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THE POTENTIAL OF ASIAN SWAMP EEL (MONOPTERUS ALBUS) AS A FUNCTIONAL FOOD FOR ANEMIA : A SCOPING REVIEW

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ABSTRACT
Anemia remains a significant global health issue. One of the causes is the inadequate of protein and iron intake. So that, erythropoiesis in body less than optimal. Asian swamp eel (Monopterus albus) can potentially be a functional food that can be included food products because it is rich in nutriens that have a potential impact on anemia. Objective: This scoping review aim was to explores the nutritional composition of Asian swamp eel and its effects on anemia, focusing on mechanisms by which its nutrients influence anemia biomarkers. Methods: This scoping review was performed using the 5-step Arkeys and O'Malelev framework and reported according to PRISMA ScR. Two electronic databases were searched systematically. Article are included if eligible. Results: The result was descriptive and qualitative analyses. A total of 1,245 articles were collected. Key findings suggest that the high protein and vitamin content in eel can significantly improve hemoglobin levels and other anemia indicators. Conclusions: This review highlights the potential of incorporating eel into dietary interventions as a sustainable and effective approach to mitigating anemia prevalence.

Keywords: anemia; asian swamp eel; functional food

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INTRODUCTION

Anemia remains a significant global health issue, affecting over 1.7 billion people worldwide, particularly women and children (World Health Organization (WHO), 2021). It is characterized by reduced hemoglobin levels, leading to diminished oxygen transport and adverse health outcomes such as fatigue, reduced cognitive performance, and increased maternal and child morbidity (McLean et al., 2015). Addressing anemia requires interventions that are both effective and culturally acceptable, particularly in regions with high prevalence rates.One of the causes anemia are inadequate of protein and iron intake (Krisnasary, A. & Yulianti, 2023). Inadequate protein and iron intake can have an impact on suboptimal process of red blood cell formation, disrupted iron transport and hemoglobin synthesid, resulting in iron deficiency anemia (Camaschella, 2015). Anemia is characterized by hemoglobin levels in women <12 g/dl and <13 g/dl in men (WHO, 2024). In addition, physically signs and symptoms who suffers from anemia looks pale, weak and tires easily (Sriningrat et al., 2019).

Among the dietary strategies proposed, the inclusion of nutrient-dense, locally available foods has shown promise. Asian swamp eel (Monopterus albus), a freshwater species rich in iron, protein, and essential vitamins, has been identified as a potential dietary supplement to combat anemia (Zhang et al., 2021) . Known for its bioavailable iron content, the eel offers an

alternative to conventional iron supplementation, which often faces challenges such as poor compliance and side effects (Kumar et al., 2022).The nutritional profile of Asian swamp eel is notable for its high levels of heme iron, which is more readily absorbed than non-heme iron from plant sources (Lynch & Cook, 2020). According to the Indonesian Food Composition Table (TKPI) (2020), the protein content of eel per 100 grams is 14.6 grams and iron (Fe) 1.5 mg (Kemenkes RI, 2020). These attributes make it a valuable candidate for fortifying traditional diets in anemia-prone populations. Despite these benefits, the application of Asian swamp eel in anemia management has not been extensively studied. Research is needed to elucidate its effects on anemia biomarkers, such as hemoglobin, serum iron, ferritin, and mean corpuscular volume (MCV). Moreover, understanding the mechanisms by which eel nutrients influence anemia can guide the development of targeted nutritional interventions (Sharma et al., 2022).This scoping review aims to explore the potential and corporate of Asian swamp eel incorporation into functional food on anemia. By analyzing recent studies, this review seeks to provide a comprehensive understanding of the nutritional benefits of eel and its potential mechanisms of action in anemia prevention and treatment.

