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Edible Insects as An Alternative Food Source and Their Potential Positive Effects on Human Health

Alternatif Bir Besin Kaynağı Olarak Yenilebilir Böcekler ve İnsan Sağlığı Üzerindeki Potansiyel Olumlu Etkileri

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ABSTRACT

The difficulty of safe/quality transportation, the rapidly increasing population and the production of protein products obtained from animals have led us to think that they can be used as an "alternative protein" source. It is reported in the literature that insects are a good source of macro (especially protein, fat and chitin) and many bioactive nutrients. The digestibility rate of edible diseases by human physiology is high, along with the physiology of the progress of the insect species. In the literature, protein content and bioavailability are compared with other plant/animal protein sources, where a good “alternative” food source can be found. In addition to its anti-carcinogenic, anti-bacterial, anti-microbial, anti-inflammatory and immuno-modulatory activities; Many clinical treatments are claimed in different areas of blood glucose levels and blood lipid profile. Authorities and current studies expressing their opinions in this field point out that edible parts of the edible parts may become a part of the more widespread human nutrition in the future as an "alternative" food source to meet the daily needs of the human body. However, comprehensive, safe and hygienic standards should be developed and implemented in order to ensure the consumption of edible insects, which have the potential of alternative food sources for the nutrition of the human population in the future.

Keywords: Edible insects, entomophagy, nutritional value, protein content

ÖZ

Güvenli/kaliteli besine ulaşımın zorlaşması, hızla artan nüfus ve nüfus artışı ile ilişkili olarak hayvansal kaynaklı protein gereksiniminin artması ile “alternatif bir protein” kaynağı olarak böceklerin kullanılabileceğini düşündürmüştür. Böceklerin iyi bir makro (*özellikle protein, yağ ve kitin)* ve birçok biyoaktif besin bileşeni kaynağı olduğu literatürde bildirilmektedir. Yenilebilir böceklerin insan fizyolojisi tarafından sindirilebilirlik oranı böceğin türü ile ilişkili olmakla birlikte, yüksektir. Literatürde protein içeriği ve biyoyararlılığı diğer bitkisel/hayvansal kaynaklı protein kaynakları ile karşılaştırıldığında iyi “alternatif” bir besin kaynağı olabilecekleri düşünülmektedir. Anti-kanserojenik, anti-bakteriyel, anti-mikrobiyal, anti-inflamatuvar, immüno-modülatör etkinliklerinin yanı sıra; kan glukoz düzeyleri ve kan lipit profilinin iyileştirilmesinde kullanılabilecekleri birçok klinik çalışmada iddia edilmektedir. Bu alanında görüş bildiren otoriteler ve güncel çalışmalar, yenilebilir böceklerin insan vücudunun günlük gereksinimlerini karşılamak için “alternatif” bir besin kaynağı olarak gelecekte daha yaygın olmakla birlikte insan beslenmesinin bir parçası olabileceğine dikkat çekmektedir. Ancak gelecekte insan nüfusunun beslenmesi için alternatif besin kaynağı potansiyeli olan yenilebilir böceklerin tüketiminin sağlanması için kapsamlı, güvenli ve hijyenik standartlar geliştirilmeli ve uygulanmalıdır.

Anahtar Kelimeler: Besin değeri, entomofaji, protein içeriği, yenilebilir böcekler

