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Systematic Review

Systematic Review of Recent Studies on Antioxidants in Edible Insects

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Abstract
The consumption of edible insects is increasingly recognized as a more environmentally sustainable alternative to conventional meat. With the potential to significantly reduce greenhouse gas emissions, research interest in this field is growing. However, recent research has addressed the bioactive components present in edible insects and their beneficial physiological effects in humans, but it lacks integration of findings across experimental approaches. As this is an emerging field of research, consolidating current findings is crucial. Therefore, this review aims to consolidate the latest evidence regarding the antioxidant properties of edible insects and their role in mitigating oxidative stress. A systematic literature search was conducted using Google Scholar to identify studies investigating the antioxidant effects of edible insects. 18 eligible studies were selected based on inclusion criteria categorized based on their experimental design. Across the selected literature, various insects demonstrated strong ability to reduce oxidative stress, determined by a range of analytical methods. While the evidence provided by the current body of literature is promising, further research to evaluate different processing methods and developmental stages for harvest would benefit the effective integration of edible insects into daily diet. Thus, there remains a strong need for human dietary intervention studies to validate the antioxidant effects of edible insects and to support their functional health benefits as an alternative to meat.
Keywords: Edible Insect, Entomophagy, Antioxidant, Nutritional Benefits, Insect Processing.

Introduction

Edible insects are gaining global recognition as a sustainable protein source and as a food source rich of functional bioactive compounds. With increasing concerns about the environmental cost of conventional livestock, insects offer a promising alternative due to their high feed conversion efficiency, lower greenhouse gas emissions, and reduced land and water usage (Dobermann *et al.,* 2017). Beyond environmental sustainability, edible insects are also rich in proteins, essential amino acids, and micronutrients, including zinc and vitamin A, nutrients that contribute to oxidative balance and overall health (Nowakowski *et al.,* 2022; Aiello *et al.,* 2023).

Recent studies have revealed that edible insects contain significant amounts of antioxidant compounds such as polyphenols, flavonoids, peptides, and tocopherols (Van Huis *et al.,* 2021; Aiello *et al.,* 2023). This was cross-checked in different insect species, both in-vivo and in-vitro (Chantawannakul, 2020; D'Antonio *et al.,* 2023).

Oxidative stress is defined as an imbalance between reactive oxygen species and antioxidant defense systems. It is closely associated with aging and the pathogenesis of chronic diseases such as cardiovascular disorders, neurodegeneration, and sarcopenia (Liguori *et al.,* 2018). Therefore, the dietary inclusion of antioxidants is essential in preventing these diseases and maintaining health. Natural antioxidants derived from food are preferred over synthetic options due to safety concerns (Lobo *et al.,* 2010).

The elderly group can benefit from the particular nutritional benefits of edible insects. Especially, edible insects as a source of natural antioxidants adds unique value for the seniors (Li *et al.,* 2023). With physiological changes including muscle loss accompanying aging, ensuring adequate protein intake is critical for preserving lean body mass and functional independence in older age groups (Deer *et al.,* 2015). Foods that support the antioxidant defense system can contribute to preventing age-related chronic conditions

(Zujko *et al.,* 2023). Given this, edible insects, being rich in complete proteins, essential amino acids, and antioxidant compounds, offer an effective and sustainable nutrition source for the elderly. It delivers high-quality protein to combat sarcopenia while providing natural antioxidants to counteract oxidative stress.

Therefore, this review aims to consolidate the latest experimental evidence on the antioxidant properties of edible insects and highlight the need for further research to utilize them in daily diet.

Material and Methods

A keyword search was conducted using Google Scholar to identify relevant articles on the topic of edible insects and antioxidants. The search terms included [entomophagy], [antioxidant], and [review] excluded. Filters were applied to select articles published within the past 10 years, specifically from 2015 to 2025.

From this initial search, a total of twelve articles were identified that discussed the potential antioxidant properties of edible insects. Each article was examined to extract references to research articles studying edible insects as a natural source of antioxidants. Through this review process, six additional primary research articles were found to fit the inclusion criteria and were also published within the same time window.

