) B2 (3.41 mg) B3 / PP (3.84 mg) B6 (0.23 mg) B12 (0.53 µg) C (3 mg)
Locusta Migratoria (lobster migratory adult**)**	400-500	40-60	TOTALS (4.3) PUFA (3.75) SFA (3.5)	0,1-2	Faith (8-20)	Provitamin A (958.44 µg/100g) Vitamin C (102.17mg/100g)
Tenebrio molitor (mealworm, larva**)**	178	24,13	TOTALS (6.14) PUFA (5.85) SFA (2.32)	1-6	Ca (24.2) Cu (0.75) Fe (2.87) Mg (69) P (295) Na (66) K (368) Zn (4.86) Mn (0.46)	A (<30 µg) E (<0.34 mg) B1 (0.1 mg) B2 (0.85 mg) B3 / PP (5,64 mg) B6 (0.81 mg) B12 (0.56 µg) C (5.4 mg)

Proteins (PP)

The biological value of the proteins found in these animals is high, especially in Orthoptera. Protein content varies according to family, species, sex, etc. and is usually expressed as a function of dry matter. Their digestibility is very variable depending on the species, this is due in part to the nitrogenous substances they contain bound to the chitin. This means that, if their nitrogen composition differs from their actual protein composition, it does not mean that a higher amount of nitrogenous substances results in a higher bioavailability (14).

Insects are rich in phenylalanine, tyrosine, lysine, threonine and tryptophan. This composition varies according to the insect's diet (natural or feed-based). It is worth mentioning leucine, since it is a limiting amino acid in this type of food source (6) (6). In the case of orthoptera, the protein content is higher than in goat meat, chicken or pork, although their digestibility is lower(11, 14).

An alternative to food shortages for obtaining high quality proteins would be to obtain them from some species of insects whose amino acid composition is optimal. Proteins found in the mealworm, Tenebrio molitor, have been shown to have a high quality protein composition (15).

It should always be noted that there is a difference between the recommended level of amino acids and the minimum required intake level of each amino acid. The PDCAAS (Protein Digestibility-Corrected Amino Acid Score) and DIAAS (Digestible Indispensable Amino Acid Index) approach to assess the quality of insect proteins can be compared with the usual peptide sources in the Western population (Table 2)

Protein hydrolysates have functional properties, including nutritional properties. These properties can be seen in flours such as the defatted and native caterpillar larvae (Imbrasia oyemensis), although their solubility is low due to their isoelectric point. The hydrolyzed protein fraction has a much higher solubility of 80%. All this would be interesting in terms of the anabolic capacities of insect meals and their possibility of increasing the postprandial availability of amino acids in the blood (16).

The use of insect protein preparations in gluten-free diets is an interesting alternative to conventional ingredients because the extraction of gluten from bakery products results in low gas retention in the fermentation process. This problem can be corrected through the addition of previously defatted insect flours, such as those of crickets, which provide gluten-free proteins (17) (17).

Table 2

Comparison of the different essential amino acids found in Tenebrio molitor and Acheta domesticus with different meat products(mg/100 g of edible portion) (6).

	Essential amino acids								
Species	**ILE**	**LEU**	**LYS**	**MTH**	**TRYP**	**PHE**	**HIS**	**THRE**	**VAL**
Acheta domesticus A	940	2050	1100	300	130	650	480	740	1070
Acheta domesticus L	710	1270	1090	274	144	587	450	680	1050
Tenebrio molitor A	1030	1960	1050	300	260	620	680	810	1500
Tenebrio molitor L	835	1400	1070	400	216	654	559	770	1280
Leg of lamb	773	1195	1267	381	196	621	425	727	785
leg of veal	826	1293	1349	413	174	660	551	688	853
Horsemeat	1457	2129	2240	627	226	853	627	874	1122
Pork shoulder	821	1432	1483	487	235	699	584	966	927
Beef tenderloin	997	1680	1844	560	232	911	706	951	1038
Rabbit carcass	825	1277	1462	452	186	771	426	717	851
Goose channel	264	493	515	144	84	254	162	268	287
Duck carcass	391	611	686	214	95	329	250	370	479

