iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** XI **Month of publication:** November 2024

DOI: https://doi.org/10.22214/ijraset.2024.64483

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XI Nov 2024- Available at www.ijraset.com

Insects: Alternative Protein Source for Human Diet

Rimpa Karmakar[1], Jyoti Rani[2], Pavneet Kaur[3]
[1, 2]School of Allied health science, Jaipur National University, Jaipur- 302017, Rajasthan, India
[3]Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan-173230, Himachal Pradesh, India

Abstract: With a growing global population, substitute protein sources, in addition to traditional animal and plant-based proteins, will be required to meet global dietary protein requirements and assure world food safety. Insects have been suggested as a substitute protein dense food source that could be produced on a more economically viable and environmentally friendly commercial scale. Edible insects as a substitute for protein for human food and animal feed are appealing due to their low greenhouse gas emissions, high feed conversion efficiency, low land use, and ability to convert low value organic byproducts into high value protein products. Edible insects must be processed and transformed into delectable dishes. Food safety can be compromised by insect toxicity, pathogen contamination, spoilage during storage, and allergies. Consumer attitudes are a major issue in the Western world, and several strategies to encourage insect consumption have been proposed. Insects present a potential sustainable food source for humans due to their high nutritive value and ubiquitous presence. Insects can provide a reliable and sustainable source of high-quality animal protein once suitable species are identified and appropriate breeding methods are developed.

I. INTRODUCTION

With human population growth, increased longevity, and the uncertainties of climate change, the ability to sustainably produce enough food to feed the world is becoming increasingly important. Insects found in agricultural, forest, and aquatic ecosystems contribute significantly to global biomass. It is estimated that over two billion people worldwide consume insects on a regular basis as part of their traditional diet. Traditionally, edible insects are harvested from nature. They aid in food security because they are frequently consumed at home, or they provide a source of income when promoted. They are an intermittent product because most species rely on host plants. Increased forest loss, increased farming (e.g., pesticide use), and environmental pollution may endanger the resource, while higher demand and higher prices may lead to excessive use. According to projections, the global population will approach nine billion by 2050. Demand for meat products is predicted to increase by about 75% by 2050 compared to current levels. Per capita meat consumption is expected to increase more in poor nations (from 28 kg in 2005/2007 to 42 kg in 2050) than in developed countries (80 to 91 kg) [20]. Population growth would be geometric, but food production would increase arithmetically. As a result, the current level of food production must be doubled to accommodate population growth. Climate change and industrial expansion have had a negative influence on food productivity, as acreage for agriculture is reducing [21]. Food production has a significant environmental impact, and any food system must consider this. Food systems must prioritize food security for people. Meat production has significant environmental impacts, including deforestation, soil erosion, public health risks, biodiversity loss, and water pollution. Because of these serious difficulties, the usage of plant-based protein in the diet has gained appeal. Plant-based proteins lack critical amino acids and are less digestible than animal-based proteins. To maintain sustainable protein production, consider using alternate protein sources, such as insects [52]. Insects can be regarded either human food or feed. Insect agriculture is more sustainable than livestock due to lower greenhouse and ammonia emissions, less land requirements, and possibility for organic farming. Insects offer higher protein content and production efficiency than other traditional protein sources [70]. Insects are promoted as a protein and micronutrient source, and FAO supports their production in developing countries. Edible insect protein also meets the WHO's essential amino acid requirements, is more digestive than plant-based protein, and only slightly less digestible than animal protein. Eating insects is generally frowned upon, particularly in Western countries. Insects should be used in a variety of forms, such as pastes, powders, concentrates, and isolates, as ingredients or fortified agents in new food products [21].

II. NUTRITIVE VALUES OF EDIBLE INSECTS

Insects are a source of energy, protein, fat, minerals and vitamins [49].The nutritional value of edible insects is very diverse mainly because of the large number and variability of species [10].Nutritional values can vary considerably even within a group of insects depending on the stage of metamorphosis, origin of the insect and its diet [15]. Similarly, the nutritional value changes according to the preparation and processing before consumption (drying, cooking, frying etc.) [61].

The Nutrient Value Score of crickets, palm weevil larvae and mealworm was significantly healthier than in the case of beef and chicken and none of six tested insects were statistically less healthy than meat. Most edible insects provide sufficient energy and protein intake in the human diet, as well as meeting the amino acid requirements. Insects also have a high content of mono- and polyunsaturated fatty acids; they are rich in trace elements such as copper, iron, magnesium, manganese, phosphorus, selenium and zinc, as well as vitamins like riboflavin, pantothenic acid, biotin, and folic acid in some cases [28].

A. Macronutrients

Some scientist have analyzed 78 kinds of insects and calculated their calorific value in the range from 293 to 762 kcal per 100 g of dry matter. The protein contents of edible insects amount to between 35.34 % for Isoptera (termites) and 61.32% for *Orthoptera* (crickets, grasshoppers, locusts).