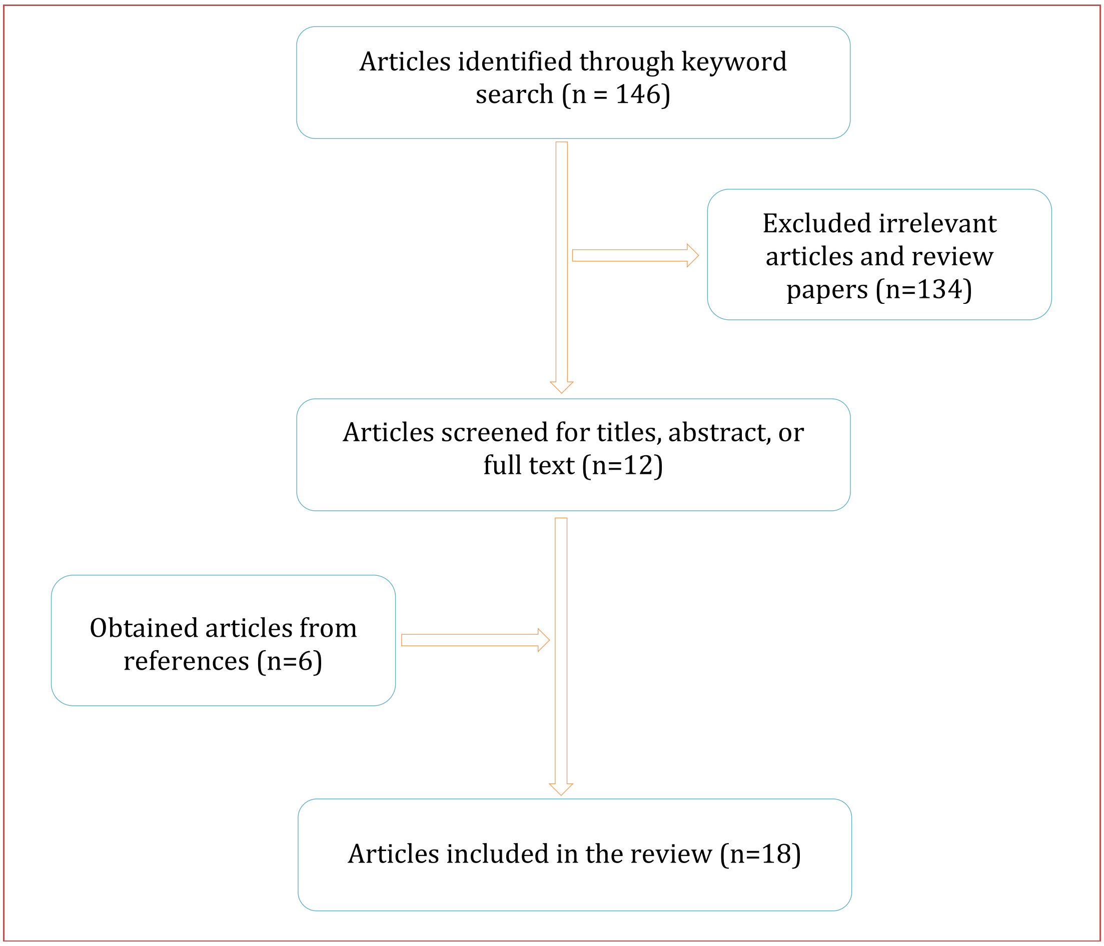

Figure 1. Flowchart illustrating the systematic search and selection process for articles related to the antioxidant properties of edible insects. A total of 146 articles were initially identified through a keyword search on Google Scholar using the terms "entomophagy," "antioxidant," and excluding "review.", with a filter applied to limit the search to publications from 2015 to 2025. 134 articles were excluded due to irrelevance or being review papers, leaving 12 articles for further screening based on titles, abstracts, or full texts. From these, six additional primary research articles were obtained from references, resulting in a total of 18 articles selected for this study.

Result

Overall, the literature search suggests that a variety of edible insects should be considered as a source of antioxidative nutrition, highlighting their potential contribution towards enhancing dietary health. The antioxidant properties of these insects could offer numerous benefits, most promisingly the mitigation of oxidative stress, which is linked to various chronic diseases and aging processes.

Table 1. List of antioxidative activity tests.

