GEOGRAPHICAL DISTRIBUTION, CHEMICAL PROFILE, AND FOOD APPLICATION OF *ACHETA DOMESTICUS*: A MINI-REVIEW

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REVIEW

Abstract
Around the world, there is a growing interest to incorporate crickets in food products for a few reasons: to protect the environment, and to use them as a rich source of nutrients, particularly protein. The aim of our study was to provide a brief overview of the insects' role with a particular focus on Acheta domesticus in protecting the environment, and enhancing a range of food products. Acheta domesticus, crickets, edible insects, bioactive substances, nutritional value, and cricket feed were among the terms utilized to collect information for this review from the following databases: PubMed, Google Scholar, Lens, and Scopus. With the aid of the VOSviewer program, a bibliometric map was produced. The geographical distribution of A. domesticus was examined using the Global Biodiversity Information Facility (GBIF) platform, showing that Europe has the highest percentage of the species, while the Netherlands has the greatest number of locations for registered crickets. Innovative foods containing cricket powder are presented alongside the proximate composition of the insect.
In summary, crickets provide an environmentally-friendly source for the food industry, and for the planet.

Keywords: *Acheta domesticus*, cricket food, house crickets, sustainable resources
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INTRODUCTION

Insects are among the predominant animals on Earth, with over 1.5 million identified species. Insects are essential to all terrestrial ecosystems due to their unique features and spatial distribution. They preserve soil structure and fertility, recycle nutrients, disseminate seeds, and act as a substantial food supply for other species (Belluco et al, 2023).

The food industry looks forward to a unique food production that is sustainable, eco-friendly, affordable, and adaptable to climate changes (Magara, 2020).

The current literature has shown the approach to edible insects. Insects, when consumed as food or feed, reduce human needs in terms of nutrient requirements and, as a result, natural resource usage. Edible insects can be incorporated in the human diets since they are a highly nutritious source of food. The most studied and consumed insect species derived from the orders Isoptera, Lepidoptera, Orthoptera, and Hymenoptera. The majority of these species live primarily on land, whilst a few of them may also be found in the biotic environment (Zhou et al, 2022).

Among the Orthopterans, crickets are the most-consumed insects all across the globe, where house cricket *Acheta domesticus* represents the preponderance consumed specie worldwide (Magara, 2020).

In accordance with the environment and sustainability, there has been great benefits of mini livestock compared to livestock. Greenhouse gas for the house cricket (*A. domesticus*) illustrates greater values in comparison to conventional livestock, even in terms of ammonia production. Furthermore, feed conversion ratios depend on the class of animal and the production practices. Based on the protein content, cricket nymphs (154g/kg edible weight) and adults (205g/kg edible weight) show appreciable content whereas values for poultry, pork, and beef are 200g/kg, 150g/kg, and respectively 190g/kg. In all likelihood, crickets convert feed more efficiently to body mass than conventional livestock and

that is due to their poikilothermic properties (Huis, 2013).

The Regulation (EU) 2015/2283 of the European Parliament and of the Council permits the commercialization of frozen, dried, and powdered alternatives of *A. domesticus*, the house cricket, as a novel and safe food source.

A. domesticus is an outstanding source of nutrition that provides high quality nutrients (Siddiqui et al, 2024). *A. domesticus* is an insect species with a great commercial potential in the EU market (Ververis et al, 2022).

This mini-review aims to explore the advantages and potential of insects in relation to the environment, and humans' health. The paper presents an in-depth study of the geographical distribution of *A. domesticus*. Furthermore, the chemical profile, utilization of insects in food, and environmental sustainability of *A. domesticus* are extensively explored.

RESEARCH METODOLOGY

This work utilized the platforms PubMed, Google Scholar, Lens, and Scopus. The key words were *A. domesticus,* crickets, edible insects, bioactive compounds, nutritional value, cricket foods.

Studies published in languages other than English and those with unrelated topics and outcomes were removed.

Special emphasis was placed on publications emphasizing the application of crickets in the food sector.

The map was generated using results from the Lens.org platform, applying VOSviewer software version 1.6.20, with a selection criterion of a minimum of five occurrences for each term, from a total of 831 words. Only 29 key words satisfied this condition.