Note: The abbreviations for the column headings are as follows: ILE: isoleucine, LEU: leucine, LYS: lysine,

Turkey breast	915	1419	2015	522	248	703	537	994	953
Turkey thigh	797	1233	1758	452	217	607	468	865	826
Chicken breast	1251	1579	2022	631	360	772	941	911	1345
Chicken thigh	982	1240	1590	497	283	606	739	715	1057

MTH: methionine, CYS: cystine, PHE: phenylalanine, TYR: tyrosine, THRE: threonine, TRYP: tryptophan, VAL: valine, A: adult insect, L: larval form.

Carbohydrates (HC)

HC is the least predominant macronutrient, accounting for 15-50% in orders such as Coleoptera and Orthoptera (18). Among them, Chitin and Threalose stand out.

In arthropods we can find chitin, a natural polysaccharide considered the second most abundant biopolymer in nature after cellulose. It is known that insects, such as crickets, have a fat-reducing effect thanks to chitin, making those animals that consume them thinner than others that consume other types of feed or food lacking chitin (19). However, chitin reduces the digestibility of insects as it is a non-digestible fiber even though the enzyme chitinase is found in our gastric juices. This is because in the European population, this protein is inactive. Due to the binding of the nitrogen chains with it, in order to obtain quality protein, it is necessary to eliminate the chitin, for example, through the lyophilization process (12).

Through the deacetylation partial deacetylation of this substance, chitosan is obtained, which is used commercially as a high-fiber supplement (19). Chitosan is often used as an additive for ruminants (thus reducing methane emissions) and for plants (activating their defenses against pathogens), among numerous other health benefits. In humans, consumption of food sources such as cricket powder increases the probiotic Bifidobacterium animalis 5.7-fold, endowing chitosan with pharmacological, antimicrobial, antiviral, anticoagulant, antihypertensive, hypolipidemic and hypercholesterolemic properties (20-24).

On the other hand, we find a disaccharide discovered in the 19th century by Berthelot in the eggs of beetles of the genus Larinus, which he called trehalose. This substance, also called mycose, is formed by two glucoses allowing the preservation of cellular structures such as membranes and proteins. It is also interesting when consuming products that cannot be obtained fresh due to their distant origin, drying them with trehalose and then rehydrating them and serving them as fresh (25).

Currently, it is known that this compound is distributed in nature from microorganisms such as bacteria, to insects, fungi and plants, even in numerous foods such as honey and fermented foods such as beer, wine or vinegar. In addition, some living organisms contain functional genes capable of encoding the trehalase enzyme that degrades this compound. Among them we find Homo sapiens capable of synthesizing it in the kidney, where osmoregulation in which trehalose plays a fundamental role is continuously taking place (25, 26). Several clinical studies point out that trehalose intolerances or mushroom intolerances are very rare and well known, in fact they are much lower compared to those caused by lactase deficiency with dairy intake (26).

Recent studies have affirmed that the use of trehalose as an artificial sweetener offers both physiological and cardiometabolic benefits; it promotes weight loss, improves glycemic control and even reduces insulin resistance. Its use could help reduce the risk of obesity and type 2 diabetes (27).

Fats (LIP)

It is the second most abundant fraction in insects after protein, especially in the larval stage. The lipid content they usually have is high, and in some of them it is even higher than the daily foods in our diet (meat, fish, milk or eggs) (24). In Orthoptera (*Acheta domesticus* and *Locusta migratoria*) it usually oscillates around 13%, while in Coleoptera (*Tenebrio molitor*) it is around 33% (11,28) (11,28).

Commonly, some species, such as crickets, contain high levels of Om3 and Om6 in a 3:1 ratio, compared to some of the terrestrial mammals and freshwater fish. It is true that animals living in salty aquatic environments tend to have higher levels of Om3 than those exposed to salty water (13) (13).