Organism	Developmental stage	Method	Antioxidant activity	Reference
Grasshopper (*Oxya yezoensis*)	Adult	SOD[1], DPPH[2], TPC[3]	+	Saiki, *et al.,* (2021)
Zophobas morio	Larvae	ABTS[4], DPPH, TPC	+	Pečová, *et al.,* (2022)
Brachytrupes orientalis	Adult	DPPH, Hydroxyl radical scavenging activity, SOD	+	Dutta, *et al.,* (2017)
Oecophylla smaragdina	Adult	DPPH	+	Raza, *et al.,* (2022)
Odontotermes sp	Adult	DPPH	+	Raza, *et al.,* (2022)
Tenebrio molitor	Larvae	HPLC[5]	+	Mattioli, *et al.,* (2021)
Red ant (*Oecophylla smaragdina*)	Egg	DPPH	+	Sailo, *et al.,* (2020)
Muga silkworm (*Antheraea assamensis*)	Pupa	DPPH	+	Sailo, *et al.,* (2020)
Honey bee (*Apis cerana*)	Pupa	DPPH	+	Sailo, *et al.,* (2020)
Winged termite (*Odontotermes obesus*)	Adult	DPPH	+	Sailo, *et al.,* (2020)
Eri silk worm (*Samia ricini*)	Pupa	DPPH	+	Sailo, *et al.,* (2020)
Red ant (*Oecophylla smaragdina*)	Adult	PRP[6]	+	Vidhu and Evans, (2015)
Schistocerca gregaria	Adult	DPPH	+	Virk, *et al.,* (2021)
Tenebrio molitor	Larvae	ABTS	+	Gaglio, *et al.,* (2021)
Alphitobius diaperinus	Larvae	ABTS	+	Gaglio, *et al.,* (2021)
Protaetia brevitarsis	Adult	CAC[7], DPPH, ORAC[8], TPC	+	Jeong, *et al.,* (2019)
Oxya japonica japonica	Adult	CAC, DPPH, ORAC, TPC	+	Jeong, *et al.,* (2019)
Tenebrio molitor	Larvae	CAC, DPPH, ORAC, TPC	+	Jeong, *et al.,* (2019)
Silk worm (*Bombyx mori*)	Larvae	CAC, DPPH, ORAC, TPC	+	Jeong, *et al.,* (2019)
Silk worm (*Bombyx mori*)	Pupa	CAC, DPPH, ORAC, TPC	+	Jeong, *et al.,* (2019)
Allomyrina dichotoma	Adult	DPPH, ABTS	+	Pyo, *et al.,* (2020)
Tenebrio molitor	Larvae	DPPH, ABTS	-	Pyo, *et al.,* (2020)
Protaetia brevitarsis	Adult	DPPH, ABTS	-	Pyo, *et al.,* (2020)
Gryllus bimaculatus	Adult	DPPH, ABTS	-	Pyo, *et al.,* (2020)
Teleogryllus emma	Adult	DPPH, ABTS	+	Pyo, *et al.,* (2020)
Apis mellifera	Adult	DPPH, ABTS	-	Pyo, *et al.,* (2020)
Tenebrio molitor	Larvae	DPPH, ABTS, FRAP[9]	+	Zielińska, *et al.,* (2017)
Schistocerca gregaria	Adult	DPPH, ABTS, FRAP	+	Zielińska, *et al.,* (2017)
Gryllodes sigillatus	Adult	DPPH, ABTS, FRAP	+	Zielińska, *et al.,* (2017)
Tenebrio molitor	Larvae	DPPH, ABTS, FRAP	+	Mancini, *et al.,* (2019)
Oxya chinensis sinuosa	Adult	DPPH	+	Kim, *et al.,* (2015)
Acheta domesticus	Adult	DPPH	+	Messina, *et al.,* (2019)
Tenebrio molitor	Larvae	DPPH	+	Messina, *et al.,* (2019)
Mealworms	Larvae	FRAP	+	Di Mattia, *et al.,*