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Introduction

In recent years, with the increasing population of the world, there have been difficulties in accessing adequate, healthy and safe food. While people's dietary habits have changed in recent years, the consumption of protein-rich foods of animal origin and the amount of daily requirements of people have increased in parallel with the spread of Western-type nutrition models, the available food sources (both animal and vegetable) have decreased. As a result of this situation, it is thought that food sources will be insufficient for the world population in the coming years; for this reason, alternative "consumable other sources" alternative to "consumed foods" are also being investigated today (Kuder & Demir, 2023). According to the report published by the Food and Agriculture Organization of the United Nations (FAO) in 2017, it is estimated that by 2050, the consumption of protein from animal sources may be about 2 times higher than at present. The same report also noted the increase in daily protein intake in high-income countries over the past 50 *years (1961: 39 g/person; 2011: 52 g/person- an increase of 33%).* It is estimated that in high-income countries, daily protein intake will reach 54 grams and 57 grams per capita in 2030-2050, respectively; in low-income countries, it will reach 22 grams and 25 grams (FAO, 2017). With the simultaneous increase in daily protein consumption per capita and population, it is one of the notable titles that traditional protein sources cannot meet the amount demanded and alternative protein sources are needed in order to solve this global problem (Aksoy & El, 2021). In response to this demand, the FAO has indicated "edible insects" as an alternative protein source due to their high-quality protein (amino acid profile) and micronutrient source and lower greenhouse gas effect compared to animal-derived proteins (Kaldırım & Keser, 2023). From the past to the present, insects are widely consumed on many continents of the world, especially in Asia, Africa and Latin America. It is estimated that insects are widely consumed by at least 2 billion people worldwide. Attitudes towards the acceptance of insect consumption are associated with sociocultural and psychological reasons. Even though edible insects are not widely consumed in Western societies and there is a prejudice against insect consumption; current studies report that the food labeling studies and the way of use that can be done for these alternative food sources will contribute to an increase in consumer acceptance (Raheem et al., 2019; Muslu, 2020). "Entomophagy" is a concept that refers to the use of insects as food. The trend towards entomophagy, an old concept, has increased in order to develop an additional strategy for animal October to solve the growing need for sustainability, food insecurity in the face of climate change. Edible insects have been characterized as a new source of high-quality proteins as an alternative to traditional animal-derived foods (Erdoğan et al., 2021; Imathiu, 2020). In addition to being considered a rich source of macro/micronutrients, edible insects are also known to have many benefits from an environmental point of view (sustainability). In the studies conducted, edible insect production is associated with less water requirements and lower greenhouse gas effect compared to pig, cattle, chicken farming. In one study, the water requirement of cricket production per gram of protein was 0.7-0.8 grams, while; it has been stated that the requirement of bovine protein per gram is about 16.8 grams. In the same study, methane and carbon dioxide emissions per kilogram of cricket were found to be 0.7 and 7.6 grams, respectively; for cattle, they were found to be 114 grams and 285 grams. There are also advantageous aspects of edible insects such as the need for less growing space, high feed conversion efficiency and high reproduction rate (Imathiu, 2020; Nowakowski et al., 2021).

Due to the fact that insects have not been used in human nutrition in Europe in the past, there are no legal regulations regarding their use, but appropriate regulations should be made on this subject, assuming that insects will be more involved in human nutrition in the future. In the *FAO 2013 Edible Insects Future Prospects for Food and Feed Security Report*, it has been reported that these alternative food sources may be a sustainable food source in the future and a comprehensive analysis has been presented. In the same report, insect consumption was encouraged due to its high-quality nutrient content (Kaldırım & Keser, 2023; Erdoğan et al., 2021). In its *2021 Report*, *the European Food Safety Authority (EFSA)* argued that insects can be considered as an alternative to basic animal sources for human nutrition, such as chicken, pork, beef and fish, and there may be various legal requirements affecting their use. EFSA has listed the insects that have a high potential to be used as food and feedstuff in agriculture as follows; black fly, black soldier, yellow flour worm, moth, silkworm, cricket and grasshopper (Kaldırım & Keser, 2023; EFSA, 2015). It has been determined that there are >1900 edible insect species worldwide. The most used ones in human nutrition are "caterpillars, wasps, ants, bees, grasshoppers, crickets, Augustan beetles, termites, dragonflies and flies" (Liceaga et al., 2022). It is thought that protein, lipids, fiber (pulp) and some micronutrient elements found in insects may have an important place in human nutrition; these nutritional components may have potential positive effects on human health. In the current literature, edible insects contain antioxidant/anti-inflammatory nutritional elements; they may have anti-bacterial, anti-obesogenic activity, immunomodulatory effects; serum glucose levels may be important for regulating the blood lipid profile (reduced risk of cardiovascular disease); as well

as having positive gastrointestinal (GI) and microbiota effects, as well as various potential health effects are claimed (Liceaga et al., 2022; Zhou et al., 2022) (Figure 1). Edible insects are among the headlines that attract attention every day Decently due to their alleged potential health benefits. In this review, the current literature has been reviewed and the total protein, total lipid, chitin content of edible insects, as well as other nutritional components that stand out in terms of human nutrition; their potential positive effects on human health have been discussed. It is aimed to present an alternative perspective on the consumption of edible insects, which are thought to find more places in human nutrition in the future, in the light of current literature.

