Global Academic and Scientific Journal of Multidisciplinary Studies (GASJMS)

Volume 4 | Issue 3, 2026 Homepage: https://gaspublishers.com/gasjms/ ISSN: 2583-8970

Earthworms as a Potential Food Source: Nutritional Value, Bioactive Compounds, Safety Considerations, and Prospects for Sustainable Protein Production

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Received: *11.02.2026* | ***Accepted:*** *24.02.2026* | ***Published:*** *01.03.2026*

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DOI: *10.5281/zenodo.18821946*

Abstract **Original Research Article**

Growing global demand for sustainable protein sources has intensified interest in unconventional organisms with high nutritional value and low environmental impact. Earthworms (Annelida: Oligochaeta), long recognized for their ecological importance in soil systems, have emerged as a promising candidate for human consumption and as a high-quality ingredient in animal feed. This manuscript reviews the nutritional composition of earthworm biomass, the presence of bioactive peptides with potential health benefits, safety considerations related to microbial load and environmental contaminants, and the role of earthworms within circular bioeconomy frameworks. The analysis highlights both the opportunities and constraints associated with integrating earthworms into future food systems.

Keywords: Earthworms, sustainable protein sources, bioactive peptides, lumbrokinase.

INTRODUCTION

The search for sustainable protein sources has accelerated in response to population growth, climate change, and the environmental impacts of conventional livestock production. Edible invertebrates have received increasing attention as viable alternatives due to their high feed conversion efficiency and low greenhouse gas emissions (van Huis, 2013). Among these organisms, earthworms represent a unique and under explored resource. Although earthworms have been consumed traditionally in parts of Asia, Africa, and South America (Paoletti, 2005; Reynolds, 2005), their potential as a mainstream food source remains largely unexamined in Western contexts. This manuscript synthesizes current knowledge on the nutritional, biochemical, ecological, and safety dimensions of earthworm consumption and evaluates their suitability as a sustainable protein source.

DISCUSSION

Nutritional Composition of Earthworms

Earthworm biomass is characterized by a high protein content, typically ranging from 55% to 70% of dry weight (Reinecke & Viljoen, 1990). Essential amino acid profiles are comparable to those of fishmeal and superior to many plant-based proteins (Zhenjun *et al.*, 1997). Earthworms also contain significant quantities of polyunsaturated fatty acids, including linoleic and α linolenic acids, as well as micronutrients such as iron, calcium, magnesium, and B complex vitamins (Edwards, 2004). Lipid content generally ranges from 7% to 10% of dry weight, while carbohydrate levels remain low. Chitin in the cuticle contributes to dietary fibre and may confer immunomodulatory benefits (Finke, 2007) (**Table 1**).

Table 1. Representative Nutrient Composition of Earthworm Biomass (Dry Weight Basis)

Component	Typical Range) (% dry weight)	Notes / Sources
Protein	55–70%	High essential amino acid content; comparable to fishmeal (Reinecke & Viljoen, 1990; Zhenjun *et al.*, 1997)
Lipids	7–10%	Contains linoleic and α linolenic acids (Edwards, 2004)
Carbohydrates	5–12%	Primarily glycogen; low digestible carbohydrate fraction
Ash (minerals)	8–12%	Rich in Fe, Ca, Mg, Zn, and B complex vitamins
Moisture (fresh weight)	80–85%	Species and substrate dependent
Chitin	2–5%	Located in cuticle; contributes to dietary fibre (Finke, 2007)
Energy value	350–420 kcal/100 g	Comparable to other invertebrate meals

Earthworm Derived Bioactive Peptides

Beyond their macronutrient composition, earthworms contain a diverse array of bioactive peptides with potential applications in human health, functional foods, and biomedical research. Proteolytic digestion of earthworm proteins yields peptides exhibiting antioxidant, antimicrobial, anti-inflammatory, and immunomodulatory activities. These compounds have been identified in several species, including *Eisenia fetida*, *Eudrilus eugeniae*, and *Lumbricus rubellus*, and are increasingly recognized as a value-added component of earthworm-based protein systems (**Table 2**).

Antioxidant peptides derived from earthworm hydrolysates demonstrate strong free radical scavenging capacity, attributed to their high content of hydrophobic and aromatic amino acids (Wang *et al.*, 2007). Antimicrobial peptides such as lysenin and fetidin exhibit activity against Gram-positive and Gram-negative bacteria, as well as certain fungi (Cooper *et al.*, 2004). Their mechanisms include membrane permeabilization and immune system activation, suggesting potential applications in natural food preservation or therapeutic development.

Earthworm peptides also exhibit immunomodulatory properties. Extracts from *Eisenia fetida* have been shown to stimulate macrophage activity, enhance cytokine production, and modulate inflammatory pathways (Balamurugan *et al.*, 2007). Additionally, fibrinolytic enzymes such as lumbrokinase have been investigated for their thrombolytic potential and are used clinically in parts of Asia for cardiovascular therapy (Mihara *et al.*, 1991).

The presence of these bioactive compounds enhances the functional value of earthworm biomass beyond its role as a protein source. Further research is required to standardize extraction methods, evaluate bioavailability, and assess long term safety. Integrating peptide recovery into vermiculture based production systems may increase economic viability and support the development of multifunctional earthworm derived products.

Table 2. Major Classes of Earthworm Derived Bioactive Peptides and Their Functional Properties

Peptide / Compound	Biological Activity	Mechanism of Action	Representative Species	Key References
Lysenin	Antimicrobial; cytolytic	Binds sphingomyelin; forms membrane pores	*Eisenia fetida*	Cooper *et al.*, 2004
Fetidin	Antimicrobial; immune modulating	Enhances innate immune responses	*Eisenia fetida*	Cooper *et al.*, 2004
Antioxidant peptides	Free radical scavenging	Hydrophobic/aromatic residues neutralize ROS	*Eisenia fetida, Lumbricus rubellus*	Wang *et al.*, 2007
Lumbrokinase	Fibrinolytic; thrombolytic	Plasmin like activity; fibrin degradation	*Lumbricus rubellus*	Mihara *et al.*, 1991
Immunomodulatory	Cytokine activation; macrophage	Modulates inflammatory pathways Pepitides stimulation	*Eisenia fetida*	Balamurugan *et al.*, 2077
Antitumor peptides (Reported)	Cytotoxic to cancer cell lines	Membrane disruption; apoptosis induction	*Eisenia fetida*	Cooper *et al.*, 2004

Cultivation and Environmental Sustainability

Vermiculture systems designed for earthworm biomass production can operate on a wide range of organic substrates, including agricultural residues, food waste, and manure. This capacity positions earthworms as a key component of circular bioeconomy models, converting organic waste streams into high value protein while simultaneously producing vermicompost as a soil amendment (Edwards & Arancon, 2004). Earthworm cultivation requires minimal land area, low water inputs, and limited energy expenditure relative to conventional livestock. Greenhouse gas emissions are substantially lower than those associated with ruminant production (Oonincx *et al.*, 2010). These attributes underscore the environmental advantages of earthworm-based protein systems (**Table 3**).

Table 3. Comparison of Commonly Cultivated Earthworm Species for Protein Production

Species	Growth Rate	Protein Yield) (% dry weight)	Optimal Substrate	Advantages	Limitations
Eisenia fetida	Fast	60–70%	Manure, food waste, compost	Highly adaptable; widely used in vermiculture; strong peptide profile	Small body size; requires controlled moisture
Eudrilus eugeniae	Very fast	55–65%	Organic residues, manure	Large biomass; high reproduction rate	Sensitive to low temperatures
Lumbricus rubellus	Moderate	55–60%	Leaf litter, compost	Source of lumbrokinase; robust anti-oxidant peptides	Slower growth; lower biomass yield
Perionyx excavatus	Fast	60–65%	Organic waste, manure	High protein yield; efficient waste conversion	Sensitive to handling and Sensitive tohandling and environmental fluctuations

Safety Considerations and Processing Requirements

Despite their nutritional potential, earthworms present several safety considerations that must be addressed before large scale adoption. Earthworms can accumulate heavy metals, pesticides, and other environmental contaminants depending on substrate quality (Suthar, 2009). Microbial load, including pathogenic bacteria, may also be elevated in organisms harvested from contaminated environments. Controlled cultivation conditions and rigorous substrate management are therefore essential.

Processing methods such as blanching, drying, roasting, or freeze drying significantly reduce microbial risks and improve shelf stability (Zhenjun *et al.*, 1997). Removal of gut contents prior to processing is recommended to minimize off flavours and reduce potential contamination. Regulatory frameworks for edible invertebrates remain underdeveloped in many jurisdictions, necessitating further research and policy development to ensure safe commercialization.

Cultural Acceptance and Sensory Characteristics

Cultural perceptions represent a major barrier to the adoption of earthworms as a human food source in many regions. Sensory evaluations indicate that processed earthworm meal possesses a mild, nutty flavour profile and can be incorporated into composite foods such as protein bars, baked goods, or pasta without strong sensory impacts (Paoletti, 2005; Reynolds, 2005). Whole worm consumption remains less acceptable in Western contexts, but powdered or defatted earthworm protein isolates may circumvent cultural resistance. Public education and exposure, similar to efforts surrounding insect-based foods, will likely influence future acceptance.

Applications in Animal Feed

Earthworm meal has demonstrated strong potential as a substitute for fishmeal and soybean meal in aquaculture, poultry, and swine diets. High digestibility, favourable amino acid composition, and immunostimulatory properties contribute to improved growth performance in several species (Prakash & Karmegam, 2010). Integration of earthworm meal into feed systems may reduce reliance on overexploited fisheries and mitigate the environmental impacts of conventional feed production.

Research Gaps and Future Directions

Several research gaps must be addressed to support the broader adoption of earthworms as a food source. These include standardized cultivation protocols, contaminant monitoring systems, optimized processing methods, and comprehensive toxicological assessments. Genomic and proteomic analyses may further elucidate bioactive compounds with potential health benefits. Economic modelling is also required to evaluate the scalability and market viability of earthworm-based protein systems.

CONCLUSION

Earthworms represent a nutritionally rich, environmentally sustainable, and potentially scalable source of protein for both human consumption and animal feed. Their ability to convert organic waste into high value biomass positions them as a promising component of future circular food systems. However, widespread adoption will depend on the development of robust safety standards, improved public acceptance, and continued research into cultivation and processing technologies. With appropriate regulatory and technological support, earthworms may contribute meaningfully to global protein security in the coming decades.

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