(*Tenebrio molitor*)		TEAC[10]	+	(2019)
		TPI[11]	-	
		TEAC (lipo-soluble)	-	
Buffalo worms (*Alphitobius diaperinus*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	+	
		TPI	-	
		TEAC (lipo-soluble)	-	
Palm worm (*Rhynchophorus ferrugineus*)	Larvae	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	-	
		TPI	-	
		TEAC (lipo-soluble)	-	
Evening cicada (*Tanna japonensis*)	Adult	FRAP	-	Di Mattia, *et al.*, (2019)
		TEAC	-	
		TPI	-	
		TEAC (lipo-soluble)	+	
Black ants (*Lasius niger*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	-	
		TPI	-	
		TEAC (lipo-soluble)	-	
African caterpillars (*Imbrasia oyemensis*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	+	
		TPI	-	
		TEAC (lipo-soluble)	-	
Silkworm (*Bombyx mori*)	Larvae	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	+	
		TPI	-	
		TEAC (lipo-soluble)	+	
Grasshoppers (*Calliptamus italicus*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	+	
		TPI	-	
		TEAC (lipo-soluble)	-	
Crickets (*Acheta domesticus*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	+	
		TPI	-	
		TEAC (lipo-soluble)	-	
Mini crickets (*Acheta domesticus*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	-	
		TPI	-	
		TEAC (lipo-soluble)	-	
Giant water bugs (*Lethocerus indicus*)	Adult	FRAP	-	Di Mattia, *et al.*, (2019)
		TEAC	-	
		TPI	-	
		TEAC (lipo-soluble)	-	
Scolopendra (*Scolopendra gigantea*)	Adult	FRAP	+	Di Mattia, *et al.*, (2019)
		TEAC	-	
		TPI	-	

		TEAC (lipo-soluble)	-	
Tenebrio molitor	Larvae	ABTS, DPPH	+	Baek, *et al.,* (2019)
Vespa affinis L.	Adult	DPPH, hydroxyl radical, superoxide radical, effect on the activities of antioxidant enzyme (GST and CAT)	+	Dutta, *et al.,* (2016)
[1]SOD: Superoxide dismutase; [2]DPPH: 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay; [3]TPC: Total phenol concentration; [4]ABTS: 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical cation-based assays; [5]HPLC: High-performance liquid chromatography; [6]PRP: Phosphomolybdenum reduction potential; [7]CAC: Cellular antioxidant capacity; [8]ORAC: Oxygen radical absorbance capacity; [9]FRAP: Ferric reducing antioxidant power; [10]TEAC: Trolox equivalent antioxidant capacity; [11]TPI: Total polyphenols index.				

The analysis of 18 journal articles included a total of 30 insect species, a combination of 16 distinct chemical analytical methodologies. Developmental stages studied include eggs, larvae, pupa and adult. Among the 18 studies examined, all the studies (n=18), demonstrated robust antioxidative activity in all of their experimental insects as determined by diverse chemical assays. Among those, 2 reported partial or nutritionally insignificant levels of antioxidative activity in some of the selected experimental insects.

Di Mattia, *et al.,* (2019) study stands out in the literature as it specifically examined the efficacy of different solvents in the extraction of nutritional components from insects. Depending on the extracting method, the bioactivity of the extracted compounds is measured differently. In Pyo *et al.,* (2020) study, only two out of six tested insect species exhibited significantly higher antioxidative activity than the control group. Notably, this research utilized ethanol as the extraction solvent. Considering the findings from the above study, different solvent may have extracted different selection of compounds.

Table 2. Type of insects.

Type	Count of tests showing positive antioxidative activity
Mealworm	9
Silkworm	7
Cricket	6
Grasshopper	5
Ant	4
Moth	3
Others	15

Among the various edible insects, it was found that mealworms, silkworms, and crickets were the most studied in recent research. There were 9 studies examining the oxidative activity of mealworms, and 7 studies examined antioxidative capabilities of silkworms. Crickets also exhibit significant interest and were experimented by 6 articles, along with grasshoppers, ants, and moths with 6, 4, and 3 studies, respectively. This showcases the diverse potential of different insect species as functional food sources rich in antioxidants. This trend highlights the importance of further exploration into various species and their applications in nutrition and health.

Table 3. Antioxidant activity: positive results across developmental stages.

Type	Egg	Larva	Pupa	Adult	Total
Mealworm	-	9	-	-	9
Silkworm	-	4	3	-	7
Cricket	-	-	-	6	6
Grasshopper	-	-	-	5	5
Ant	1	-	-	3	4
Moth	-	-	-	3	3
Others	-	3	1	11	15

Examining the diverse insect species studied in the literatures, the majority were evaluated at specific stages in their life cycles. However, silkworms and ants were analyzed across multiple developmental stages. This comprehensive approach to study these particular species would provide a better understanding of how antioxidative properties may differentiate throughout an insect's lifespan. Such stage-specific analyses can be insightful to identify optimal harvesting periods and potential variations in nutritional value. It offers valuable insights into the dynamic nature of antioxidant production in insects, potentially informing future studies and applications in the field of entomophagy and further food development.