From the 3504 articles obtained with the Lens.org database, dating since 1957, the greatest attention paid to *A. domesticus* used in food industry was registered in 2022, with 23.23% of the total results. In network visualization maps (**Figure 1**), each label is denoted by a colored node. The frequency of usage of the item determines the size of the node. The size of an item's label increases with its frequency of use. In addition, the internode's thickness and the connecting line's thickness indicate how frequently the labels appear together. Nodes that have the same color are more strongly linked. The keywords in the list are categorized into 5 clusters, designated with different colors.

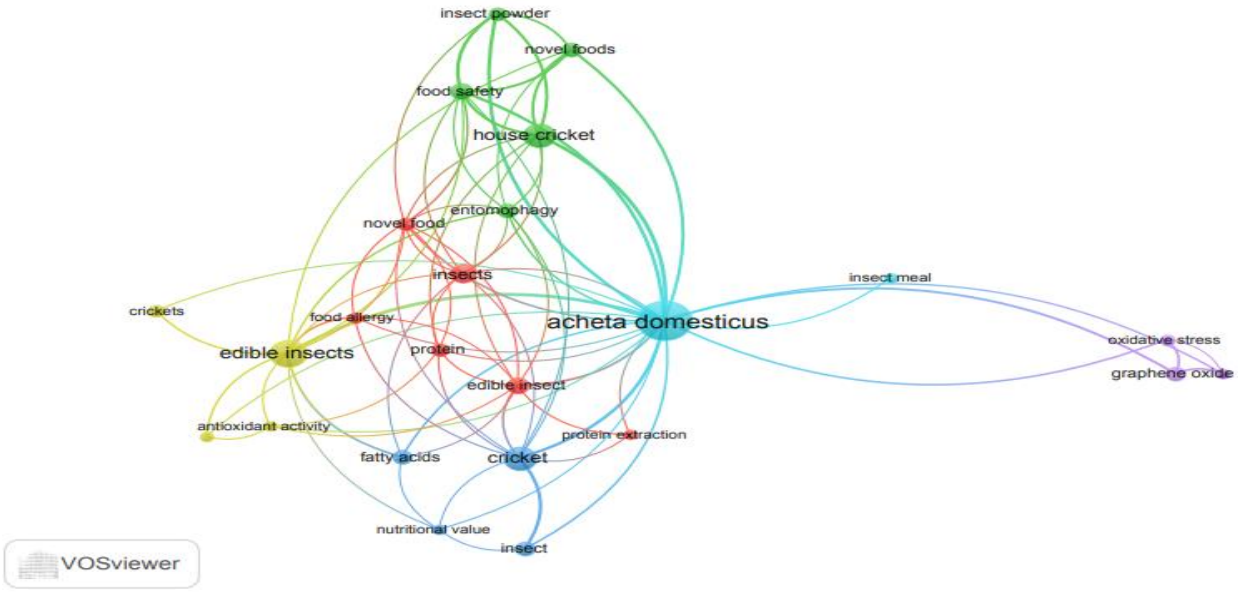

Figure 1. **The bibliometric map related with key words linked with *Acheta domesticus***

Figure 1 illustrates the keywords map of the investigated literature from the Lens.org database. The figure shows the links between the 831 keywords selected as having at least five occurrences in the corpus. In the top of the most common keywords, we found: "*A. domesticus*" with 72 appearances, "edible insects" with 33 appearances, "cricket" with 25 appearances, "edible insects" with 13 appearances and "house cricket" with 25 appearances.

These findings indicate that *A. domesticus* is starting to be used more and more in the food industry.