METHOD

Review in this study used a scoping review design. The review was carried out to summarize, map, and present the findings of research paper using descriptive approaches. Validation was performed using the 5-step Arkeys and O'Malelev framework and reported according to PRISMA ScR (priority reporting item for systematic review and a meta-analysis extension for scoping reviews) (Westphaln et al., 2021). The studies included in this review were selected based on their focus on the nutritional composition of Asian swamp eel and its impact on anemia biomarkers. Articles published between 2014 and 2024 were identified through systematic searches of databases such as PubMed and Science Direct. The language restrictions to English articles. Eligibility criteria included studies on human or animal models, with outcomes related to hemoglobin levels, serum iron, transferrin and ferritin. Articles were obtained from two electronic databases, such as PubMed and Science Direct to identify studies in the last ten years between January 2014 and January 2024. Two databases were chosen because they all have a nutrition and medical sciences concentration and fit the study's objectives.

The search strategy was designed to comprehensively identify relevant studies on Asian swamp eel and its effects on anemia biomarkers. A systematic search was conducted using key databases (Science Direct and PubMed) with primary keywords including "Asian swamp eel" OR "Monopterus albus" OR "rice field eel". These terms were combined using Boolean operators with anemia-related keywords such as "anemia" OR "anaemia" OR "hemoglobin" OR "haemoglobin" OR "iron deficiency" OR "blood markers" OR "hematological parameters". The search was further refined by applying specific filters to ensure the most relevant and current evidence was captured. These filters included a publication date range of 2014-2024 and language restrictions to English articles. Article types were limited to research articles and reviews to maintain the quality of evidence.

Data were extracted using a standardized form, which included information on study design, population, intervention details, and outcome measures. Nutritional analysis of the eel and its impact on anemia biomarkers were the primary focus. Key variables such as iron content, hemoglobin changes, and dietary patterns were systematically recorded for analysis. Descriptive and qualitative analyses were performed to synthesize findings from the selected studies. A thematic approach was applied to identify common mechanisms by which Asian swamp eel nutrients affect anemia biomarkers. Results were presented in tabular format to summarize key findings and trends across studies.

RESULT

Selection of sources evidences

This comprehensive search strategy resulted in the initial identification of 1,245 articles (Science Direct: n=680; PubMed: n=565), which were then subjected to the systematic screening process according to the predefined inclusion and exclusion criteria. The systematic analysis of selected studies on Asian swamp eel nutrition and its effects employed both descriptive and qualitative methodologies to ensure comprehensive understanding of the research findings. Each study was carefully examined for key variables including experimental design, population characteristics, intervention methods, and measured outcomes, with particular attention paid to the statistical significance of reported results and the reliability of the methodological approaches used by the researchers.