Antinutrients

Antinutrients are natural or synthetic compounds that interfere with nutrient absorption (29). Among those that can be found in insects, we highlight toxins, phytates, tannins, phenols, hydrocyanides (HCN), oxalates and phytic acid (30). Some of these substances also offer beneficial health effects such as phytates, tannins and phenols for their antioxidant properties (31) (31)although the latter can interfere with iron absorption and generate anemia (32). It should be noted that in order to truly exert an anti-nutritional effect, these compounds must be present in sufficient quantities. In the case of insects, their levels are very low and are therefore considered safe and nutritionally acceptable (33) (33).

Antimicrobial peptides

AMPs or antimicrobial peptides are small polypeptides (30-60 amino acids) found in insects. They are encoded by genes and are created in cells by a structure called a ribosome. Among the most outstanding are lebocins, attacins, cecropins, defensins.... Among many others rich in moricins, prolines and gloverines. The use of AMPs as antimicrobial substances has been extensively studied, in fact, it has been shown that peptides rich in proline (abaecin) and rich in glycine (hime-noptaecin) combined have bactericidal effect (34). In these animals, AMPs can be classified into cysteine-rich peptides, proline-rich peptides, glycine-rich peptides and α-helical peptides, which can be effective in the fight against *Escherichia coli* to *Listeria monocytogenes* (35).

It is true that the largest reservoir of antimicrobial peptides is found in the different and unexplored insect species that can be useful as an alternative to conventional antibiotics, facing the pathogenicity of multiresistant microorganisms (36) (36).

Antioxidant compounds

Humans undergo a biochemical process essential for life called oxidation. Sometimes it is produced excessively and generates what is known as oxidative stress, which, together with free radicals, damages the body's cells. To combat this stress, we need the help of compounds called antioxidants that inhibit and/or reduce this process (37).

Some insect species possess these compounds, and insect protein hydrolysates and flours have been shown to be promising antioxidants in terms of free radical scavenging and reducing power (38) (38). In the following study, antioxidant activity was calculated using extracts of freeze-dried larvae of Tenebrio molitor. It has been shown that extracts of raw larvae dried with infrared, microwave or high frequency indicate higher amounts of compounds and antioxidant capacity than those dried in an oven (39) (39). The mechanisms through which protein hydrolysates exert antioxidant activity are not fully understood, but it is known that both the type of amino acids that compose them and their sequence are essential for their antioxidant activity (40, 41) (40, 41).

The ability of insects to inhibit pancreatic lipase has also been demonstrated, in fact, this study states that extracts of *Tenebrio molitor* compared to *Acheta domesticus* have greater antioxidant activity, and thus a greater ability to inhibit pancreatic lipase (42).

Others

Numerous studies in obese mice fed with powdered *Tenebrio molitor* larvae have revealed their reducing power on type II diabetes and the accumulation of lipids and triglycerides in adipocytes (43) (43). In turn, the role of wax moth, silkworm and yellow worm in reducing hypertension (HTN) in mice, through inhibition of angiotensin (ACE), is speculated (44) (44).

Security

Nowadays, insects can be a risk, in terms of food safety, through 4 ways; the toxicity of the insect itself; the acquisition of harmful substances or pathogens; because of the production cycle; or, simply, as a consequence of an allergic reaction to them. Therefore, the need for good hygienic practices and HACCP in the case of being a producer of edible insects is established, especially in more developed countries with stricter regulations as in Europe (11).

The European Commission requires a science-based authority such as EFSA to assess the safety of edible insects before adopting the above-mentioned regulation. This agency evaluated microbiological, parasitic, environmental, chemical, allergy and intolerance risks. All of these are both in the consumer and in the animals, since they consume them whole or through feed containing them. The evaluation was carried out at all metamorphic stages of insects, including rearing, production and final consumption of insects, concluding that in the recommended quantities, the insects approved by EU legislation are safe for human consumption (7).