The species *Melanoplus femurrubrum*, *Sphenarium histrio*, and *Melanoplus mexicanus* (all from the order Orthoptera) yielded the highest protein contents with 77.00, 71.15–77.00, and 58.90–77.13 %, respectively [43] representing a valuable alternative protein source. The nutrient quality of the insect protein is promising in comparison to casein and soy but varies and can be improved by the removal of the chitin.

Most edible insects provide satisfactorily with the required essential amino acids [43]. The fat content of insects varies between 10 and 70 % on a dry matter basis [66].Caterpillars belong among insects with the highest fat content. Some studies determined the total fat content in caterpillars (Lepidoptera) from 8.6 to 15.2 g per 100 g of insects. In contrast, the fat content ranges from 3.8 g to 5.3 g per 100 g of insects in grasshoppers and related *Orthoptera* species [59].The carbohydrate content of yellow mealworm larvae can vary between one and seven percent [44]. Edible insects contain a significant amount of fiber. Insoluble chitin is the most common form of fiber in the body of insects contained mainly in their exoskeleton [61]. Generally, adults are composed of a high amount of chitin which is indigestible, and are thus low in calories. Larvae and pupae are usually composed of high amounts of proteins and fats, corresponding to high calories. Hence, products made from insects of different stages can fit people with different needs [56].

B. Micronutrients

Minerals are classified as macro-minerals (calcium, phosphorus, magnesium, sodium, potassium and chloride) and micro or trace minerals (iron, zinc, copper, manganese, iodine and selenium). For example, the large caterpillar of the moth *Gonimbrasia belina* called mopani or mopane has a high iron content (31–77 mg per 100 g of dry matter) and so does the grasshopper L. migratoria (8–20 mg per 100 g of dry matter) [39].

While the exoskeleton of most insects is primarily composed of protein and chitin, black soldier fly larvae [53], and face fly larvae (*Musca autumnalis*) [8, 47], have a mineralised exoskeleton in which calcium and other minerals are incorporated into the cuticle. Therefore, they can contain high levels of calcium. Most insects contain more phosphorus than calcium, except for species with a mineralised exoskeleton (i.e. face fly and black soldier fly larvae)[8]. Insects typically contain more potassium than sodium whereas chloride levels are intermediate. Most insect species likely contain adequate amounts of these three minerals to meet the dietary requirements of most animal species[15].

Bukkens (2005) listed a variety of insects containing thiamine. Its content ranges from 0.1 to 4 mg per 100 g of dry matter. Riboflavin is represented in edible insects in amounts from 0.11 to 8.9 mg to 100 g. Vitamin B12 is found in abundance in larvae of the yellow mealworm beetle T. molitor (0.47 µg per 100 g) and the house cricket *Acheta Domesticus* (5.4 µg per 100 g in adults, 8.7 µg per 100 g in nymphs).

However, many other species that have been analyzed contain only negligible amounts of this vitamin (Finke 2006).The silkworm Bombyx mori contained 9.65 mg of tocopherols per 100 g of dry matter (Tong *et al*., 2011). Insects are generally rich in riboflavin, pantothenic acid, and biotin. On the other hand, they are not an efficient source of vitamin A, vitamin C, niacin, and in most cases thiamin [48]. The vitamin E content was low for most analyzed insect species (6–16 mg/kg DM), except for *Dorsophila Melanogaster* and *Microcentrum Rhombifolium* (112 and 110 mg/kg DM).

III. BENEFITS OF EDIBLE INSECTS

Insects are a good source of bioactive peptides (3–20 amino acids residues in length that promote beneficial effects for human health), including antihypertensive, antidiabetic, antioxidant, ant obesity , immunomodulatory , anti-inflammatory , antimicrobial , antiviral , and antithrombotic properties, among others.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XI Nov 2024- Available at www.ijraset.com

Fig: Health Benefit of edible insect

Table: Example of Edible insect with there health curing property

S.No.	Properties	Insects
1.	Antioxidant activity	*Adult B. mori*
2.	Anti-hypertensive activity	*M. domestica* *G. sigillatus*
3.	Anti – obesity & anti- diabetic effect	*Bombyx mori* *Korean horn beetle,*
4.	Anti-cancerous and anti-inflammatory activity	*Lycormadelicatula* *G. sigillatus* *T. molitor,* *S. gregaria*
5.	Antimicrobial activity	*G. sigillatus*
6.	Sustainability	*Acheta domesticus*
7.	Alternative source of protein	*Tenebrio molitor* L , *Bombyx mori* L, *Pyralidae* L

A. Antioxidant Activity

Various components of edible insects have been reported to have antioxidant activity, from hydrolysates obtained through various enzyme treatments to peptides obtained through purification and identification processes, extracts using water and organic solvents, and chitosan present in the skin of larvae [21]. For example, *Adult B. mori* (silk moth) hydrolysates obtained using alkalize and alkaline protease also exhibit high radical scavenging activity, as estimated using oxygen radical absorbance capacity (ORAC) and 1,1-diphenyl-2-picrylhydrazyl (DPPH) assays [34]. Peptide fractions obtained from *T. Molitor* subjected to different heat treatments (boiling and baking) exhibited antioxidant, anti-inflammatory, and inhibitory activities against key enzymes relevant to metabolic syndrome [64].