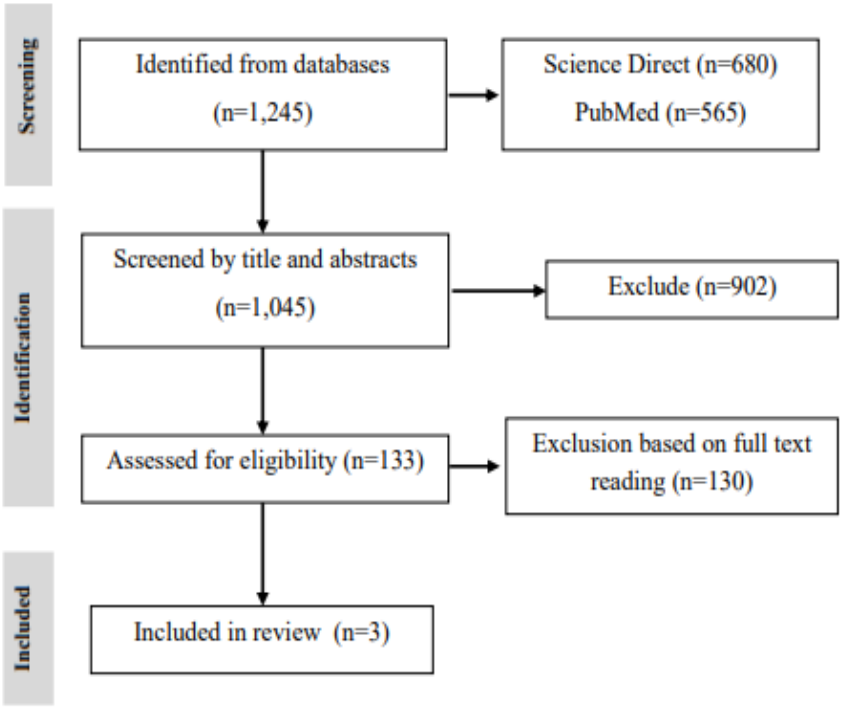

Figure 1. PRISMA flow diagram

The analytical process incorporated multiple stages of data extraction and synthesis, focusing on identifying common themes and patterns across the selected studies while maintaining attention to the unique contributions of each research effort. The extraction process paid particular attention to the specific nutrient profiles identified, bioactive compounds isolated, and the physiological responses observed in various experimental conditions, creating a comprehensive dataset that allowed for meaningful comparisons across studies.The synthesis phase employed a structured approach to organizing and interpreting the collected data, with emphasis on establishing connections between different studies' findings and identifying potential mechanisms of action. This process included careful consideration of both primary outcomes and secondary findings, ensuring that subtle but potentially significant effects were not overlooked in the final analysis.

Comprehensive Findings Analysis

The analysis of Sabrina et al. (2022) revealed groundbreaking insights into the bioactive peptide composition of combined eel and soy-based tempe flour, demonstrating significant potential for nutritional enhancement in malnourished conditions. The researchers identified multiple peptide sequences with biological activity, each showing promising effects on

various nutritional biomarkers such as hemoglobin, suggesting a synergistic effect when these protein sources are combined in specific ratios. Building upon these findings contributed valuable data through their preclinical trial examining the effects of eel and tempe composite flour supplementation on rats maintained on a restricted protein diet. Their results showed significant improvements across multiple nutritional status biomarkers, providing strong evidence for the potential therapeutic applications of this combination in addressing protein malnutrition and related nutritional deficiencies (Mentang et al., 2023). The most recent contribution by Herawati et al. (2022) expanded our understanding by examining the specific effects of eel cookie supplementation on hemoglobin levels of pregnant women. Their comprehensive study indicated that consumption of eel cookies and IFAS for 1 month could increase the mean hemoglobin levels of pregnant women by 1.69 g/dL, while in the control group, the increase was only 0.69 g/dL. Based on the statistical analysis, there was a significant difference in the protein intake as well. In addition, this study founded that compliance with consuming iron supplementation has an impact on preventing anemia in pregnant women (Fitri et al., 2015).

Table 1.
Mapping, synthesis, and analysis

Title	Study type	Population	Nutritional Focus	Key Findings	Analysis	Study
Bioactive Peptides Identification and Nutritional Status Amelioratin g Properties on Malnourishe d Rats of Combined Eel and Soy-Based Tempe Flour	Post-test only with control design	Malnourish ed rats	Combined eel and soy-based tempe flour	Identified bioactive peptides with nutritional benefits (protein serum, hemoglobin and IGF-1)	Combined eel and soy-based tempe flour contains bioactive peptides which play a role in improving serum protein and hemoglobin.	(Sabrina et al., 2022)
Effect of Eel and Tempe Composite Flour Supplement ation on the Nutritional Status Biomarkers of Rats with a Restricted Protein Diet : Data From a Preclinical Trial	Post-test only with control design	Rats with restricted protein diet	Eel and tempe composite flour	Improved nutritional status biomarkers	Eel and Tempe Composite Flour contains protein and vitamin B9 which plays a role in the synthesis of purines and thymidylate to optimize of erythropoiesis..	(Mentang *et al*., 2023)
Effect of Eel Cookie Supplement ation on the Hemoglobin Status of Pregnant Women with Anaemia: A Pilot Study	Pre-test–post-test design	Pregnant women with Anemia	Eel Cookie	Supplementation with eel cookies and IFAS for 1 month could improve the hemoglobin status in pregnant women with anaemia.	Eel cookies have an effect on increasing hemoglobin status because they contain high levels of protein and vitamin A which play a role in iron absorption and also optimize of erythropoiesis.	(Herawati et al., 2022)