Consumer attitude

People develop in geographic areas and cultures that shape our preferences and tastes when it comes to food choices. Our childhood marks unique eating pleasures that provide us with security and stability, rather than nutritional quality (1).

In the world there are an infinite number of food patterns and technological progress allows us to reach and diversify our diet in such a way that we adopt new experiences and flavors to our palates (45,46). The population that, in addition to its usual diet, is insectivorous, i.e. feeds on insects, is increasingly more abundant than many people think (Figure 1) (47).

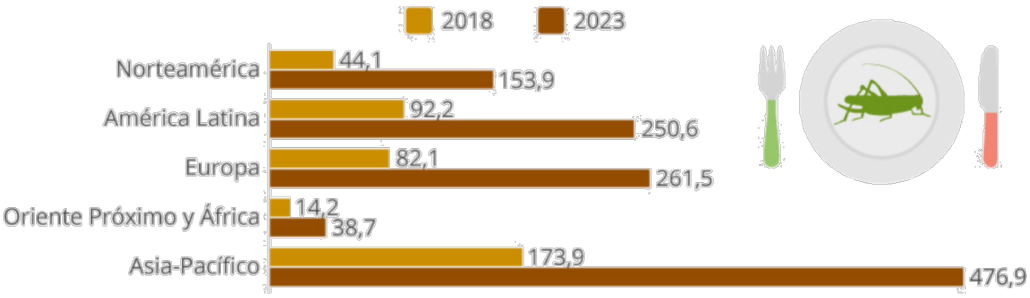

Figure 1: Edible insects market volume (47).

The acceptance of entomophagy is influenced, among many things, by price, taste, availability... (48). We must be aware that, directly or indirectly, humans practice entomophagy within the food chain, through the consumption of birds, livestock or fish whose diet is based on insects (41) (41). There are some questionnaires to determine the acceptance of different consumers towards these invertebrates such as: the food neophobia scale and the insect phobia scale (Table 3) (49).

Table 3

Food Neophobia Scale (FNS) and Insect Phobia Scale (IPS) (49).

Number	Statement	Median	IQR
1	I am constantly trying new and different foods (R).	3	2
2	I don't trust new foods.	3	2
3	If I don't know what a food is, I don't try it.	4	3
4	I like foods from different cultures (R).	2	3
5	Ethnic food seems too weird to eat.	2	2
6	At dinners, I will try new foods (R).	2	2
7	I'm afraid to eat things I've never eaten before.	3	3
8	I am very particular about the foods I eat.	4	3
9	I will eat almost anything (R).	2	2
10	I like to try new ethnic restaurants (R).	2	3

Note: R, inverse coding and IQR, interquartile range

Number	Statement
1	The idea of eating insects makes me repulsed/repulsed.
2	The consumption of insects is not socially acceptable.
3	I'm afraid that insect-based foods have an unpleasant taste.
4	I'm afraid that insect-based foods have an unpleasant consistency.
5	I think insect-based foods have poor hygiene.
6	I believe that eating insects is not suitable for our diet.

At the same time, it is worth noting the existence of aversions to these products for purely cultural reasons, for example, the consumption of the sea lobster (*Palinurus elephas*) is considered a delicacy in the West despite being in the phylum arthropods along with insects, arachnids and myriapods (50) (50). To increase their acceptance, insects are being used as ingredients in many preparations such as breads, hamburgers and tortillas (47). Other strategies to address consumer concerns include: providing more information on the benefits of insect consumption (51, 52), insect banquets where insects are offered for tasting, the use of role models such as top chefs, or the promotion of their environmental benefits (53).

Discussion and conclusions

From the literature search, 10 articles of experimental studies were selected and divided according to the study model used (Figure 2).