GEOGRAPHICAL DISTRIBUTION OF *ACHETA DOMESTICUS*

The house cricket, notable under the scientific name of *Acheta domesticus* or *Gryllus domesticus,* taxonomically derives from *Acheta* genus*, Gryllidae* family, *Orthoptera* order. Globally, the information owned by Global Biodiversity Information Facility (GBIF) at the end of 2023, shows that the specie is wide-spread on five continents (**Figure 2**), and is identified with the geographic coordinates in 7612 regions. Continental distribution of the house crickets is illustrated in **Table 1.**

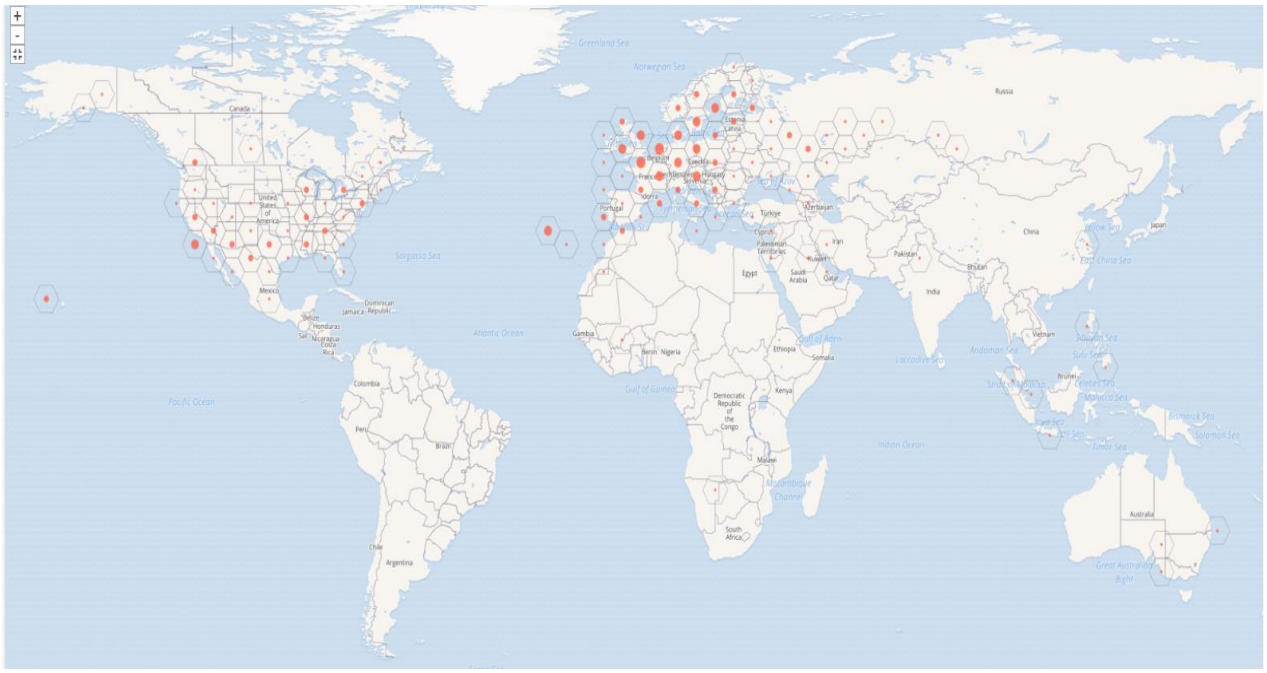

Figure 2. **Global distribution of *Acheta domesticus* (https://www.gbif.org/species/1718308)**

Table 1.
Continetal distribution of *Acheta domesticus*

Continent	Identified locations with geographic coordinates
Europe	6816
North America	713
Asia	43
Oceania	28
Africa	8
South America	0
Antarctica	0

Source: https://www.gbif.org/species/1718308

Continental Europe is faced with the greatest number of insects from this specie in reference to GBIF. The country division of *A. domesticus* in terms of the identified regions are shown in the **Figure 3**. All of the European countries with more than ten places that have been located and declared are included in **Figure 3.**

ENVIRONMENTAL BENEFITS AND CHALLENGES OF INSECTS

Insects have evolved worldwide, adapting to their surroundings. The diversity of the species and the geographical distribution amplifies their significance in the environment. Each insect is a constituent of an ecosystem and play a vital role in maintaining the overall health, sustainability, and activity of the environment (Verma et al, 2023). Furthermore, the contribution of insects to the ecosystems is highly remarkable. They act as bioindicators to signal the health of the ecosystem; soil aeration and decomposition to aerate and break down the organic matter; and have an economic impact in agriculture.