B. Antihypertensive Activity

Many investigations on the ACE inhibitory activity have been carried out to explore the anti-hypertensive properties of edible insects. ACE inhibitors have been explored as anti-hypertensive treatment agents [31]. There have been reports of anti-hypertensive activity for extracts of *M. Domestica* [34], hydrolysates of Bombus terrestris [63], and *G. sigillatus* [23]. *Tenebrio molitor* larvae's epidermis is rich in chitin and chitosan, which can lower blood pressure, blood lipid levels, and improve cholesterol metabolism[22].

C. Anti-obesity and anti-diabetic Effects

The Korean horn beetle, *A. dichotoma*, exhibits anti-obesity properties. Using *A. dichotoma* ethanol extracts and 3T3-L1 adipocytes for lipid accumulation and adipocyte-specific gene expression analysis assessed the anti-obesity activity [7,68]. Furthermore, a lot of polysaccharides found in grubs, honey, and silkworm pupae have the ability to reduce blood sugar [24].When alkaloids with hypoglycemic action in insects are reported, Bombyx mori and 1-deoxynojirimycin (DNJ) are the most common products. Treating diabetes and obesity without causing sugar absorption disorders or other side effects, DNJ and its derivatives can effectively inhibit sucrase, maltase, isomaltase, trehalase, and lactase on small intestinal microvilli. However, they do not inhibit α-amylase, which delays the absorption of carbohydrates in food [27].

D. Anti-cancerous and anti-inflammatory Activity

Heat-killed bacterial mixture (Escherichia coli D31 and Micrococcus luteus A270) to immunize Calliphoravicina, resulting in the particular peptide alloferon 1 (HGVSGHGQHGVHG)[6]. Through the stimulation of lymphocytes natural killer (NK) activity in mouse spleen or human peripheral blood, alloferon 1 demonstrated potent anti-cancer efficacy. The proliferation of K562 tumor cells was found to be suppressed by these mimicked lymphocytes. One of the three animal species in the world that never gets cancer is the cockroach, and an extract of their steroidal substance has been shown to boost human immunity, encourage granulation formation, and have anticancer properties [22].Lycormadelicatula [1], *Polyrhachis, G. Sigillatus, T. Molitor, and S. Gregaria* [57] are some edible insects with anti-inflammatory properties.

E. Antimicrobial Activity

Using a crossover trial study [55] found that eating G. sigillatus boosted the growth of Bifidobacterium animalis, a well-known beneficial probiotic that enhances gastrointestinal function, avoids diarrhea, and lessens antibiotic side effects.

F. Sustainability

According to a wealth of studies, producing edible insects uses less water and land and emits fewer greenhouse gases [9]. For instance, it takes 15 m2 of land for crickets to generate 1 kilogram of protein, compared to 50 m2 for pigs and 200 m2 for cattle [18]. Moreover, it takes 2,000 L of water for crickets to generate 1 kg of protein, compared to 2,300, 3,500, and 20,000 L for chicken, pork, and beef, respectively [16].Compared to livestock, insects have a higher total ECI. As per Nakagaki and Defoliart 1991 study, house crickets (*Acheta Domesticus*) need an average of 1.7 kg of feed to generate 1 kilogram of protein, while beef and pork require 5 kg and 10 kg of feed, respectively.

G. Alternative Source of Protein

There is growing interest in edible insects as possible sources of protein that could assist reduce the anticipated 2050 protein demand [33] Because insect farming offers a significant economic potential and has a little environmental impact, the FAO currently promotes entomophagy [22].

Reforestation of agricultural land and a reduction of at least 4% in agricultural greenhouse gasses (GHG), or 23 million metric tons annually, would be made possible by replacing at least 25% of the protein from livestock with other, more sustainable sources [51, 54]. An analysis of the nutritional profiles of more than 200 edible insect species revealed that protein and fat make up the majority of these insects' nutritional makeup, with fiber, nitrogen free extract, non-fiber carbs and ash [48]. Insects can primarily be an excellent source of protein, as they contain all essential amino acids. The protein having overall the highest protein content (61% dry basis), followed by dragonflies and damselflies with 55% protein (dry basis); cockroaches and termites have the lowest overall protein content (35% dry basis) [22]