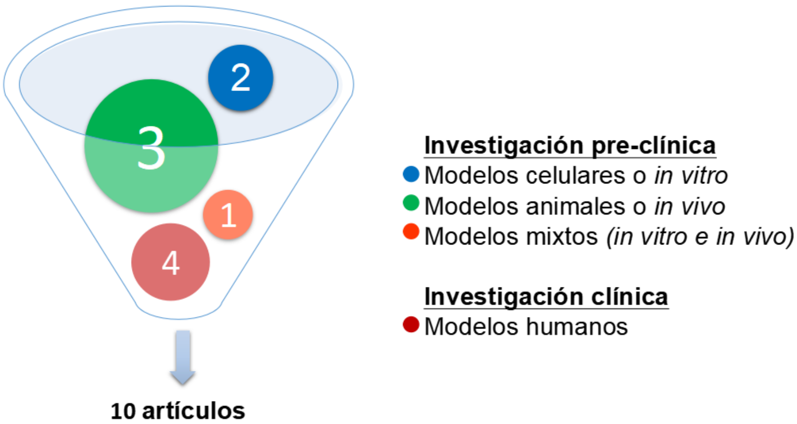

Figure 2: Classification of the different experimental studies according to the study model used (15, 18, 19, 24, 27, 39, 41, 42, 49, 51). Own elaboration.

Regarding the consumption of insects and their nutritional value, 5 review articles (6, 11, 13, 14, 29) incorporated in the work propose edible insects as an interesting part to adopt in the food chain of human beings due to their high nutritional value. We have also included 3 experimental articles on this subject. Based on the experimental model used, we can divide these studies into: 1 clinical study (humans) (15) and 1 experimental study in animals or *in vivo* (insects) (18).

In relation to the consumption and nutritional value of insects, Orkusz A (6) and Payne CLR et al (29) state that insects have a high nutritional value, as do meat products, since they are rich in macro and micronutrients, some of which are essential, although few data are available on vitamin content. Adult forms of insects contain the highest protein content, followed by larvae. On the other hand, according to Van Luis A (11), females have more lipid content than males. It is true that the nutritional composition of these animals stands out for containing Om3/Om6, iron, zinc and proteins of high biological value that provide significant health benefits, and can alleviate malnutrition in countries with nutritional deficiencies, in war conflicts, in droughts, etc., or be used as an extra contribution to improve the health status of people (13,14). Hermans WJH et al conducted a study in humans in which it was demonstrated that protein derivatives of mealworm have, after ingestion, the same capacity for amino acid release into the blood, rate of protein synthesis and digestibility as those derived from dairy products. Today, the main disadvantage is that they are products with very high prices due to their low production (15). On the other hand, Adámková A et al (18) analyzed other nutrients such as fat and chitin in the domestic cricket as well as in the common mealworm and the giant mealworm, concluding that the cricket had more chitin than the worms and the latter had more fat, being higher in the giant mealworm (35%) than in the common mealworm (31%).

Referring to these substances such as chitin, trehalose, antimicrobial peptides and antioxidant compounds, among others, based on the experimental model used we can divide the experimental studies on the subject into: 1 clinical study (humans) (27), 2 experimental studies in animals or *in vivo* (insects) (19, 39), 1 mixed experimental study (*in vivo and in vitro*) (42) and 2 *in vitro* studies (24, 41). Five relevant review articles have also been included (21, 23, 26, 34, 43).

Several researches relate chitin with a fat mass reducing effect in broilers due to its performance as dietary fiber, in fact Lokman IH et al (19) revealed that chitin from cricket at 0.5 g/kg significantly improved growth performance and organ characteristics, and reduced fat accumulation in broilers with respect to a basal diet, in turn, according to Tripathi K et al (21) it improves the composition of the microbiota among many other interesting effects explained above as antihypertensive and hypocholesterolemic, however, Betchem G et al (23) and Di Mattia C et al (24) state that due to their difficult digestion they are used as ingredients in pharmaceuticals, cell cultures, engineering, etc, rather than as a food ingredient. As for another carbohydrate such as trehalose, Ahmed A et al (26) have observed, apart from its participation in kidney osmoregulation, that its consumption as an artificial sweetener offers the capacity to control blood glucose, decreasing the prevalence of obesity and type II diabetes. Although Yoshizane C et al (27) state that studies in prediabetic and type 2 diabetic patients are needed to confirm this.

