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Feeding Preferences of *Chanos chanos* Cultivated in an Urban Area

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Abstract. The aquaculture area in the Gunung Anyar region, affected by domestic and industrial pollution, presents challenges in sustaining natural food resources for milkfish cultivation. This research aims to evaluate the feeding preferences of milkfish (*Chanos chanos*) in this urban aquaculture setting, focusing on their dependency on phytoplankton, zooplankton, and other resources. Stomach content analysis was performed using the Gastro-somatic index, preponderance index, and numerical diet composition index. The data obtained were then analyzed descriptively and quantitatively. Findings indicate a strong preference for phytoplankton (85%), with Chlorophyta as the predominant species (54%). The results highlight the planktivorous feeding habits of milkfish, classified as high-intensity feeders (Gastro-Somatic Index: 1.86–2.90). The feeding preference for phytoplankton stems from a lack of zooplankton due to the presence of multiple harmful algal bloom (HABs species. These findings underscore the need to manage water quality and natural food availability to sustain milkfish aquaculture productivity in urban areas. This research promotes the United Nations Sustainable Development Goals (SDGs), specifically enhancing SDG 14 (Life Below Water) through the evaluation of estuarine biodiversity, advancing SDG 2 (Zero Hunger) by ensuring urban aquaculture productivity, and supporting SDG 11 (Sustainable Cities and Communities) by developing resilient urban food systems in the face of industrial limitations.

Keywords: aquaculture; dietary diversity; feeding preferences; natural food; urban fisheries.

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INTRODUCTION

As one of Indonesia's largest cities, Surabaya strongly influences its coastal regions, which host diverse fishery resources and ecosystems with excellent potential (Taufiqurrahman et al., 2023). One of these is milkfish farming, which accounts for a significant total of 5,438.93 tons out of 7,932.84 tons produced in Surabaya's brackish water (Rosyidah et al., 2021). Milkfish are omnivores (Hortillosa et al., 2022) and favor plankton, which consists of phytoplankton and zooplankton as their natural food (Arfiati et al., 2023). Natural food refers to nutrients that are readily available in aquatic ecosystems (Fittrie & Rosidah, 2023). Live or natural food offers a notable advantage compared to prepared diets, helping fish larvae grow quickly. The movement of live feed stimulates the natural feeding instincts of fish larvae and prrovides a richer nutritional composition because it contains exogenous enzymes that assist digestion and is easy to handle (Rahman et al., 2023). However, due to pollution from cities, industries, and agricultural areas, aquatic biodiversity is continuously declining in both freshwater and marine ecosystems (Irfan & Alatawi, 2019).

Rapid industrialization and the careless use of chemical fertilizers and pesticides in agriculture are reducing marine biota and contaminating surface water with chemicals (Heneash et al., 2021). Water pollution, such as heavy metal contamination, pesticides, household waste, and insecticides from agricultural activities, can cause acute and chronic effects, leading to the death of aquatic organisms (Malik et al., 2020). These can act as stress factors and impact the phytoplankton community, change the phytoplankton physically and morphologically, affect the phytoplankton characteristics, and induce the generation of reactive oxygen species (ROS) in microalgae (Ismail & El Zokm, 2023). Moreover, water pollution can cause the death of copepods and reduce the number of zooplankton in polluted ecosystems (Bowszys et al., 2020).

Surabaya, as a metropolitan city, features an estuary that serves as a basis for its community. However, Surabaya's estuaries are declining due to rising populations that are increasing water pollution (Rudianto et al., 2021). This condition is suspected of affecting plankton diversity (Aida et al., 2022). In addition, the Gunung Anyar River is included in the East Coast of Surabaya, where it receives estuarine pollution from the upstream tributaries and large rivers (Hendrasarie & Kartika, 2024). There are few opportunities for direct observation of feeding behavior and prey selection in studies of aquatic species such as fish. Stomach contents analysis is thus a significant and ubiquitous method for extensive research of diet composition and feeding ecology (Amundsen & Sánchez-Hernández, 2019). In this study, special emphasis is placed on investigating the feeding preferences of milkfish, particularly how urban pollution in Gunung Anyar, Surabaya, influences their reliance on specific food sources.