IV. INSECT FARMING AND PRODUCTION

Gathering insects in the wild, which includes forests, streams, and agricultural fields, is the most popular method of collecting them. According to the traditions and cultural practices of small-scale producers, this approach permits the collecting of a broad variety of species at various phases of life [60]. These growers have the skills and understanding to determine the best times, weather, and host plants to produce specific edible species without endangering the ecosystem [11] Gathering insects from fields, mostly for home use, has little effect on the environment and helps to stabilize insect populations over time. Depending on the stage of development (eggs, pupae, larvae, or adults), the season (rainy or dry), and the region (forest, desert, or agricultural fields), each species has a unique harvesting technique. When the rainy season starts, red maguey worms (Hypoptaagavis) are harvested from the pineapples of the maguey (*Agave Saliminara*); grasshoppers of the species *Sphenarium Purpurascens* are harvested by hand from fields; and pupae of the ant species *Limetopumapicuatum* are collected during the warm dry season (February to May) and the eggs are taken out of the anthills [35].Despite the vast land area of India, Nepal, Pakistan, and Sri Lanka combined, information sources only discovered 57 edible insects. The low number could be partly explained by the large numbers of vegetarian Hindus and Buddhists living there. Although they are being experimented with as poultry and pond fish feed, pupae are not consumed by people in Nepal, unlike in India [12]. But because the trophic chain is shifting as a result of unchecked overharvesting, ecological harm is being done [17, 59].Due to the rising demand for a small number of insect species, more aggressive harvesting methods have been used without the appropriate care, which could reduce or even completely eliminate the area's biodiversity [59]. For example, overexploitation in Australia due to restaurant and ecotourism demand is threatening the number of wood grubs and honey ants [66].

V. PROCESSING AND UTILIZATION OF INSECTS

The edible insect industry is expanding at an astounding rate, and there is a growing demand for new products in both identifiable forms and as ingredients [61]. The manufacturing processes begin with the post-harvesting of raw insects and conclude with the production of foodstuffs and wastes, some of which are recovered and reused as products. Although the number of processes currently in use in the edible food industry is enormous and varies depending on the species used and the final product to be developed, the majority of them can be grouped into a small number of operations with similar basic principles, essentially focusing on similar purposes. Some of the techniques utilized in this industry include blanching, drying, as well as various extraction methods [34]. Some commercially available products made from insects:

Table 1: commercially available products

S.No	Brand	Products	Country
1.	Aldento	Pasta with *Tenebrio molitor.*	Belgium
2.	Aketta	Roasted cricket and powder.	USA
3.	Chapul	Cricket energy bars and protein powders	USA
4.	Critter Bitters	Cocktail bitters made with toasted crickets.	USA
5.	NutriBug	Cricket powder (75% protein), cricket powder (76% protein), cricket protein bars, and cricket protein pasta.	United Kingdom
6.	Yumpa	Energy bars made with protein-packed cricket flour	United Kingdom
7.	Delibugs	Freeze dried, energy bars, candy & lollipops, spreads, made from a wide variety of insects.	Netherlands

8.	Ihou	The houtou products are sourced exclusively from their farming operation based in eastern France. Dehydrated crickets (salted, sweet, chili, and natural).	France
9.	Micronutris	Insect crackers (chili, thyme, sesame, tex-mex), cooking packs with dehydrated insects, high protein bars, including mealworm bars	France
10.	Gran Mitla	Agave worm salt 100% chinicuil, grasshopper salt, ground agave worms	Mexico
11.	Merci Mercado	Gourmet seasoned chapulines (grasshoppers), agave worm salt, red maguey worms, and ground grasshoppers.	Mexico
12.	Beneto Foods	BenetoFoods is a new innovative food company that produces high-protein and high-quality foods based on barbequed protein. Three different flavors of cricket pasta.	Germany
13.	Imago-Insects	Cricket Burger Quinoa, Cricket Falafel Curry, Cricket Bolognese, Cricket Burger Classic, crispbread with flaxseed, and so on.	Germany
14.	Bugsy Bros	Crispy baked crickets, 100% cricket powder, protein ball mix, sample packs, among others	Australia
15.	Leap Protein	Peanut Butter Cricket Protein Bar, Cricket Skin Glow Bar (Orange & Goji Berri), Cricket Protein Bar (Chocolate Coconut).	Australia
16.	Thailand Unique	Canned, bulk, candies and powders of a wide variety of insects including crickets, dung beetles, larvae, pupae, shield bugs, scorpions, black ants, cicada, weaver ants, silk moth pupae, ant eggs, squash bugs, and grasshoppers.	Thailand
17.	Insekterei	Pat´e with mealworm, crispbread with cricket flour, high-quality protein cricket balls, and dried crickets' powder (Protein 60%).	Switzerland
18.	Edible-bug	Dried edible insects, edible cranberry cookies, and mealworm powder.	South Korea
19.	UNIKMAT	Insect flour, insect protein bars, whole billbill larvae, Siris flour (100% Acheta siris	Norway

VI. SAFETY CONCERNS

Hazardous substances prevalent in nature, such as cyanogenic glycosides, may also be present in some insects [68]. According to Vijver *et al.*, the concentrations of Cd and Pb in the bodies of the *T. molitor* larvae matched the total metal pool of the soil in which they resided. According to Eating grasshoppers and locusts without taking off their feet can result in intestinal blockage, which can be lethal. Eating insects can also cause allergies. Certain insects have an exterior covering of chitin on their bodies that is difficult for humans to digest [2]. Therefore, even though a variety of pollutants may compromise the food safety of edible insects, regulated insect farming and production can reduce these risks to human health. The same food safety regulations that apply to traditional foods also apply to the preparation and storage of edible insects [28].