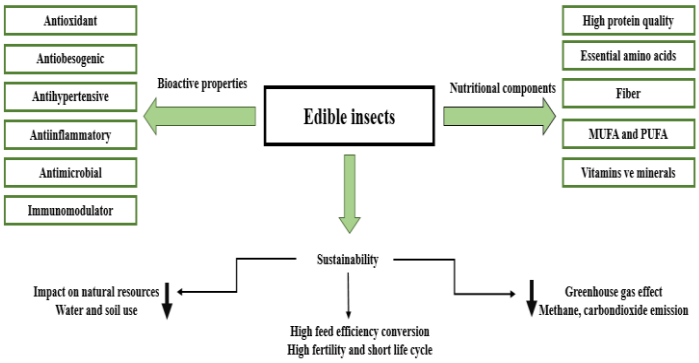

Figure 1. The reasons for using edible insects as a food source and their positive effects on health. †MUFA: Monounsaturated fatty acids; †PUFA, Polyunsaturated fatty acids

Components of Macro/Micronutrient Elements that Come to the Fore in Edible Insects

For many years >2,000 insect species have been used as a basic food source in many regions of the world. In the studies conducted, it is reported that edible insects contain high amounts of important nutritional components in terms of human nutrition. Although it varies depending on the species, it has been shown that about 77% to 98% of the total weight of edible insects is digestible in terms of human physiology, but the analyses conducted in the field of digestibility and bioavailability of edible insects are not yet sufficient in the literature and more research is needed on this issue. As a result of the studies, insect species, processing method, antinutritional factors were identified as factors affecting digestibility and bioavailability. Alternative these food sources can be consumed raw or processed, roasted, fried, boiled. The nutritional composition may vary depending on the genus, stage of development, mode of nutrition and processing method of the insect. Insects are seen as a rich source of energy, protein, fats and minerals and are associated with positive effects on human health (Imathiu, 2020; Nowakowski et al., 2021). Nutritional element compositions prepared by considering the amount of dry matter of edible insect species that are widely consumed are given in Table 1 (Castro et al., 2018).

Table 1. Macro and some micronutrient components prepared by considering the amount of dry matter of edible insects that are widely consumed

Insect species (100g per)	*Protein (g)*	*Fat (g)*	*Carbohydrate (g)*	*Mineral (g)*	*Energy (kcal)*
Coleoptera	3.7-54	3.7-52	12-34	1-3	126-574
Flies	17.5-67	4.2-31	8.38-23	1.24-8	199-460
Insects	33-65	7-54	7-19	1-19	329-622
Bees, Wasps, Ants	1-81	1.3-62	5-94	0-6	234-593
Butterflies and moths	13.2-69.6	7-77	3-41	2-8	126-762
Grasshoppers and crickets	13-77	2.4-25.14	16-30	2-27	117-436

Total Protein Content and Amino Acid Profile

When the dry weight of insects is considered, proteins constitute the largest component of the total mass. It has been reported that the total protein content of edible insects is high (7% to 91% by dry weight), the amino acid profile is balanced (Zhou et al., 2022; Huis, 2016). In a study, the nutritional composition of 6 different insects, including cricket, giant flour worm, yellow flour worm, silkworm, Java grasshopper and paddy grasshopper, were studied by drying at 60-70 degrees Celsius (°C) in the range of 12-24 hours. As a result of the protein analysis performed by the Kjeldahl method, it has been reported that the protein compositions of insects differ significantly from each other (they contain protein that varies by 32.59-76.69% for every 100 grams of dry weight). Among these 6 species, cricket is the species with the lowest protein content with a ratio of 32.59% Dec. Edible insect alternatives Compared to soybeans, which are a plant-based protein source (they contain 35.8% plant-based protein), it was thought that insects might also be a good protein alternative (Kuntadi Adalina & Maharani, 2018). Insects, which are rich in protein, have a wide range of amino acids and a large amount of essential amino acid content (Zhou et al., 2022). In another study in which the protein and amino acid composition of 4 insects, namely Bombay grasshopper, scarab beetle, grasshopper and mulberry silkworm, was investigated; As a result of the analysis performed according to the Kjeldahl method, 100 grams of insects had protein contents that differed in the range of 27-54 grams. The insect samples in the same study contained 18 of the 20 amino acids; the essential amino acids contained all of them (the highest proportion of essential amino acids was 44%