In spite of all beneficial impact insects possess in the environment, there are unfavorable circumstances related to the environment. The occurrence of climate change due to global factors, habitat destruction, and pollution has influenced the distribution of certain insect species (Prakash et al, 2023).

NUTRITIONAL COMPONENTS OF ACHETA DOMESTICUS

The nutritional profile of edible insects includes all the essential nutrients for a proper human growth and development. Edible insects have great amounts of energy, high quality protein, fats of which polyunsaturated fatty acids (linoleic acid and alpha-linolenic acid) more than flesh animal. The protein content of most insects, especially crickets (*A. domesticus*), reaches a maximum of 60% in dry weight (dw), and a fresh weight of 20.50g/100g. The carbohydrate content on *A. domesticus* is relatively low and is mainly found in the insect's exoskeleton (the major source of cellulose, chitin, and chitosan), and glycogen (Zhou et al, 2022).

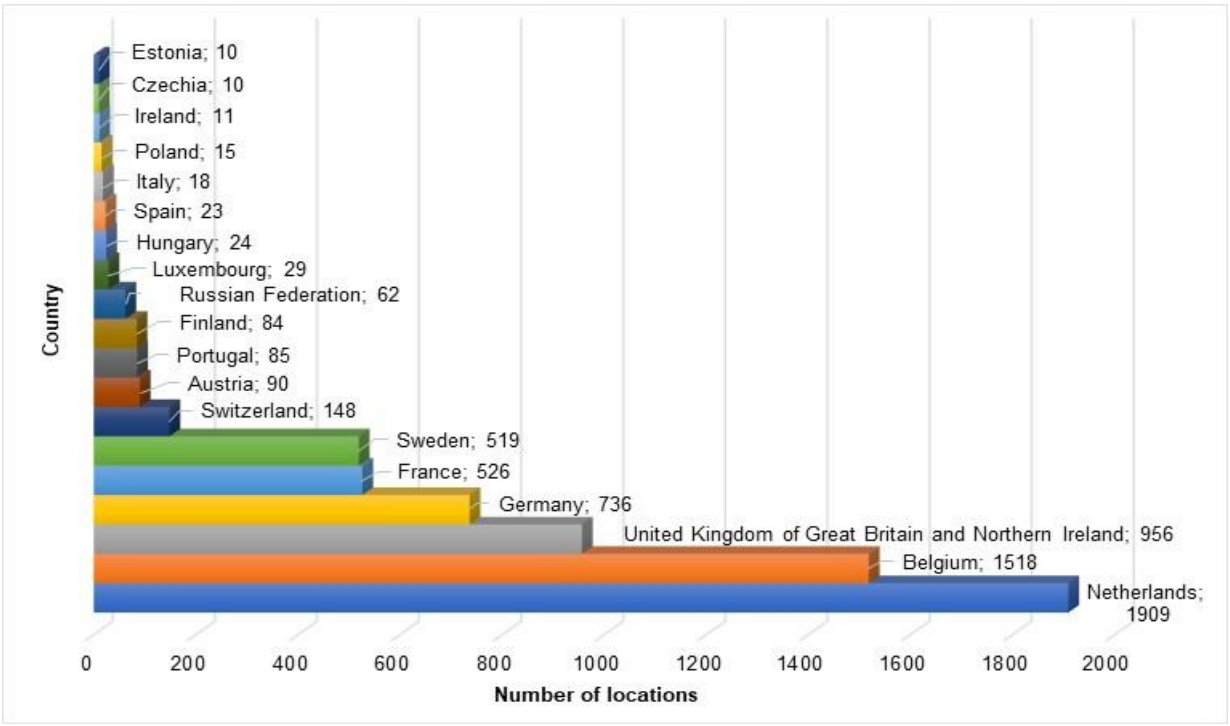

Figure.3. **Europe distribution of *Acheta domesticus***

The Kjeldahl method requires identifying all nitrogen in a sample in order to determine the crude proteins. Insect protein content is overestimated because of the abundance of nitrogen in the exoskeleton provided by the nitrogen-rich polysaccharide chitin. Consequently, the conversion factor employed in the quantification of protein in insects is 5.25, as instead of 6.25 in the case of meat (Boulous, 2020; Murugu et al, 2021).