VII. EDIBLE INSECT REGULATIONS

In recent times, there has been a notable shift in the consumption patterns of many consumers due to their increased consciousness of their entitlement to nutritious and safe food. This undoubtedly includes foods derived from insects and edible insects themselves, particularly for Western customers who seem especially reluctant to participate in entomophagy. There are no regulations governing the production, handling, or distribution of edible insects in the underdeveloped countries where entomophagy is most common; hence, there are no restrictions on their use [24].The availability of insects and insect-based meals in American distribution channels raises concerns about their regulatory classification [29]. To be lawfully sold in the US market, they must either be permitted as food additives, or their usage must be generally recognized as safe (GRAS). Insects and insect compounds are classified as food additives and require FDA approval after a petition demonstrating safety when added to food. The authorization would include a regulation outlining the safe use conditions for the insect species. Legalizing insects as food additives could reassure consumers about their safety, but there are limitations to this strategy [3].

REFERENCES

[1] Baek, S. H., Joung, O., Lee, H. Y., Shin, J. C., Choi, W. S., Lee, T. H., and Lee, S. H. (2018). Anti-oxidative fraction of Lycorma delicatula alleviates inflammatory indicators. Natural Product Communications, 13(4), 1934578X1801300413.

[2] Bouvier, G. (1945). Some questions of veterinary entomology and the fight against certain arthropods in tropical Africa. Acta tropica, 2(1), 42-59.

[3] Boyd MC (2017) Cricket soup: a critical examination of the regulation of insects as food. Yale Law and Policy Rev 36(1):17–81

[4] Bukkens, S. G. (2005). Insects in the human diet: nutritional aspects. Ecological implications of minilivestock: potential of insects, rodents, frogs and snails, 545-577.

[5] Bußler S, Rumpold B A, Jander E, Rawel H M and Schlüter O K 2016 Recovery and technofunctionality of flours and proteins from two edible insect species: Meal worm (Tenebrio molitor) and black soldier fly (Hermetia illucens) larvae Heliyon 2 e00218

[6] Chung, M. Y., Yoon, Y. I., Hwang, J. S., Goo, T. W., & Yun, E. Y. (2014). Antiobesity effect of A llomyrina dichotoma (A rthropoda: I nsecta) larvae ethanol extract on 3T3-L1 adipocyte differentiation. Entomological Research, 44(1), 9-16.

[7] Dashefsky, H. S., Anderson, D. L., Tobin, E. N., & Peters, T. M. (1976). Face fly pupae: a potential feed supplement for poultry. Environmental Entomology, 5(4), 680-682.

[8] de Carvalho, N. M., Madureira, A. R., & Pintado, M. E. (2020). The potential of insects as food sources–a review. Critical reviews in food science and nutrition, 60(21), 3642-3652.

[9] Dobermann, D., Swift, J. A., & Field, L. M. (2017). Opportunities and hurdles of edible insects for food and feed. Nutrition Bulletin, 42(4), 293-308.

[10] Durst, P. B., & Hanboonsong, Y. (2015). Small-scale production of edible insects for enhanced food security and rural livelihoods: experience from Thailand and Lao People's Democratic Republic. Journal of Insects as Food and Feed, 1(1), 25-31.

[11] Durst, P. B., Johnson, D. V., Leslie, R. N., & Shono, K. (2010). Forest insects as food: humans bite back. RAP publication, 1(1), 1-241.

[12] Finke, M. D. (2002). Complete nutrient composition of commercially raised invertebrates used as food for insectivores. Zoo biology: published in affiliation with the American zoo and aquarium association, 21(3), 269-285.

[13] Finke, M. D. (2007). Estimate of chitin in raw whole insects. Zoo biology: published in affiliation with the American zoo and aquarium association, 26(2), 105-115.

[14] Finke, M. D., & Oonincx, D. (2023). Insects as food for insectivores. In Mass production of beneficial organisms (pp. 511-540). Academic Press.

[15] Gahukar, R. T. (2016). Edible insects farming: efficiency and impact on family livelihood, food security, and environment compared with livestock and crops. In Insects as sustainable food ingredients (pp. 85-111). Academic Press.

[16] Goodland, R. (2013). Lifting livestock's long shadow. Nature Climate Change, 3(1), 2-2.