The purpose of stomach content analysis is to provide information on food ingestion and provide dietary information at the individual and population levels (da Silveira et al., 2020), which can later be used to identify the feeding preferences (Mumby et al., 2018). These aquaculture systems in urban areas face unique challenges due to pollution and urbanization. Understanding these challenges is critical for adapting cultivation practices to maintain sustainable fish farming in such environments. Based on this background, an evaluation of the feeding preferences for milkfish cultivated in the Surabaya urban area, located in Gunung Anyar pond, will be conducted based on stomach content analysis. This research is essential for sustaining milkfish farming in the Surabaya urban area, as it highlights the critical role of proper nutrition in ensuring economic viability and producing high-quality, healthy fish.

METHODS

Collection of Milkfish Samples

Milkfish samples were collected from Gunung Anyar ponds (shown in Figure 1) from December 2023 to January 2024, along with water samples to measure pH, dissolved oxygen (DO), temperature and salinity. Seven replicate samples of milkfish measuring approximately 30 cm in size and ready for harvest were collected from each of the three replicate ponds per month, making a total of 42 samples of milkfish.

Preparation of Milkfish Stomach and Stomach Content Samples

Morphometric data including total length (cm) and wet weight (gr) were measured prior to dissection of milkfish samples. The stomach of each fish was removed from the coelomic cavity and preserved separately in Falcon bottles containing 10% neutral buffered formalin (de Matos et al., 2021). Each of the preserved stomach samples was wet-weighed to obtain Total Stomach Weight (TSW) (Habib & Adunga, 2021), and its contents were extracted and passed through a Whatman GF/C filter paper. The emptied stomach was rinsed in 5% formalin (Aprianti et al., 2022) and reweighed to obtain Empty Stomach Weight (ESW), which was then used to calculate the Stomach Content Weight (SCW) using the difference between TSW and ESW (van Deurs et al., 2014).

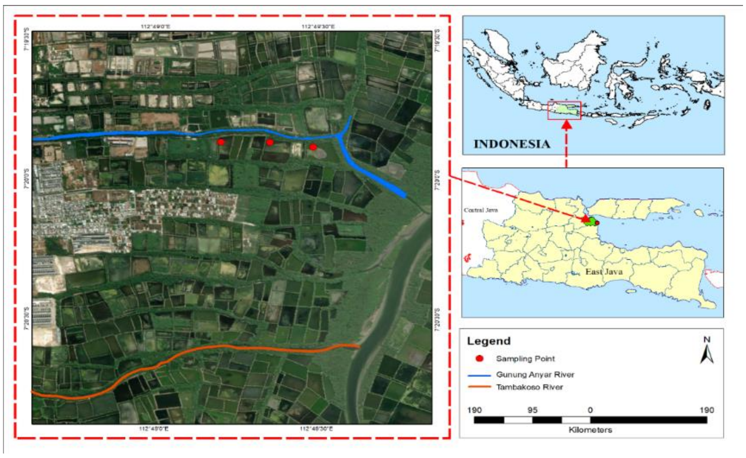

Figure 1. Sampling points of milkfish (*Chanos chanos*) in the urban area of Gunung Anyar, Surabaya, East Java, Indonesia.

Stomach Content Analysis

The identification of stomach contents aims to determine the natural diet of milkfish in Gunung Anyar Pond and classify their food by type and size. Contents of individual fish stomach samples were examined in petri dishes (Poiesz et al., 2024) prior to microscopic analysis (Olympus-SZ61-ILST). Furthermore, the stomach content sample was pipetted and placed in a Sedgewick Rafter for examination of microscopic organisms using a compound microscope (Olympus CS 21), and the organisms were counted and identified to determine their species.

Data Analysis

Gastro-Somatic Index

The Gastro-Somatic Index (GaSI) is used to measure and compare feeding intensity (food consumption) over time, as well as to determine the effects of environmental and physiological factors on feeding patterns (Roshdy et al., 2024). This index aims to observe the variation in the average stomach weight relative to the size of the fish in order to understand the fish's feeding behavior and rhythms. The formula of GaSI is presented below.

$$\text{Gastro Somatic index} = \frac{\text{Weight of gut}}{\text{Weight of body}} \times 100\%$$

Preponderance Index

The Index of Preponderance (IP) was employed to determine the most significant food species by evaluating the overall importance of each prey item through the integration of its volume and frequency of occurrence, thereby elucidating its dietary habits (Prastiwi et al., 2026).