mulberry silkworm; the lowest rate is 33% in the Bombay locust), and it has been reported that the amino acid “leucine” has the highest concentration among these insect species (Köhler et al., 2019). On the other hand, it has been shown that the average amino acid score of edible insects is between 46-96% (in human nutrition Decrees that the basic amino acid score should be at least 40%). Edible insects, in relation to the species, are 67-98% digestible; therefore, they can be described as a source of high-quality protein. Compared to animal-derived and vegetable-derived protein sources such as beef, chicken, eggs, edible insects can be characterized as “nutritious” in the human diet and are thought to have potential positive effects on health (Imathiu, 2020; Nowakowski et al., 2021). In a study conducted, the amino acid profile and quality of moth caterpillar, termite, cricket and grasshopper insect species common in Nigeria were examined. As a result of the examination conducted using the Technican sequential multi-sample amino acid analysis, it was found that edible insects are good sources of various essential amino acids such as lysine, threonine, leucine, isoleucine, valine, phenylalanine and tyrosine. In the analysis of protein quality studied by the corrected protein digestibility method, digestibility was found to be in the 76-98% range (Inje et al., 2018).

Total Fat Content and Fatty Acid Profile

The second highest amount of edible insects’ nutritional component in the analysis of the composition of the nutrients in fats. The total fat content, although the amount varies in different stages of the life of the insects, 80% of the triacylglycerols (TG) and 20% trans fatty acids. While the total fat content of insects is the highest at the “larval” stage, which is the beginning of life, the amount in dry weight can vary by about 10% to 50% (Castro et al., 2018; Lucas et al., 2019). The total lipid content of insects may vary depending on many factors such as “species, diet, extraction method and environmental differences”. Considering the amount of dry matter, the fat content of grasshoppers varies between 17-28%, while the larvae of the black soldier fly have a fat content of 6.6-39%, and the yellow flour wolf has a fat content of 21-31% range of grasshoppers have a fat content of 6.6-39%. It has been reported that flour wolf contains a higher amount of oil when comparing the oil content with soybeans, which contain about 20% oil by dry matter weight (Oonincs et al., 2019; Paul et al., 2017). In the analyses carried out, it was shown that oleic acid, linoleic acid, linolenic acid, palmitic acid and stearic acids constitute the fatty acid components of edible insects. These alternative food sources are rich in monounsaturated (MUFA), polyunsaturated (PUFA) fatty acids; they contain a high amount of C:18 fatty acids. In the “pupal” stage, saturated fatty acids are more dominant compared to unsaturated fatty acids; in the ”adult" period, this is the opposite (Castro et al., 2018; Meyer-Rochow et al., 2021). When the nutritional values of meat and edible insect species in the human diet are compared, it is concluded that both meat and insects are rich in protein, fat, minerals and vitamins, including essential amino acids and PUFA, which are considered essential for human physiology. In the same study, it was also reported that the types of fatty acids found in the highest amounts in meats and insects are “oleic acid” and “linoleic acid”. In addition to meat, it can be concluded that insects are also nutritious sources (Orkusz, 2021).

Contents of The Chitin

One of the important components in the recognition of insects as a valuable alternative food source is the content of chitin. Chitin is a natural carbohydrate polymer that is most found in nature after cellulose. Its basic molecular structure is given in Figure 2 (Orkusz, 2021). It is described as the main component found in the shells of crustaceans, the cell wall of fungi and the exoskeleton of insects (Rehman et al., 2023; Abram et al., 2019). Insects may contain different amounts of chitin in relation to the stage of development. The older the insect, the greater the content of the kit. In the studies conducted, it has been reported that edible insects contain an average of 15-25% chitin (yellow flour worms have a chitin content of 16-17%, house cricket has a chitin content of 4-7% and silkworm has a deciency of 3-20%. Insects can also be described as a good source of fiber (pulp) due to the amount of chitin they contain (23, 25).