[17] Grafton R Q, Daugbjerg C and Qureshi M E 2015 Towards food security by 2050 Food Secur. 7 179–83

[18] Gravel A and Doyen A 2020 The use of edible insect proteins in food: Challenges and issues related to their functional properties Innov. Food Sci. Emerg. Technol. 59 102272

[19] Hall, F. G., Jones, O. G., O'Haire, M. E., & Liceaga, A. M. (2017). Functional properties of tropical banded cricket (Gryllodes sigillatus) protein hydrolysates. Food chemistry, 224, 414-422.

[20] Hall, F., Johnson, P. E., & Liceaga, A. (2018). Effect of enzymatic hydrolysis on bioactive properties and allergenicity of cricket (Gryllodes sigillatus) protein. Food chemistry, 262, 39-47.

[21] He, Z. (2011). Yellow mealworm polysaccharide response surface method extraction and antioxidant activity. Journal of Food and Biological Technology, 30(5), 641-647.

[22] Imathiu, S. (2020). Benefits and food safety concerns associated with consumption of edible insects. NFS journal, 18, 1-11.

[23] Kong, W. H., Oh, S. H., Ahn, Y. R., Kim, K. W., Kim, J. H., & Seo, S. W. (2008). Antiobesity effects and improvement of insulin sensitivity by 1-deoxynojirimycin in animal models. Journal of agricultural and food chemistry, 56(8), 2613-2619.

[24] Kouřimská, L., & Adámková, A. (2016). Nutritional and sensory quality of edible insects. NFS journal, 4, 22-26.

[25] Lange, K. W., & Nakamura, Y. (2021). Edible insects as future food: chances and challenges. Journal of future foods, 1(1), 38-46.

[26] LeBeau A (2015) Insect protein: what are the food safety and regulatory challenges?, available on the website: http://burdockgroup.com/insect-protein-what-are-the-food-safety-and-regulatorychallenges/. Last accessed on 25 June 2019

[27] Lee, J. H., Kim, T. K., Jeong, C. H., Yong, H. I., Cha, J. Y., Kim, B. K., & Choi, Y. S. (2021). Biological activity and processing technologies of edible insects: a review. Food Science and Biotechnology, 30, 1003-1023.

[28] Li, H., Inoue, A., Taniguchi, S., Yukutake, T., Suyama, K., Nose, T., & Maeda, I. (2017). Multifunctional biological activities of water extract of housefly larvae (Musca domestica). PharmaNutrition, 5(4), 119-126.

[29] Liceaga, A. M. (2022). Edible insects, a valuable protein source from ancient to modern times. In Advances in food and nutrition research (Vol. 101, pp. 129-152). Academic Press.

[30] Liu, Y., Wan, S., Liu, J. U. N., Zou, Y., & Liao, S. (2017). Antioxidant activity and stability study of peptides from enzymatically hydrolyzed male silkmoth. Journal of Food Processing and Preservation, 41(1), e13081.

[31] Melgar Lalanne, G., Hernández Álvarez, A. J., & Salinas-Castro, A. (2019). Edible insects processing: Traditional and innovative technologies. Comprehensive Reviews in Food Science and Food Safety, 18(4), 1166-1191.

[32] Nakagaki, B. J., & Defoliart, G. R. (1991). Comparison of diets for mass-rearing Acheta domesticus (Orthoptera: Gryllidae) as a novelty food, and comparison of food conversion efficiency with values reported for livestock. Journal of Economic Entomology, 84(3), 891-896.

[33] Nowak, V., Persijn, D., Rittenschober, D., & Charrondiere, U. R. (2016). Review of food composition data for edible insects. Food chemistry, 193, 39-46.

[34] Oonincx, D. G. A. B., & Dierenfeld, E. S. (2012). An investigation into the chemical composition of alternative invertebrate prey. Zoo Biology, 31(1), 40-54.

[35] Oonincx, D. G., Van Itterbeeck, J., Heetkamp, M. J., Van Den Brand, H., Van Loon, J. J., & Van Huis, A. (2010). An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. PloS one, 5(12), e14445.

[36] Orkusz, A. (2021). Edible insects versus meat—Nutritional comparison: Knowledge of their composition is the key to good health. Nutrients, 13(4), 1207.

[37] Qian, L., Deng, P., Chen, F., Cao, Y., Sun, H., & Liao, H. (2022). The exploration and utilization of functional substances in edible insects: A review. Food Production, Processing and Nutrition, 4(1), 11.

[38] Ramos-Elorduy, J., Costa Neto, E. M., Pino, J. M., Correa, M. D. S., Garcia-Figueroa, J., & Zetina, D. H. (2007). Knowledge about useful entomofauna in the county of La Purísima Palmar de Bravo, Puebla State, Mexico.

[39] Ramos-Elorduy, J., González, E. A., Hernández, A. R., & Pino, J. M. (2002). Use of Tenebrio molitor (Coleoptera: Tenebrionidae) to recycle organic wastes and as feed for broiler chickens. Journal of economic entomology, 95(1), 214-220.