$$\text{Ip} = \frac{\text{Vi x Oi}}{\sum \text{Vi x Oi}} \text{x}100$$

Description:

Ip : Preponderance Index

Vi : Percentage with a Single Type of Food

Oi : Percentage with Frequency of Occurrence of a Single Type of Food

N : Number of fish food organisms

Numerical Diet Composition Index

The Numerical Diet Composition Index (Cn), or the dietary composition value index, is aimed at assessing the food preferences of a particular fish species (Scholz *et al.* 2020). Data on Numerical Diet Composition Index (Cn) is used to categorize the fish feeding habits.

$$\%\text{Cn} = \frac{\text{Nj}}{\text{Np}} \text{x}100\%$$

Description:

Cn : Numerical Diet Composition Index

Nj : The number of food types of j in the stomach content.

Np : Total food quantity in the stomach content

RESULTS AND DISCUSSION

Gastro-Somatic Index

Milkfish cultured in the Gunung Anyar pond exhibited high feeding intensity with the average GaSI values of 1.86 in December and 2.90 in January. Stomach content analysis revealed a planktivorous feeding habit, with Chlorophyta dominant in December and Dinoflagellates in January. These findings align with the numerical diet composition index, indicating a strong preference for phytoplankton. Fish feeding behavior and habits vary across species and sizes (Kurbah & Bhuyan, 2018), often influenced by gape size and developmental stage (Heuvel et al., 2019), with larger individuals shifting from zooplankton to more complex prey like crustaceans and fish (Dunic & Baum, 2017).

The diversity of plankton species in milkfish stomachs remained consistent across both months, with 13 phytoplankton species identified each month. However, zooplankton diversity declined from five species in December to three in January, while individual counts showed slight variation, as shown in Table 3. In addition, the average GaSI value in January is higher compared to December, which could correlate with the rainy season. The study took place during East Java's rainy season (December–February) (Wibawanty et al., 2025), when increased rainfall boosts phytoplankton density (Frank et al., 2023). These enhancements were caused by the enrichment of allochthonous nutrient inflow, which contributed to the consistent phytoplankton availability and supported the observed feeding patterns (da Silva & Jati, 2024).

Milkfish Stomach Content

Kurbah & Bhuyan (2018) describe that fish feeding behavior is ecologically diverse, encompassing zooplankton, phytoplankton, insects, larvae, worms, and smaller fish in natural environments. Understanding these habits is essential for effective fishery management and feed formulation (Temesgen et al., 2022). In the

Gunung Anyar pond, milkfish were found to consume both natural and artificial feed, with 100% (42 fishes) of samples containing natural feed and 60% (28 fishes) containing pellets. This reflects the semi-intensive farming system used, which combines environmental conditioning with managed feeding strategies (Umidayati et al., 2021).

Table 3. Natural foods found in *Chanos chanos* stomach in December 2023 and January 2024.

Species	December 2023	January 2024
Phytoplankton		
Glenodinium sp.	8	9
Peridinium sp.	6	5
Gymnodinium sp.	15	20
Alexandrium sp.	4	5
Proteperidinium sp.	5	12
Ceratium sp.	2	5
Chlorella sp.	11	17
Chaetophora sp.	22	1
Ulothrix sp.	21	31
Epithemia sp.	14	13
Surirella sp.	3	8
Microcystis sp.	21	1
Mallomonas sp.	3	3
Zooplankton		
Chromogaster sp.	9	14
Cyclops sp.	1	0
Bosmina sp.	1	2
Arcella sp.	1	1
Euglypha sp.	3	0

Based on Table 3, several phytoplankton phyla were identified, including *Glenodinium* sp, *Peridinium* sp, *Gymnodinium* sp, *Alexandrium* sp, *Protoperidinium* sp, and *Ceratium* sp, which belong to the phylum Dinoflagellate (Gómez, 2020). *Chrorella* sp, *Chaetophora* sp., and *Ulothrix* sp., are classified under the phylum Chlorophyta (Jin et al., 2023). Additionally, *Epithemia* sp., and *Surirella* sp., fall under the phylum Bacillariophyta (Cocquyt & Verschuren, 2023). *Mycrocytis* sp., is part of the phylum Cyanobacteria (Mirasbekov et al., 2021), while *Mallomonas* sp., belongs to the phylum Ochrophyta (Hao et al., 2024). For zooplankton found in the stomachs of milkfish, *Bosmina* sp., is classified under the phylum Branchiopoda (Wang et al., 2019). *Cyclops* sp., belongs to the phylum Arthropoda (Alekseev, 2021), *Arcella* sp., and *Euglypha* sp., are part of the phylum Protozoa, and *Chromogaster* sp., is classified within the group Rotifera (F. Li et al., 2021). Milkfish in this semi-intensive system exhibited a strong preference for natural feed, particularly planktonic microorganisms, consistent with their classification as microphagous planktivorous (Sandeep et al., 2022). The presence of multiple phytoplankton species and high individual counts in the stomachs supports the ecological adaptability and nutritional reliance of milkfish on diverse planktonic communities.

Preponderance Index

Milkfish in Gunung Anyar pond showed seasonal shifts in diet. Based on the results of the preponderance index calculation shown in Table 4, Chlorophyta dominated in December (54%), while Dinoflagellates led in January (50%). Supplementary foods varied, and zooplankton consistently remained below 3%, classifying them as additional food (Prastiwi et al., 2026). These changes reflect seasonal prey availability, influencing feeding ecology and resource use (Heuvel et al., 2019).

Table 4. Preponderance index (Ip) results for *Chanos chanos* cultivated in the Gunung Anyar pond in December 2023 and January 2024

Phylum	%Ip		Food Category	
	December 2023	January 2024	December 2023	January 2024
Phytoplankton				
Dinoflagellata	29.88	50.67	Supplementary	Main
Chlorophyta	54.45	38.79	Main	Supplementary
Bacillariophyta	5.40	7.13	Supplementary	Supplementary
Cyanobacteria	8.24	0.02	Supplementary	Supplementary
Ochrophyta	0.17	0.15	Additional	Additional
Zooplankton				
Rotifer	1.51	3.17	Additional	Additional
Arthropoda	0.02	0.00	Additional	-
Branchiopoda	0.02	0.06	Additional	Additional
Amoebozoa	0.30	0.02	Additional	Additional
Fish				
Fish Pieces	0.00	0.00	-	-

Fish feeding habits are a direct reflection of their capacity to assimilate various food components. The structure of the digestive tract, the digestive enzymes released, and the composition, quantity, and variety of the intestinal microbiota all influence the fish's capacity to digest and use the various nutrients in their diet (Jiao et al., 2023). Fish that are herbivorous have longer stomachs than those that are omnivorous, whereas omnivorous fish have longer stomachs than carnivorous fish. The stomach of milkfish (*Chanos chanos*) is divided into the cardiac and pyloric sections. The cardiac section is usually larger due to its higher muscle mass. The pyloric section is used for grinding food, making it finer. The relationship between stomach volume capacity and fish body weight can vary depending on feeding intensity, with stomach volume during a single meal ranging from as little as 10% to as much as 50% of its total volume (Karachle & Stergiou, 2010). Milkfish have a full stomach intensity during the daytime because they are actively feeding during this period (Kühlmann et al., 2008).

Numerical Diet Composition Index

The Numerical Diet Composition Index is used to assess feeding habits and identify dietary preferences in fish species (Scholz et al., 2020). Analysis of milkfish stomach contents from Gunung Anyar pond revealed an omnivorous diet with a strong preference for phytoplankton, including species from Dinoflagellate, Chlorophyta, Bacillariophyta, Cyanobacteria, and Ochrophyta. Zooplankton from Rotifer, Copepod, Cladocera, and Amoebozoa were also present, though less dominant. With a Cn value exceeding 90%, milkfish in this study are classified as planktivorous, aligning with what Sandeep et al. (2022) described. Their feeding behavior reflects traits of opportunistic generalists and shallow-water substrate feeders (Hantoro et al., 2024), favoring planktonic organisms over other natural feed sources (Arfiati et al., 2023).

Milkfish are broadly classified as omnivores, with a strong preference for planktonic organisms (Herawati et al., 2021; Hortillosa et al., 2022). In this study, preponderance index results showed that phytoplankton from the phyla Dinoflagellate and Chlorophyta were the most abundant, with additional taxa (Cyanophyta and Bacillariophyta) also present in the milkfish stomach. These results align with previous studies from Arfiati et al. (2023), which showed that milkfish-preferred taxa include Chlorophyta, Cyanophyta, and Bacillariophyta, with green and blue algae frequently consumed (Lückstädt & Reiti, 2002). The presence of detritus and benthic organisms in stomach contents suggests opportunistic feeding behavior, particularly among juveniles, whose diets also include diatoms and crustaceans (Lückstädt & Reiti, 2002). Despite their omnivorous classification, the dominance of phytoplankton—comprising over 80% of the diet in both December and January—supports their categorization as planktivorous in this semi-intensive system.

Table 5. Numerical diet composition index (Cn) results for *Chanos chanos* cultured in the Gunung Anyar pond in December 2023 and January 2024

Phylum	%Cn		Feeding habits	
	December 2023	January 2024	December 2023	January 2024
	Phytoplankton			
Dinoflagellate	26.49	38.10		
Chlorophyta	35.76	33.33		
Bacillariophyta	11.26	14.29		
Cyanobacteria	13.91	0.68		
Ochrophyta	1.99	2.04		
	Zooplankton		Planktivore	Planktivore
Rotifer	5.96	9.52		
Arthropoda	0.66	0.00		
Branchiopoda	0.66	1.36		
Amoebozoa	2.65	0.68		
	Fish			
Fish	0.00	0.00		

Table 6. Water quality measurement in the Gunung Anyar pond

Month	Locations	pH	DO	Temperature (°C)	Salinity (%)
December 2023	A	7.63	6.7	25.5	24.5
	B	7.63	6.4	25.5	25
	C	7.61	6.2	25.5	25
Average		7.62 ± 0.01	6.43 ± 0.25	25.50 ± 0	24.83 ± 0.29
January 2024	A	7.93	6.1	25.5	28
	B	7.92	5.6	25.5	29
	C	7.89	5.5	25.5	29
Average		7.91 ± 0.02	5.73 ± 0.32	25.50 ± 0	28.67 ± 0.58

Water Quality Parameters

The measurement of water quality parameters (Table 6) aims to assess the abundance of natural food available to milkfish (*Chanos chanos*). and understand what type of natural food would survive in an urban area (Musa et al., 2023). Furthermore, monitoring water quality is essential, as industrial, agricultural, and community activities around the river can alter aquatic conditions (Cahyonugroho et al., 2022).

Water quality parameters at the Gunung Anyar sampling site were consistent with previous studies on Surabaya's east coast (Hendrasarie & Kartika, 2024; Wijaya et al., 2022). The average pH remained around 7, within the good range for milkfish cultivation (6.5–9) (Arfiati et al., 2023). This pH was also within the optimal range for plankton growth, although it can vary depending on species and water conditions (Hansen, 2002). Dissolved oxygen (DO) levels averaged 6.43 ± 0.25 mg/L in December and 5.73 ± 0.32 mg/L in January. Despite the contribution of phytoplankton to oxygen through photosynthesis, eutrophication and mixing with urban runoff likely reduced DO levels at pond outlets (Hendrasarie & Kartika, 2024).

Temperature remained stable at 25.5°C, supporting optimal plankton growth (Trombetta et al., 2019). Salinity increased from 24.83 ± 0.29‰ in December to 28.67 ± 0.58‰ in January. While higher salinity can inhibit phytoplankton, this effect is mitigated by elevated total organic carbon and nitrogen levels, which promote diversity in moderately saline systems (Z. Li et al., 2021). Variations in DO, salinity, and pH between months were likely influenced by rainfall, which enhances aeration and dilutes organic matter in early rains but may reduce DO and pH with prolonged runoff and nutrient loading (Gassen et al., 2024; Ling et al., 2017; Luo et al., 2024).

The dissolved oxygen (DO) value of 6 mg/L falls within the safe range, as values above 5 mg/L are considered essential for fish productivity (Ganesh et al., 2020). Hendrasarie & Kartika, (2024) research in the Gunung Anyar mangrove estuary and coastal area found nitrate content at 0.124-0.25 mg/L and phosphorus at 0.78-2.83 mg/L. Nitrate can cause eutrophication when its content exceeds 0.2 mg/L (Suprayogi et al., 2020), leading to reduced water quality and the loss of dissolved oxygen in water bodies (Hanjaniamin et al., 2023). Urban runoff from impermeable surfaces concentrates pollutants during rainfall events, increasing loadings to receiving waters and exacerbating water-quality stress on aquaculture systems (Jia et al., 2021). Low water quality in water bodies will impact the quality of aquaculture (Mutea *et al.* 2021). Besides being caused by human activities, the high content of organic pollutants is also caused by the semi-intensive type of aquaculture. This would make organic matter settle longer because only 50% of the water is replaced once per month (Tran et al., 2023). Hence, these nutrients and biotic factors would influence the plankton abundance in the pond (Ariadi et al., 2024).

High organic loading and nutrient enrichment promote cyanobacterial blooms (Piontek et al., 2023). This event is exemplified by the detection of *Microcystis* sp. in this study, which thrives under elevated nitrogen and correlates with phosphorus levels (Junjun et al., 2022; Piontek et al., 2023). Harmful algal blooms (HABs) from cyanobacteria and toxin-producing dinoflagellates such as *Gymnodinium* sp. and *Alexandrium* sp. would increase turbidity, depress dissolved oxygen, and produce toxic metabolites that degrade water quality and impair aquatic life (Hwang et al., 2022; Igwaran et al., 2024). HABs will alter phytoplankton and zooplankton communities, leading to a decrease in zooplankton species richness, diversity and evenness (Amorim & Moura, 2021). This can be seen from the comparison of forage species found in the stomach of milkfish in Table 3, which shows that phytoplankton outnumber zooplankton. This could have a negative effect as zooplankton are essential for the growth of fish in hatcheries and for the aquatic food chain. An adequate supply of zooplankton remains essential for successful rearing (Ashaari et al., 2024). Thus, the limited abundance of zooplankton, caused by the emergence of some harmful algae species, is one of the main reasons why milkfish cultured in Gunung Anyar prefer phytoplankton as their main food source.

This study empirically elucidates the trophic plasticity and dietary adaptations of milkfish cultivated within an urbanized aquaculture environment degraded by domestic and industrial pollution. By demonstrating how pollution-induced HABs suppress zooplankton richness, the research reveals an opportunistic dietary shift wherein *C. chanos* functions as a high-intensity planktivore relying predominantly on phytoplankton. Utilizing quantitative frameworks including the Gastro-Somatic, Preponderance, and Numerical Diet Composition Indices, this study integrates urban environmental toxicology with trophic ecology, offering critical baselines to optimize water quality and feed management in anthropogenic ecosystems. Consequently, this work actively advances the United Nations Sustainable Development Goals (SDGs), directly contributing to SDG 14 (Life Below Water) through the assessment of estuarine biodiversity, SDG 2 (Zero Hunger) by securing urban aquaculture productivity, and SDG 11 (Sustainable Cities and Communities) by fostering resilient urban food systems against industrial constraints.

CONCLUSION

Milkfish cultured in the Gunung Anyar pond exhibited high feeding intensity in both December 2023 and January 2024, with gastro-somatic index values of 1.86 and 2.90, respectively. Stomach content analysis revealed a planktivorous feeding habit, with phytoplankton—particularly Chlorophyta and Dinoflagellates—as the dominant dietary components. This preference is likely linked to reduced zooplankton emergence due to harmful algal blooms (HABs), which alter plankton community structure. Future research should explore strategies to restore zooplankton diversity and investigate the nutritional role of dominant phytoplankton species. These insights will be vital for optimizing sustainable urban aquaculture and mitigating ecological impacts in polluted environments.

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AUTHOR CONTRIBUTION STATEMENT

All authors made substantial contributions to the conception, design, analysis, and interpretation of this study. DH was responsible for the overall study design and conceptual framework. NA and JOP contributed to study design and critically reviewed the manuscript, ensuring scientific rigor and coherence. MZR was primarily involved in data interpretation and manuscript drafting, integrating key findings into the discussion. AAR contributed to data collection, performed data visualization, and assisted in data interpretation. All authors participated in the revision process, approved the final manuscript, and agreed to be accountable for all aspects of the work, ensuring accuracy and integrity in the study's findings.

CONFLICT OF INTEREST STATEMENT

The authors affirm that there are no competing interests or financial relationships that could influence the findings or conclusions presented in this paper.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors acknowledge the use of Quillbot AI for grammar correction during manuscript preparation. This tool was not used to create content or interpret data. The authors are fully responsible for the manuscript's content and conclusions.

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