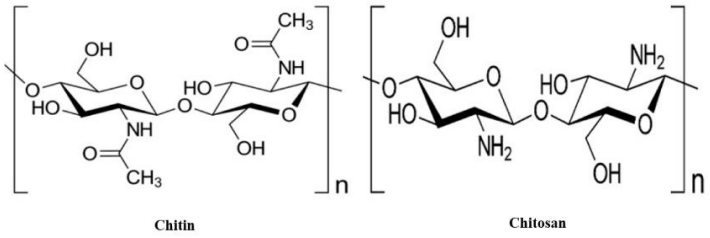

Figure 2. Chitin and chitosan structures

Potential Positive Effects of Insects on Human Health

Current literature draws attention to the fact that edible insects can be part of the daily diet to meet the daily requirement of the human body. Bioactive nutritional components found in insects may have various functional properties that make a potential contribution to human health. Thanks to the macro- and micronutrient elements contained in edible insects; it can provide anti-cancer, anti-bacterial, anti-microbial, anti-inflammatory, immunomodulatory effects through different mechanisms; it is noted that they may influence improving blood sugar and blood lipid profile (Zhou et al., 2022; Roos & Huis, 2017). Some biological activities and potential mechanisms of action associated with bioactive nutrient components found in the

structure of these alternative food sources were summarized in Figure 3 (Zhou et al., 2022).

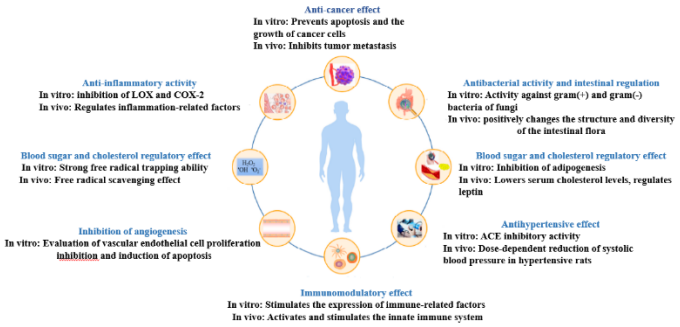

Figure 3. Some biological effects and potential mechanisms of action associated with some bioactive nutritional components found in edible insects

Edible insects naturally bioactive food components that are included in several of antioxidants (Aox) is known to have effect. Hydrolysis products obtained from insects by different methods (some substances such as peptides and chitosan) have different degrees of Aox activity. These components have anti-inflammatory effect, many of the ones that have protein-based while; LOX peptide substances (lipoksijenaz), COX-2 (Cyclooxygenase-2) and nuclear factor kappa-B (NF-kB) signaling by inhibiting anti-inflammatory effects, there are studies that support that it can have. “Glycosaminoglycans”, a type of polysaccharide found in crickets, have been shown to have an anti-inflammatory effect by inhibiting C-reactive protein (CRP) and Rheumatoid Factor (RF) (Zhou et al., 2022; Nowakowski et al., 2021). On the other hand, the antibacterial activities of insects have been associated with inhibiting Gram (+) and Gram (-) bacteria. The inhibition of these bacteria supports the effects of improving intestinal health. In recent years, the positive effects of edible insects on the intestinal microbiota have been associated with “chitin”. In animal studies, it is noted that chitin optimizes intestinal health by increasing short-chain fatty acids (SCFA) in the intestines and inhibits pathogenic bacteria (Zhou et al., 2022; Kipkoech, 2023). In one study, the effect of applying black soldier fly-larval flour on the microbiota and the production of SCFA’s was studied; as a result, it was shown that there was an increase in SCFA’s (a good prebiotic nutrient component in terms of microbiota) in the microbiota (Borrelli et al., 2017). Chitin can also bind cholesterol, reducing its absorption and helping to ensure the elimination of excess cholesterol; it activates natural/adaptive immune cells, induces cytokine production, and may exert an immuno-modulatory effect by activating macrophages (Kipkoech et al., 2023; Roos & Huis, 2017). The fatty acid profile contained in yellow flour worms, crickets and housefly maggots may have a positive effect on the risk of developing CVD. At the same time, thanks to the glucose-aminoglycan content found in crickets, a decrease in serum blood sugar and LDL cholesterol levels can also be achieved (Nowakowski et al., 2021). Studies conducted in mice have drawn attention to the fact that insects contain bioactive components that can be effective in controlling body weight. A study conducted in obese mice showed that consumption of yellow flour worm larva powders can lead to a decrease in body weight by reducing fat accumulation in adipocytes and serum TG levels. The anti-hypertensive effect of edible insects is explained by the fact that they contain powerful ACE inhibitor components. In one study, it was pointed out that silkworm, yellow flourworm, wasp and wax moths contain peptides that can show hypotensive activity (Roos & Huis, 2017). Its anti-carcinogenic activity is one of the most important potential effects of insects. As a result of another study, it was found that silkworm pupal protein hydrolysate prevents proliferation by inducing apoptosis (Zhou et al., 2022).