Discussion

In conclusion, based on the systematic review, recent studies strongly suggest edible insects are a reliable source of bioactive ingredients with antioxidant properties, verified by diverse analytical methods. In the context of the growing importance of edible insects as a future nutritional source, our comprehensive review has brought significant insights into their antioxidative potential. All 18 studies published from 2015 to 2025 demonstrated meaningful antioxidative activity in various insect species, as determined by diverse chemical assays. This reinforces the potential of entomophagy in addressing latest nutritional challenges and promoting health through dietary interventions.

The researches cover a wide range of edible insect species, a total of 30, majority of which showed significant levels of antioxidative activity, implying most edible insects could be considered as a good source of natural antioxidants. The level of antioxidative activity differs in various studies, depending on the species they study, sample preparation and analytical methodologies. Particularly, Di Mattia, *et al.,* (2019) study compared the antioxidant activity of water and liposoluble extracts obtained by different insects, with significantly more bioactivity observed in water soluble extracts. In relation to this, there are recent studies on different processing methods that should be evaluated to optimize nutritional benefits from insects as food sources (Liceaga, 2021; Ojha *et al.,* 2021).

Another important element of our review was the analyses by developmental stage of each experimental insect, particularly in silkworms and ants. This approach provides valuable insights into the varying nature of antioxidant component production throughout an insect's lifespan, potentially informing the most effective harvesting periods and managing nutritional value variations. This aligns with multiple studies on the different development stages of edible insects where varying nutrient qualities were observed in *Tebebrio molitor* (Ramos-Elorduy *et al.,* 2002), *Oryctes rhinoceros* (Omotoso *et al.,* 2018), and *Apis mellifera ligustica* (Ghosh *et al.,* 2016).

Conclusion

This research contributes significantly to the growing interest supporting entomophagy as a possible solution to recent nutritional and environmental challenges. As consumer awareness of health and environmental sustainability grows, insect-based products rich in antioxidants could occupy an irreplaceable position in the future food sector. The diversity of insect species offers opportunities for a variety of products and targeted nutritional solutions.

Specifically, edible insects present a unique opportunity to address the specific nutritional requirements of the elderly population. This demographic group faces distinct health challenges associated with aging, such as muscle loss and increased vulnerability to oxidative stress-related conditions. Edible insects, with their rich content of antioxidant compounds, can offer a nutritional solution to address the specific needs in this age group.

The incorporation of edible insects into the diets of older adults also contributes to sustainable nutrition. As the global population ages and the demand for high-quality protein sources increases, insects offer an efficient alternative to traditional animal proteins. Their lower environmental impact in terms of land use, water consumption, and greenhouse gas emissions positions them as an eco-friendly option for efficiently fulfilling the nutritional needs of an aging population.

Therefore, our study not only highlights the high nutritional value of edible insects but also suggests the way for their integration into the future dietary market. This research contributes significantly to the growing body of evidence supporting entomophagy as a viable solution to contemporary nutritional and environmental challenges. It would be worth studying further in the details, for example, in-depth study to compare different levels of antioxidative activity in various edible insect families. Di Mattia *et al.,* (2019) research emphasized the significance of solvent choice in extracting nutritional components from insects, demonstrating that extraction methods can vary the measured antioxidant activity of compounds. This was further supported by Pyo *et al.,* (2020) study, which utilized ethanol as an extraction solvent and found significant antioxidative activity in only two out of six tested species. These findings underscore the need for standardized extraction protocols to ensure accurate and comparable assessments of antioxidative activity between different insects.

Also, it would be interesting to research how insect-oriented antioxidants are beneficial to human health, with better understanding of their role in specific biological signalling pathways. One interesting finding from a previous study is that synthetic antioxidants such as BHT and BHA could be associated with potential toxic and carcinogenic effects, (Lobo *et al.,* 2010) suggesting further research in natural-sourced antioxidants can be critical in understanding human health and nutrition.

Declarations

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