Derived from other study, the major component of *A. domesticus* in terms of nutritional composition is also the protein content, followed by other essential constituents (**Table 2**), (Udomsil et al, 2019).

Table 2. Nutrient content of *Acheta domesticus*

Constituents	% dry matter	References
Protein	60	Zhou et al, 2022
	71.7±0.5	Udomsil et al, 2019
Lipid	13.41	Zhou et al, 2022
	10.4±0.1	Udomsil et al, 2019
Carbohydrate	2.6	Pan et al, 2022.
	1.6±0.1	Udomsil et al, 2019
Ash	5.4±0.3	Udomsil et al, 2019
	4.45±0.05	Kittibunchakul et al, 2023

The quality of the protein results from the amino acid composition. All essential amino acids are present in *A. domesticus* with higher amount for valine (4.50±0.03 g/100g), leucine (3.80±0.14 g/100g). In a similar way, the high lysine and threonine content in *A. domesticus* may help supplement cereal based diets (Udomsil et al, 2019).

The lipid content is primarily determined by the quantity and type of present fatty acids. In a recent study, it was demonstrated that unsaturated fatty acids predominate in the chemical composition. In *A. domesticus,* the reference value for fat reaches 22.8 g/100g dry weight (Orkusz et al, 2024).

A. domesticus is considered a complex source of vitamins and minerals. Based on dry matter, the highest reference values in case of vitamins are for riboflavin (11.07mg/100g), niacin (12.59mg/100g) ascorbic acid (9.74mg/100g) and pantothenic acid (7.47mg/100g). In correlation to mineral content, crickets are rich in K (1126.62mg/100g), P (780–957.79mg/100g), next to effective bioavailable Ca, Mg, Fe, Cu, Mn, Zn (Pan et al, 2022).

Because protein hydrolysates have biological activity, consuming insects has many health benefits. They support the synthesis of novel bioactive peptides and have remarkable biomass and biodiversity characteristics. Numerous researches have reported the antibacterial, antidiabetic, and antioxidant properties of insect peptides and polypeptides. Peptides were found in the trypsin lysates, especially in cricket powder, and showed satisfactory thermal stability. When free amino acids and peptides are released during enzymolysis, hydrolysates are vulnerable to Maillard reaction. As a result, hydrolysis and Maillard reaction changes the flavor of cricket proteins remarkably. In a recent study, the application of microwave radiation in combination with enzymatic hydrolysis to reduce allergenicity factor and enhance the peptides' bioactivity has been investigated. To this point, it has been confirmed that microwave-assisted protein hydrolysates of crickets amplify the hydrolysis reaction time.

Ultrasound pretreatment, as an innovative technique, has been demonstrated to be beneficial in the release of smaller active peptides. In a conducted test on *A. domesticus* with ultrasound pretreatment and pressurized liquid extraction using ethanol and hydroethanol as solvents, the extract revealed antioxidant capacity, and the inhibition of lipase activity (Pan et al, 2022).

In addition to the nutritional field, phytosterols and policosanols are also significant bioactive compounds with a beneficial impact on the human's health (Estrada et al, 2021).

ENHANCED FOOD PRODUCTS

Over the past few years, the consumer interest for an alternative and sustainable food source has driven to the development of innovative food products enriched with edible insects (Amoah et al, 2023).

Edible insects can be used as a food ingredient to enhance the nutritional value of various dishes and food products all around the world. This can be accomplished to improve the population's nutritional intake where access to a protein source is limited (Estrada et al, 2021). The most recent research on the use of cricket powder in various food products is shown in **Table 3.**