Consumer Acceptance

2100 insect species in about 80 countries around the world are widely consumed by edible insect ethnic groups. Although edible insects have been part of the daily diet in Asia for many years, the acceptance of insects in Western countries is still quite low (Tekiner et al., 2022; Gkinali et al., 2024). Although it is considered a new practice, insect consumption in Europe dates to Ancient Roman times. In Ancient Rome, insects were consumed as a luxury food, but they were also consumed as a response to food shortages (Platta et al., 2024). Even though their consumption dates to a long history, they are met with significant skepticism, security concerns and alienation in Western societies. Research shows that the acceptability of insect-based foods is influenced by various factors such as sociodemographic characteristics, psychological factors, environmental awareness, knowledge and awareness, cultural norms, social influences and product characteristics (Rehman & Ogrinc, 2024). In a study focusing on the accessibility of edible insects to consumer acceptance, frequency of consumption and motivation, it was concluded that religion and traditions are the main factors affecting entomophagy (Anagonou et al., 2023). In a study conducted on domestic tourists in Turkey, it was found that the participants' perceptions of insect consumption showed a significant difference according to sociodemographic characteristics such as gender, educational level and personality traits (Karaman & Bozok, 2023). Studies have highlighted the role of emotional variables in the development of negative attitudes. The most important of this disgust, and the perception of risk has been identified as neofobi food (Vanutelli et al., 2024).

Potential Health Risks

It is also very important to evaluate the potential health benefits of edible insects given above in terms of food safety (Lisboa et al., 2024; Aguilar-Toala et al., 2022). Before these insects are recommended as a “safe food”, it will be important to evaluate the associated risk factors as well. Edible insects have the potential hazards based on (a) chemical risks, (b) microbial

risks, and (c) are to be considered as a potential allergen (Hassan et al., 2024). The “chemical threats” carried by edible insects can be listed primarily as containing mycotoxins, heavy.

Conclusion

It is thought that insects can be used as an “alternative protein” source due to the increasing difficulty of access to reliable and high-quality food in recent years, the rapidly increasing population and the increase in the need for animal-derived protein in connection with population growth. It is reported in the literature that insects are a good source of macro and micronutrients. The digestibility rate of edible insects by human physiology is high, although it is related to the type of insect. It is thought that they may be a good “alternative” food source whose protein content and bioavailability are compared to other plant/animal protein sources. In addition to their anti-carcinogenic, anti-bacterial, anti-microbial, anti-inflammatory, immunomodulatory activities; it is claimed in many clinical studies that they can be used to improve blood glucose levels and blood lipid profile. Authorities and current studies expressing opinions in this field draw attention to the fact that edible insects can be an “alternative” to meet the daily requirements of the human body and may become part of human nutrition more widely in the future. There is a need to establish guidelines for comprehensive, safe and hygienic practices to ensure the safety of the consumption of edible insects.

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