DISCUSSION

Nutritional Properties and Bioactive Components

The nutritional profile of Asian swamp eel, particularly when combined with complementary protein sources, has emerged as a promising area of research with significant implications for nutritional intervention strategies. Initial research by Sabrina et al. (2022) demonstrated that the combination of eel with soy-based tempe flour produces a unique profile of bioactive peptides. All bioactive peptides each with specific physiological effects that contribute to improved nutritional status one of which is hemoglobin as a biomarker for anemia. Their detailed analysis revealed multiple peptide sequences with potential therapeutic applications, suggesting a more complex and beneficial nutritional profile than previously understood (Sila & Bougatef, 2016).Further investigation by Mentang et al. (2023) expanded our understanding of these nutritional properties through their preclinical trial examining the effects of eel and tempe composite flour supplementation. Their research provided crucial evidence for the practical applications of these nutritional components that is protein and vitamin B9 which plays a role in the synthesis of purines and thymidylate to optimize of erythropoiesis, demonstrating significant improvements in various biomarkers of nutritional status one of shinch is hemoglobin among subjects with protein-restricted diets. The study's comprehensive approach to measuring multiple biomarkers provided valuable insights into the mechanisms through which these nutritional components exercise their beneficial effects.

The recent work by Herawati et al. (2022) has added another layer of understanding to the nutritional properties of Asian swamp eel, particularly through their investigation of eel cookies. Their findings revealed previously unknown aspects of how specific dietary components that is higher protein and vitamin A can enhance both the nutritional value and physiological function of eel-based foods, suggesting new possibilities for optimizing the nutritional benefits of eel consumption through targeted dietary modifications.

Metabolic and Physiological Effects

The investigation of metabolic and physiological effects has revealed complex interactions between eel-derived nutrients and various biological systems. Sabrina et al. (2022) provided foundational insights into how bioactive peptides from combined Asian swamp eel and tempe flour. Study result from Laily et al., (2023) about consumption of the test product containing bioactive peptide of less than 15 kDa for 14 days can increase the serum iron and Increased levels of iron stored in the body can be detected by increasing serum ferritin levels. Biopeptides from protein hydrolyzate could increase the bioavailability of minerals. The size of the amino acids, the amino acid sequence, and the presence of specific amino acids affect the chelating ability and iron bioavailability (Susanti et al., 2020). The mechanism by which bioactive peptides increase in iron absorption is by keeping the iron dissolved, reducing ferric ions to ferrous, and increasing iron transport through the cell membrane in the gastrointestinal tract (Li et al., 2017). The work of Mentang et al. (2023) significantly advanced our understanding of these effects through their careful examination of nutritional status biomarkers in response to supplementation. Their research revealed complex interactions between the supplemented nutrients and various physiological systems, demonstrating how these interactions contribute to improved nutritional status and overall health outcomes. Their research provided crucial evidence for the practical applications of these nutritional components that is protein and vitamin B9 which plays a role in the synthesis of purines and thymidylate to optimize of erythropoiesis. Erythropoiesis is dependent on vitamin B9 (folic acid), vitamin B12 (cobalamin) and iron, and mainly regulated by erythropoietin (EPO), which is produced in the kidney and to a lesser extent in the liver in response to hypoxia (Lanser et al., 2021). In healthy individuals a feedback loop regulates EPO synthesis to

maintain production of erythrocytes equable to erythrocyte destruction to sustain sufficient tissue oxygenation (Kuhrt & Wojchowski, 2015).

The main mechanism associated with anemia is iron. According to the Indonesian Food Composition Table (TKPI) (2020), the iron (Fe) content in eel is 1.5 mg per 100 grams (Kemenkes RI, 2020). The iron contained in eel is heme iron which has an absorption rate of 15-35% higher than non-heme iron(Abramowski et al., 2014). Iron absorption occurs in the intestine and begins with the reduction of ferri to ferro by ascorbic acid and duodenal cytochrome B (DcytB) or ferri reductase on the surface of erythrocytes. Ferri attaches to enterocytes and the ferro formed will be absorbed through DMT 1. Heme iron is absorbed into enterocytes by heme carrier protein 1 (HCP-1). The distribution of iron from the enterocyte cytosol into the blood through the basolateral membrane is mediated by ferroportin found in all types of cells. Furthermore, iron is oxidized (Fe^{3+} to $Fe^{2+)}$ by haphaestin before binding to transferrin in plasma and circulating in the blood (Coad and Pedley, 2014).