Other bioactive compounds to be highlighted are antimicrobial peptides and antioxidant compounds. As for peptides, Jantzen da Silva Lucas et al (34) have shown that they have an effect mainly in reducing the levels of *Listeria monocytogenes* and *E. coli*. It should be noted that peptides have other properties such as their high emulsifying or foaming capacity, which makes them ideal for use as a food ingredient, giving products high nutritional value and better organoleptic characteristics (39). The antioxidant compounds of the edible insect extracts *Acheta domesticus* and *Tenebrio molitor,* in relation to their antioxidant capacity and their possible effects on pancreatic lipase inhibition according to Navarro Del Hierro J et al, both showed antioxidant capacity, but in the case of pancreatic lipase inhibition those of *Tenebrio molitor* were the most effective (41).

In relation to other benefits that insects can provide, Seo M et al (42) have shown that *Tenebrio molitor* larvae powder influences adipogenesis and metabolic syndrome by attenuating body weight gain in obese mice. This leads us to affirm its potential as a therapeutic agent in the treatment of obesity in humans. In turn, Cito A et al (43) support the ACE inhibitory effect of bioactive peptides from insect protein hydrolysates for the treatment of hypertension.

Regarding consumer attitudes toward entomophagy, 2 reviews (48, 50) and 2 human clinical trials (49, 51) show that one of the major, if not the major, impediments to increasing insect consumption on a large scale is the strong rejection or reluctance toward insects as food. Numerous studies have attempted to find out how to achieve greater public acceptance of entomophagy, beyond demonstrating its potential health benefits.

In the review conducted by House J (48) in the Netherlands, the acceptance of insect-based convenience foods by diners was critically evaluated, concluding that attention should not be based on their acceptance but on the evaluation of social, practical and contextual factors that determine it. In the case of Italy, Moruzzo R et al (49) conducted a study through 420 questionnaires introducing an experimental scale specific to insects and one referring to neophobia, whose results were inconclusive due to the lack of specific scales to determine "insect phobia". On the other hand, Toti et al (50) showed that the Italian diet is still clearly influenced by local tradition and its psychological motivation needs to be increased. In contrast, a substantial proportion of Americans (72%) and Indians (74%) were at least willing to consider eating some type of insect-based food, especially by men, although disgust appears to be the most common reaction of both groups to the prospect of eating insects, as noted by Ruby MB et al (51).

Further research is needed to assess the effect of cultural variations among the population of different countries, especially in Europe, on food neophobia and acceptance of insects. This is because the potential success of a strategy in one country may not be suitable for others.

With all this we can conclude that insects contain proteins of high biological value and bioactive peptides which are a key complement to the usual dietary pattern of the population, enriching their diet and providing anabolic and antimicrobial effects, among others. Some extracts extracted from some insects, such as *Acheta domesticus* and *Tenebrio molitor,* have antioxidant activity, as do potato hydrolysates. In addition, mealworm has possible effects on pancreatic lipase inhibition. On the other hand, they also contain interesting carbohydrates such as trehalose, whose use as an artificial sweetener could improve glycemic control and even reduce insulin resistance in people who suffer from it. Fiber such as chitin, found in small invertebrates with an exoskeleton, although difficult to digest, has been attributed possible effects as a regulator of adipogenesis and, together with one of its components, chitosan, may contribute to improving the composition of the microbiota, among other effects such as antihypertensives, anticoagulants and antivirals. In terms of lipid content, insects stand out for their composition of Om3 and 6 fatty acids essential for humans, even at the same level as those found in fish, especially freshwater fish. It has been shown that, together with proteins, fat is the main component to be taken into account to avoid malnutrition, undernutrition and starvation, especially in underdeveloped countries.

Thus, it can be concluded that all these substances together confer on insects the ability to provide health benefits to humans and even safeguard food safety, enhance environmental sustainability, optimize agriculture and enrich existing food products.

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