[40] Ramos-Elorduy, J., Moreno, J. M. P., Prado, E. E., Perez, M. A., Otero, J. L., & De Guevara, O. L. (1997). Nutritional value of edible insects from the state of Oaxaca, Mexico. Journal of food composition and analysis, 10(2), 142-157.

[41] Roseland, C. R., Grodowitz, M. J., Kramer, K. J., Hopkins, T. L., & Broce, A. B. (1985). Stabilization of mineralized and sclerotized puparial cuticle of muscid flies. Insect biochemistry, 15(4), 521-528.

[42] Rumpold, B. A., & Schlüter, O. K. (2013). Nutritional composition and safety aspects of edible insects. Molecular nutrition & food research, 57(5), 802-823

[43] Rumpold, B. A., & Schlüter, O. K. (2013). Potential and challenges of insects as an innovative source for food and feed production. Innovative Food Science & Emerging Technologies, 17, 1-11.

[44] Sarwar G 1997 The Protein Digestibility–Corrected Amino Acid Score Method Overestimates Quality of Proteins Containing Antinutritional Factors and of Poorly Digestible Proteins Supplemented with Limiting Amino Acids in Rats J. Nutr. 127 758–64

[45] Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., Matthews, E., & Klirs, C. (2019). Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. Final report.

[46] Shantibala, T., Lokeshwari, R. K., & Debaraj, H. (2014). Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India. Journal of Insect Science, 14(1), 14.

[47] Spranghers, T., Ottoboni, M., Klootwijk, C., Ovyn, A., Deboosere, S., De Meulenaer, B., ... & De Smet, S. (2017). Nutritional composition of black soldier fly (Hermetia illucens) prepupae reared on different organic waste substrates. Journal of the Science of Food and Agriculture, 97(8), 2594-2600.

[48] Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., & De Haan, C. (2006). Livestock's long shadow: environmental issues and options. Food & Agriculture Org..

[49] Stull, V. J., Finer, E., Bergmans, R. S., Febvre, H. P., Longhurst, C., Manter, D. K., ... & Weir, T. L. (2018). Impact of edible cricket consumption on gut microbiota in healthy adults, a double-blind, randomized crossover trial. Scientific reports, 8(1), 1-13.

[50] Tang, C., Yang, D., Liao, H., Sun, H., Liu, C., Wei, L., & Li, F. (2019). Edible insects as a food source: a review. Food Production, Processing and Nutrition, 1(1), 1-13.

[51] Tang, J. J., Fang, P., Xia, H. L., Tu, Z. C., Hou, B. Y., Yan, Y. M., ... & Cheng, Y. X. (2015). Constituents from the edible Chinese black ants (Polyrhachis dives) showing protective effect on rat mesangial cells and anti-inflammatory activity. Food Research International, 67, 163-168.

[52] Tong, L., Yu, X., & Liu, H. (2011). Insect food for astronauts: gas exchange in silkworms fed on mulberry and lettuce and the nutritional value of these insects for human consumption during deep space flights. Bulletin of entomological research, 101(5), 613-622.

[53] Tzompa-Sosa, D. A., Yi, L., van Valenberg, H. J., van Boekel, M. A., & Lakemond, C. M. (2014). Insect lipid profile: aqueous versus organic solvent-based extraction methods. Food research international, 62, 1087-1094.

[54] Van Huis, A., & Oonincx, D. G. (2017). The environmental sustainability of insects as food and feed. A review. Agronomy for Sustainable Development, 37, 1-14.

[55] Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). Edible insects: future prospects for food and feed security (No. 171). Food and agriculture organization of the United Nations..

[56] Van Thielen, L., Vermuyten, S., Storms, B., Rumpold, B. A., & Van Campenhout, L. (2018). Consumer acceptance of foods containing edible insects in Belgium two years after their introduction to the market. Journal of Insects as Food and Feed, 5(1), 35–44

[57] Vercruysse, L., Van Camp, J., & Smagghe, G. (2005). ACE inhibitory peptides derived from enzymatic hydrolysates of animal muscle protein: a review. Journal of agricultural and food chemistry, 53(21), 8106-8115.

[58] YANG, L. F., Siriamornpun, S., & Li, D. U. O. (2006). Polyunsaturated fatty acid content of edible insects in Thailand. Journal of Food Lipids, 13(3), 277-285.

[59] Yen, A. L. (2009). Edible insects: Traditional knowledge or western phobia?. Entomological research, 39(5), 289-298.