Table 3. **Studies that included *A. domesticus* powder in food products**

Country of study	Year	Form of insect used for enrichment/substitution	Product	Optimal substitution	Reference
Italy	2018	Powder (10%, 30%)	Bread	↓ Acceptability of cricket enriched bread	Osimani et al.,2018
Spain	2019	Powder 5%	Bread	NS	Gonzalez, Garzon, & Rosell, 2019
Thailand	2020	Powder (5%, 10%, 15%)	Bread Cookies	10% substitution bread 5 and 10% enriched cookie	Bawa, Songsermpong, Kaewtapee, & Chanput, 2020
Italy	2020	Powder (5%, 10%, 15%)	Bread	NS	Cappelli, Oliva, Bonaccorsi, Lorini, & Cini, 2020
Ungary	2020	Powder (5%, 10%, 15%)	Biscuits	5% cricket powder-enriched biscuits	Biro et al., 2020
Italy	2022	Powder (10%, 20%)	Bread	5 and 10% enriched bread	Bresciani, Cardone, Jucker, Savoldelli, & Marti, 2022)
Poland	2022	Powder (10%, 20%, 30%)	Bread	10% buffalo worm and cricket powder enriched bread	Kowalski, Mikulec, Mickowska, Skotnicka, & Mazurek, 2022
Thailand	2022	Powder (10%, 15%, 20%, 25%, 30%)	Bread	10% cricket powder enriched bread	Mafu, Ketnawa, Phongthai, Schonlechner, & Rawdkuen,

					2022
Romania	2022	Powder (5%, 10%, 15%)	Bread	NS	Mihaly Cozmuta et al., 2022
Honduras	2022	Powder (5%, 7.5%, 10%)	Cookies	5% enriched cookie	Aleman et al., 2022
USA	2022	Powder 6.9%	Pita chips	6.9% cricket powder pita chips seasoned with Italian-style herb seasoning	Gurdian, Torrico, Li, & Prinyawiwatkul, 2022
Bulgaria	2022	Powder (5%, 10%)	Cake	5% cricket powder-enriched sponge ca	Vlahova-Vangelova, Balev, Kolev, Dinkova, & Stankov, 2022
USA	2022	Powder 7.5%	Brownies	NS	Ho et al., 2022
Turkey	2022	Powder (10%, 15%, 20%)	Biscuits	Up to 20%	Bas & El, 2022
Portugal	2023	Powder (10%, 20%, 30%)	Bread	NS	Bartkiene, E et al., 2023
Czech Republic	2023	Powder (5%, 10%, 15%, 20%, 25%)	Gluten-free bars	Up to 15%	Pecova M. et al., 2023
Poland	2024	Powder (5%, 10%, 15%)	Bread	5% enriched bread	Gantner M. et al., 2024
Poland	2024	Powder (1,5%, 3%, 5%)	Yoghurt	1.5% enriched yoghurt	Karwacka M. et al., 2024

NS - not specified

The progress of the bakery industry in developing savory food products enriched with edible insects has gained a lot of attention. Although bakery products are considered to be a good source of carbohydrates, they are not nutrient-dense food sources. Therefore, specialists in the food industry have come to the enrichment of these products with insect powder, especially resulted from *A. domesticus*, to improve the nutrient quality and quantity.

The most common bakery products enriched with *A. domesticus* powder are bread, cakes, muffins, cookies. For example, bread enrichment with 2, 6 and 10% cricket powder resulted in a considerable increase of 52, 79, respectively 85.5% in protein concentration compared to their control samples of bread. In a similar way, cookies enriched with 5, 7.5, 10% cricket powder resulted in an increase of protein concentration by 56.2, 67.2, respectively 70.7%. As a result, the incorporation of cricket powder in bakery products promotes a high protein food source and may supplement the required protein content in human diets (Amoah et al, 2023).

The World Health Organization and Food and Agriculture Organization classify a high protein food based on a 10g/100g edible part protein content (Udomsil et al, 2019).

CONCLUSIONS AND FUTURE PERSPECTIVE

The current review has shown the diversity of edible insects, and their role in all terrestrial ecosystems. As crickets are the most-consumed insects from Orthoptera species, they shape a sustainable and clean environment compared to other animals. *A. domesticus* is an excellent source of essential nutrients for the human body since crickets are rich in protein, lipids, vitamins, and minerals. They contribute in the synthesis of bioactive peptides and have biological constituents.

The food industry has fulfilled to produce innovative food products enriched with crickets. Therefore, the bakery industry produces a variety of food products with cricket powder to improve human diets.

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