Protein as a macronutrient has a role in anemia as a transport protein. Transport proteins are functional groups of proteins that act as carriers of substances, such as vitamins, minerals and other nutrients. One of the transport proteins, namely globulin, is a heterogeneous group of proteins with various transport functions. Most globulins are synthesized in the liver, especially alpha and beta globulins through the process of gene transcription, translation and post-translational modification which is the process of adding sugar or phosphate groups to form functional globulins. The transporter proteins that play a role in anemia are the α2-globulin group such as haptoglobin, which is a hemoglobin transporter that is released from damaged erythrocytes and transferrin, which is a type of β-globulin that plays a role as an iron transporter (Gropper et al., 2018).Herawati et al. (2022) made substantial contributions to our understanding of specific metabolic effects through their investigation of eel cookies suplementation. Their research revealed detailed mechanisms by protein intake in the intervention group could be the reason for the greater improvement in hemoglobin status. The content of fish protein in the cookies, as well as beef protein according to Geissler and Singh, was able to improve the absorption of non-heme iron, resulting in increased hemoglobin levels (Geissler & Singh, 2011).

Eel cookies had a high vitamin A content, which is essential in the metabolism/absorption of iron. Vitamin A deficiency often occurs simultaneously with iron deficiency anemia, this is related to the interaction between vitamin A and iron. Iron metabolism disorders due to vitamin A deficiency are triggered through the mechanism of cytokine release. So that, hepcidin production by the liver increases. Increased hepcidin will reduce circulating and stored iron, reduce erythropoietin regulation, decrease hemoglobin production and then anemia. In addition, vitamin A deficiency affects the expression of iron regulatory protein 2 (IRP2) which then affects the expression of intracellular iron metabolism genes (Mejia and Erdman, 2025). The iron level in the human body is regulated mainly by absorption, and there is no physiological mechanism for iron excretion. Vitamin A affects iron metabolism by promoting erythropoiesis and the release of iron from ferritin stores (Michelazzo et al. 2014).

Future Research Directions

The current state of research on Asian swamp eel nutrition has opened numerous promising avenues for future investigation, particularly in the areas of bioactive compound identification and characterization. Building on the foundational work of Sabrina et al. (2022), there is a clear need for more detailed analysis of the specific mechanisms through which identified bioactive peptides exercise their effects on nutritional status and metabolic function. This research direction could lead to more targeted and effective nutritional interventions based on

eel-derived compounds.The findings of Mentang et al. (2023) suggest the importance of conducting more extensive clinical trials to validate the observed effects of eel-based supplementation in different populations and under various conditions. Future research should focus on optimizing supplementation protocols, understanding individual variations in response to supplementation, and developing more effective delivery methods for eel-derived nutritional compounds. These studies would benefit from longer observation periods and larger sample sizes to better understand the long-term effects and safety profiles of eel-based interventions.Herawati et al. (2022) findings regarding consumption of eel cookies and IFAS for 1 month could increase the mean hemoglobin levels of pregnant women. Future studies should examine additional dietary modifications that could enhance the health benefits of eel consumption, while also investigating potential synergistic effects between different dietary components. This research direction could lead to more effective strategies for optimizing the nutritional and therapeutic value of eel-based foods.

CONCLUSION

This scoping review highlights the potential of Asian swamp eel as a functional food for addressing anemia. The nutritional composition of the eel, particularly its high protein, vitamin and mineral content, offers a natural and effective means of improving anemia biomarkers such as hemoglobin serum iron and ferritin levels. Additionally, its integration into traditional cuisines makes it a culturally feasible and cost.

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