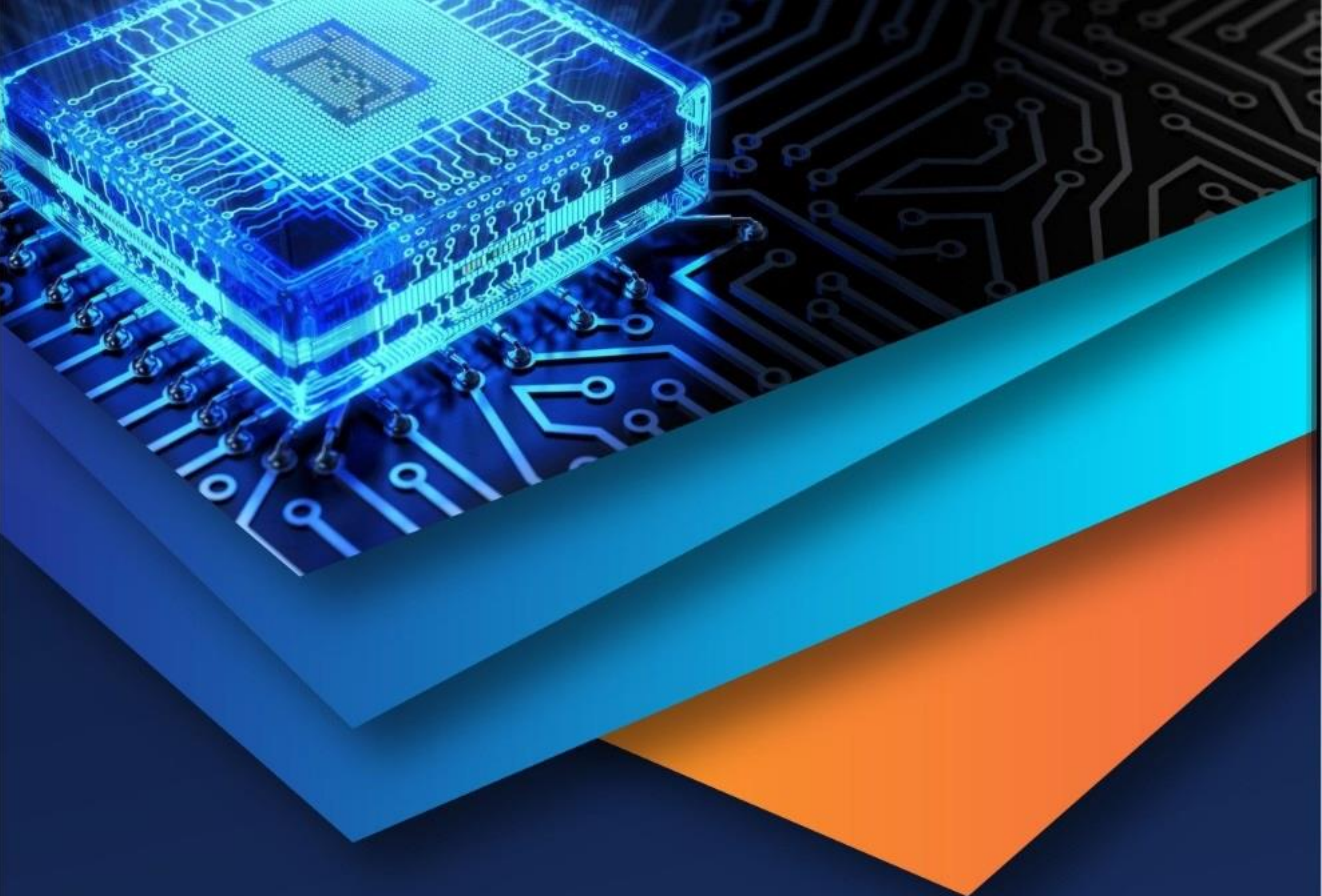
[60] Yoon, Y. I., Chung, M. Y., Hwang, J. S., Han, M. S., Goo, T. W., & Yun, E. Y. (2015). Allomyrina dichotoma (Arthropoda: Insecta) larvae confer resistance to obesity in mice fed a high-fat diet. Nutrients, 7(3), 1978-1991.

[61] Zagrobelny, M., Dreon, A. L., Gomiero, T., Marcazzan, G. L., Glaring, M. A., MøLler, B. L., & Paoletti, M. G. (2009). Toxic moths: source of a truly safe delicacy. Journal of Ethnobiology, 29(1), 64-76.

[62] Zielińska E, Karaś M and Baraniak B 2018 Comparison of functional properties of edible insects and protein preparations thereof LWT 91 168–74

[63] Zielińska, E., Baraniak, B., & Karaś, M. (2018). Identification of antioxidant and anti-inflammatory peptides obtained by simulated gastrointestinal digestion of three edible insects species (Gryllodes sigillatus, Tenebrio molitor, Schistocerca gragaria). International journal of food science & technology, 53(11), 2542-2551.

[64] Zielińska, E., Baraniak, B., Karaś, M., Rybczyńska, K., & Jakubczyk, A. (2015). Selected species of edible insects as a source of nutrient composition. Food Research International, 77, 460-46.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY