Nutritional Potential of Freshwater Snails (*Pila ampullacea*) from Lake Rawapening for Sustainable Food Security

Syarif Prasetyo[1]*, *Rosalin*a Eka Permatasari[2], *Rossi* Prabowo[3]

[1]Research Center for Limnology and Water Resources, National Research and Innovation Agency (BRIN), Soekarno's Science and Technology Area Jalan Raya Jakarta- Bogor, Km 46 Cibinong, Bogor – West Java, Indonesia – 16911
[2]Chemistry Education Study Program, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, East Java, Indonesia
[3]Agribusiness Study Program, Faculty of Agriculture, Universitas Wahid Hasyim, Indonesia,

Abstract. Sustainable food security is a major challenge in tropical regions facing the pressures of population growth and climate change. Freshwater snails (*Pila ampullacea*), abundant in Lake Rawapening, Central Java, Indonesia, have the potential to become a local food source due to their nutritional content essential for body metabolism. This article is a literature review with a narrative approach. This approach was chosen because it allows the synthesis of diverse literature related to freshwater snails, including nutritional content, ecology, food, and processed products. Literature was collected from various sources such as the Scopus database, Google Scholar, and Web of Science. The keywords used in the literature search were *P. ampullacea* and nutrition, nutrition, food, and ecological risks. The inclusion criteria were studies on nutritional composition, population distribution, food potential, ecological impacts, and risks of consumption or cultivation. Irrelevant articles were excluded. Articles used for this study were only those published between 2015 and 2025. The collected data were analyzed descriptively. From this study, it was found that freshwater snails contain 57.76% protein, 14.62% fat, and 15.3% ash. The Ca content in freshwater snail meat reaches 812 mg 100 g^{-1}, with high Fe and Zn contents, namely 102 mg 100 g^{-1} (Fe) and 12 mg 100 g^{-1} (Zn). Freshwater snail mucus contains vitamin C, which functions as an antioxidant. The nutritional profile of freshwater snails makes them potentially suitable for development as functional foods to support sustainable food security. Freshwater snails are among the biota that are vulnerable to heavy metal pollution, so appropriate strategies are needed to maintain the health of their habitat to ensure the safety of this species.

Corresponding author:* rosalinapermatasari@unesa.ac.id

1 Introduction

Food security is a major issue at the national and global levels, especially for developing countries like Indonesia. Population growth, extreme climate change, and widespread environmental degradation have reduced food availability [1]. This situation demands diversification of natural resources to meet the need for nutritious and affordable food. Efforts can be made to utilize the potential of underutilized local resources, including freshwater biota. Freshwater snails (*Pila ampullacea*) are a candidate species for food with their high nutritional content, making them a potential source of protein to support local food security [2]. Freshwater snails live in freshwater habitats such as rivers, swamps, rice fields, and lakes, including Lake Rawapening in Central Java, Indonesia. They are mollusks of the gastropod class [3]. Ihsani et al., (2020), in their research, showed that freshwater snails have potential as a functional food ingredient, with antioxidant activity that can add value to processed food products. Rice field snails also contain vitamin C, which plays an important role in the body's metabolic processes [4]. The application of technology and innovation in developing processed food products made from freshwater snails has the potential to increase economic value and food diversification in the community. Freshwater snails are rich in nutrients such as protein, vitamins, minerals, and other bioactive compounds that can be processed into various functional food products and ready-to-eat foods.

The use of freshwater snails as a local food source must consider aspects of ecosystem sustainability and resource conservation in the Lake Rawapening area. Wild capture of freshwater snails must be controlled and non-exploitative to ensure the sustainability of this biota. Furthermore, water quality monitoring is necessary to ensure the natural habitat remains intact and prevent damage or pollution that could endanger the Lake Rawapening ecosystem. With the right approach, freshwater snails not only have the potential to increase local food security but also support the community's economy through the development of functional foods based on local resources [5].

Based on these considerations, this study aimed to examine the nutritional potential of freshwater snails, abundant in Lake Rawapening, and to evaluate their role in supporting sustainable food security. We also expect this study to serve as a reference for future research in tropical regions with similar ecosystems.

2 Methodology

This study uses a narrative approach to assess the nutritional potential of freshwater snails from Lake Rawapening and their relevance to sustainable food security. This narrative approach was chosen because it allows for the synthesis of diverse literature related to freshwater snails, covering nutritional content, ecology, food, and processed product development. Literature was collected from various sources, including the Scopus database, Google Scholar, Web of Science, and other relevant scientific sources, using keywords related to *P. ampullacea* and nutrition, food utilization, and ecological risks. Inclusion criteria for the literature collection included studies on nutritional composition, population abundance and distribution, food potential, ecological impacts, and risks of consumption or cultivation. Publications that were irrelevant or discussed other species were excluded. All literature used in this study was limited to those published between 2015 and 2025. The collected data were then analyzed descriptively using a narrative approach in accordance with international review guidelines [6], allowing for a comprehensive synthesis of diverse literature while providing a comprehensive overview of the nutritional potential of freshwater snails and their implications for local food security sources.

3 Result and Discussion

The results of the literature study related to freshwater snails are discussed in five sub-chapters, which include the biological characteristics and distribution of freshwater snails (1); nutritional composition and bioactive content (2); the role of freshwater snails in sustainable food security (3); the risks and challenges in utilizing freshwater snails as a food source (4); and the prospects for developing freshwater snails as a food source (5). The discussion of each subchapter is presented comprehensively as follows:

3.1. Biological Characteristics and Distribution

The freshwater snail (*Pila ampullacea* Linnaeus, 1758) belongs to the Ampullariidae family. The biological characteristics of this freshwater snail of the genus Pila (Figure 1) include a large, globose shell with a short, almost flat spine. This freshwater snail has a convex shell whorl with a smooth, shiny surface, ranging in color from brownish green or olive green to black with long, longitudinal stripes. Its width and length range from 45 to 80 mm and 55 to 86 mm, respectively. This freshwater snail has a wide and deep opening at the base of its shell (*umbiculus*) compared to other snail species. Its shell cover (*operculum*) is thick and hard, capable of closing the shell tightly. This species has a concentric pattern on the outer surface and a shiny white interior. The inner lip of the shell has a white color and a purple and white striped alternating pattern [7].

a b

Fig. 1. Freshwater mussel (*Pila ampullacea* Linnaeus, 1758): whole species with shell (a); freshwater snail meat (b) [personal document]

The species *P. ampullacea* is very common in tropical freshwater bodies worldwide [7]. Freshwater snails are also evenly distributed in Southeast Asian countries, including Indonesia, Thailand, Malaysia, the Philippines, and Laos. In Indonesia, freshwater snails from the genus Pila are found in various freshwater habitats, including rivers, swamps, lakes, and rice fields. Lake Rawapening, located in Semarang Regency, Central Java Province, Indonesia, is a freshwater ecosystem that is home to various flora and fauna, including freshwater snails [8]. Lake Rawapening covers an area of approximately 2,670 hectares with lush aquatic vegetation, providing an ideal habitat for the growth and development of freshwater snails. In Lake Rawapening, this species is found living in shallow waters, attached to aquatic vegetation such as water hyacinth, rice fields, and river estuaries that irrigate the lake.

The abundance of freshwater snails in Lake Rawapening makes them a potential and strategic alternative protein source for local communities, especially those with limited access to other animal proteins. The abundance of freshwater snails is influenced by environmental factors such as the physicochemical quality of the water (e.g., temperature and pH) and the availability of food for their growth. Habitats with calm water flow and abundant aquatic vegetation significantly support the growth and reproduction of freshwater snails.

The ecological conditions and various challenges faced require the development of sustainable and environmentally friendly strategies for the utilization of freshwater snails. These efforts play a crucial role in supporting local food security while maintaining the balance of the aquatic ecosystem in Lake Rawapening, ensuring its productivity and sustainability.

3.2 Nutritional Composition and Bioactive Content

Freshwater snails have a nutritional composition and bioactive content (Table 1) that offer significant potential as an animal-based food source to meet the community's nutritional needs. The protein concentration in freshwater snail meat reaches 57.76%, making it an aquatic protein source with high biological value. This high protein content is comparable to that of other mollusks and fish for consumption. Protein is essential for building structural and metabolic components of the body, as well as providing essential amino acids required for various physiological functions. Protein also functions not only as an energy source but also plays a role in the synthesis of enzymes, hormones, antibodies, and various bioactive molecules essential for maintaining metabolic balance and cellular immunity [9].

Table 1. Nutritional content and bioactive components of freshwater snails

Component / Nutrient	Content / Description	Analytical Method	Reference
Moisture content	11.05%	Oven drying method	[10]
Protein	57.76%	Kjeldahl method	
Fat	14.62%	Soxhlet extraction	
Carbohydrate	0.68%	By difference	
Ash (total minerals)	15.3%	AOAC method	
Vitamin C (100% snail mucus)	2.372 mg L^{-1}	UV–VIS spectrophotometry (260 nm)	[4]
Total peptides (bromelain hydrolysate)	10.89 ± 0.09 mg mL^{-1}	Folin–Phenol method	[11]
Total amino acids	95.34 ± 0.12 ppm	Moore–Stein method	
Degree of hydrolysis (DH, bromelain)	56.56 ± 1.65%	Lowry protein assay	
Calcium (Ca)	812 mg 100 g^{-1} (snail meat)	Nutritional profile	[12]
Iron (Fe)	102 mg 100 g^{-1}	Nutritional profile	
Zinc (Zn)	12 mg 100 g^{-1}	Nutritional profile	
Magnesium (Mg)	High concentration; contributes to antioxidant and anticancer activities	AAS / literature synthesis	

Freshwater snails have a fat content of 14.62%, which contributes as an important energy provider through essential fatty acids that support cellular and metabolic functions. Fat originating from iron (Fe) and in organisms functions in the formation of cell membranes, transport of fat-soluble vitamins, helps regulate cell signals, and produces eicosanoids . The high ash content of 15.3% is an indicator of substantial macromineral and micromineral accumulation in freshwater snail tissue, including magnesium (Mg), calcium (Ca), iron (Fe), and zinc (Zn). The Ca content in freshwater snail meat reaches 812 mg 100 g^{-1}, with high Fe and Zn contents, namely 102 mg 100 g^{-1} (Fe) and 12 mg 100 g^{-1} (Zn) [12]. The content of various minerals is very important in physiological mechanisms such as Ca, which plays a role in bone growth and strength, and Fe and Zn, which play an important role in the process of hematopoiesis and the immune system. Mg contributes to maintaining enzymatic stability and preventing oxidative stress in biological tissues. This nutritional profile strongly supports

the potential of freshwater snails as a functional food source, as they can meet the nutritional needs of the community.

Freshwater snails possess bioactive compounds with therapeutic potential. Their mucus contains vitamin C, reaching 2,372 mg/L in 100% pure mucus without any additives, which functions as a natural antioxidant to ward off free radicals and strengthen the immune system [4]. Peptides produced from the protein hydrolysis process of freshwater snails exhibit significant biological activity, including antioxidant and antimicrobial activity, and also help enhance the umami taste. Peptides resulting from the hydrolysis of snail protein reached 56.56% (Rosida et al., 2024), indicating significant biological activity in enhancing the umami taste. Various studies on other snails also show that peptides provide antimicrobial and antioxidant effects .

The complex nutritional content of freshwater snails, encompassing macronutrients, micronutrients, peptides, and bioactive compounds in their mucus, has made this species a multi-purpose food source and bioactive ingredient. Freshwater snails have significant potential for development in the fields of functional foods and biopharmaceuticals. This is well-founded, as optimizing the utilization of freshwater snail resources can support the One Health concept, which integrates nutrition, ecology, and human health in a sustainable manner.

3.3 Role in Sustainable Food Security

Utilizing freshwater snails as a local food source can strengthen sustainable food security in tropical regions such as the area around Lake Rawapening. The nutritional profile of freshwater snails is high in protein and essential amino acids for physiological mechanisms such as enzyme and hormone synthesis, which are often limited [10]. From an economic and accessibility perspective, freshwater snails are easily found in aquatic ecosystems such as swamps, rivers, rice fields, and lakes, thus offering an affordable alternative to poultry and beef, whose prices and availability fluctuate. Research on freshwater snails generally indicates that this species has a high protein content and essential minerals, thus complementing the nutritional needs of local food-based communities. Furthermore, consuming freshwater snails can also reduce dependence on imported animal protein sources.

Beyond nutritional aspects, freshwater snails have the potential to be a local commodity that can empower communities. Processed products based on freshwater snails, such as protein flour, snacks, and treats, can provide added value and create business opportunities for communities around lakes. This approach is highly relevant to the principles of sustainable food development, which integrates economic, social, and environmental aspects [10].

Harvesting freshwater snails for food also has positive ecological implications if carried out sustainably. Appropriate cultivation techniques and natural habitat management can help maintain the balance of freshwater ecosystems, prevent environmental damage, and reduce pressure on fish species and other sources of animal protein. From this description, it is clear that freshwater snails not only contribute to local food security but also play a role in freshwater resource conservation [13].

3.4 Risks and Challenges of Utilization

Despite the various advantages and nutritional potential of freshwater snails in supporting food security, they still face a number of risks and challenges to ensuring ecosystem sustainability and food security. The risks facing waters include pollution from various human activities, including agriculture, domestic, industrial, and other activities, one of which is heavy metal contamination. This heavy metal contamination can accumulate in

freshwater biota, including freshwater snails. Several studies have shown that freshwater snails can accumulate heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg), which can pose health risks if consumed excessively . Therefore, regular monitoring of water quality and heavy metal content in freshwater snails is crucial for food product development.

Ecological pressures also pose a significant challenge to the utilization of freshwater snails. The invasion of non-native freshwater snails, such as *Pomacea canaliculata*, has disrupted the population balance of the freshwater snail species *P. ampullacea* (the species discussed in this article) in Lake Rawapening. This situation significantly impacts local food stocks if utilization is not managed sustainably. Ecosystem damage due to eutrophication, sedimentation, and pesticide application in agricultural lands around the lake also negatively impacts the reproduction and survival of freshwater snails [13].

Social and economic challenges also arise, particularly in the utilization of freshwater snails as a commodity. Public perception of freshwater snails as a traditional food product tends to be low among some consumer groups, necessitating increased education and promotion efforts to ensure widespread acceptance of processed products [2]. Furthermore, the success of freshwater snail utilization is also influenced by the availability of effective and efficient processing technology, product shelf life, and supportive market access. A strategic and integrated strategy is needed, encompassing lake ecosystem management, monitoring aquatic environmental quality, sustainable cultivation, and innovation in processed products that are safe and attractive to consumers. This approach is crucial for minimizing ecological and health risks while also increasing the economic value of freshwater snails as a safe and sustainable local food commodity risks while.

3.5 Development Prospects and Recommendations

The development of freshwater snails as a food source has positive prospects, both in terms of nutrition, economics, and environmental sustainability. From a nutritional perspective, freshwater snails offer high-quality protein, supported by essential macronutrients to meet community nutritional needs, especially in areas with limited access to conventional animal protein sources [2], such as poultry, beef, lamb, or expensive fish. This potential can be enhanced through the application of technology and innovation in processing freshwater snail products into protein flour, snacks such as chips, and ready-to-eat products, allowing for food diversification and increasing economic added value (Figure 2).

Fig. 2. Processed foods from freshwater snails: crackers (a) [10]; satay (b) [14]; and Stir-fry (c) [15].

From an economic perspective, the utilization of freshwater snails can be achieved through empowering local communities through the development of small and medium-sized enterprises based on local aquatic resources. This step aligns with the principles of sustainable food development, which integrates three main aspects: economic, social, and environmental. Productive utilization of freshwater snails can drive the development of ecotourism based on aquatic ecosystem conservation, which can add economic and social

value [13]. From an environmental perspective, controlled freshwater snail cultivation can support lake ecosystem balance, prevent habitat destruction, and reduce pressure on fish populations and other protein sources. An appropriate management strategy is required, including monitoring water quality, regulating population density, and preventing the risk of invasive species that could threaten other species in the ecosystem.

Optimizing freshwater snail utilization requires an integrated strategy that includes (1) innovation in developing sustainable freshwater snail cultivation in Lake Rawapening and the surrounding waters; (2) application of technology and innovation in processing freshwater snails into nutritious, attractive, and long-storage food products; and (3) regular monitoring of water quality and heavy metal content in freshwater snails. (4) improving educational and promotional strategies for the community to increase acceptance and demand for processed freshwater snail products; and (5) further research on bioactive compounds and the potential for functional foods in a comprehensive manner. Implementing an integrated strategy for freshwater snails will increase the opportunity to become a sustainable food solution that benefits local nutrition, economy, and ecology.

4 Conclusion

The abundant freshwater snails in Lake Rawapening possess nutritional value, including high protein, macronutrients, and bioactive compounds, which have the potential to be developed as functional foods to support sustainable food security. Optimizing the utilization of freshwater snails requires an appropriate and integrated strategy, encompassing ecosystem management, environmentally friendly cultivation methods, water quality monitoring and pollution risk mitigation, the application of technology and product processing innovation, and education to increase added value and consumer acceptance. Through this approach, freshwater snails can contribute to food diversification, local economic empowerment, and freshwater ecosystem preservation and serve as a basis for further in-depth research in similar tropical waters.

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