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RESEARCH ARTICLE
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Nutritional and Nutraceutical Profiles of Different Types of Shells in Tambaklorok, Semarang, Indonesia

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ABSTRACT

Tambaklorok Semarang is an area abundant in pond resources, particularly shellfish farming. However, not all information regarding the nutritional and nutraceutical profile of Tambaklorok shellfish is fully understood. The research aims to identify the commercial types of shellfish, assess the water quality in the pond area, and analyze the shellfish morphometry as well as the amino acid and fatty acid contents in different species of Tambaklorok shellfish. The method involved identifying different commercial shellfish types by observing and classifying them based on specific morphological characteristics. Water quality was assessed by measuring nitrate levels using equipment designed for testing seawater quality. Morphometric analysis is conducted by measuring the length and weight of the shells and calculating the growth index. Amino and fatty acid content analysis uses UPLC-PDA and LC-MS/MS methods. The research findings reveal the presence of three types of commercial shellfish in Tambaklorok Semarang: *Anadara granosa*, *Perna viridis*, and *Meretrix meretrix*. The water quality in this region needs to meet the standards required for marine life, mainly due to high nitrate levels. Analysis of mussel morphometry indicates that growth in shell length is more prominent than growth in weight. The amino acid and fatty acid content analysis revealed significant differences among the three shellfish species, with variations in the highest and lowest compositions. It is concluded that Tambaklorok Semarang consists of three commercially valuable types of shellfish and does not meet the required standards for water quality. Furthermore, differences were observed in the three shellfish species' morphometry, amino acid, and fatty acid composition. This data can be utilized to improve the cultivation and quality of Tambaklorok shellfish and serve as a basis for further research on shellfish farming in terms of nutrition and nutraceuticals.

Keywords: Amino acid, Fatty acid, LC-MS, UPLC-PDA.

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INTRODUCTION

Marine ecosystems, from the coast to the deep seabed, have provided resources for humans. According to Nugroho and dan Budianto (2021), seafood with high biological value is one of the main benefits of this resource (as a source of animal protein). Seafood is an excellent source of protein with high biological value. Animal protein has a higher biological value compared to vegetable protein because animal protein has a more complete composition and amino acid contents (Hoffman and Falvo, 2004). The shellfish population in Tambaklorok, Semarang City, is an important source of seafood due to its various benefits and nutritional content that can positively

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impact human health. In addition to being a good source of protein, shellfish are also rich in iron, calcium, amino acids, phosphorus, and vitamin B12, although their nutraceutical profile is not well understood (Venugopal & Gopakumar, 2020). Moreover, (Hasler 1998; Venugopal & Lele, 2014) explained that shellfish contain carotenoids, PUFAs (EPA & DHA), and bioactive peptides that can be used as nutraceuticals. Nutraceuticals are substances in food ingredients that can provide health benefits and prevention and treatment of diseases in humans (Venugopal, 2009). For example, the amino acid content in shellfish can improve the immune system and maintain heart health, as discovered in the gonads of sea urchin eggs (Pringgenies et al., 2020).

As public awareness of the importance of a healthy diet grows, research on the nutritional and nutraceutical profiles of different types of pond fish, particularly Tambaklorok shellfish, is becoming more important. The size of the mussel affects its nutritional content (Tari et al., 2018), therefore morphometric studies are imperative. Morphometric studies allow us to deeply understand the biological and ecological aspects of mussels (Sulistiyaningsih and Arbi, 2020). In addition, knowledge of the size and shape of mussels also provides insight into their growth and development patterns and the role of nutrition in these processes (Notonegoro and Pratiwi, 2022). For instance, in certain shellfish species, body size and shape can impact their ability to obtain nutrients. The research focuses on amino acids and fatty acids as nutrients. It is expected that the amino acids market will reach $27.22 billion by 2023, with an anticipated annual growth rate of 8.5% over the next seven years. The global amino acids market is primarily driven by the animal feed and human nutrition sectors, which are currently the most valuable sectors in terms of application (Sikorsa, 2023). As a result, shellfish can play an important role in global market demand, since it is one of the many commodities rich in amino acids. Amino acids in shellfish are used for human maintenance and growth (Dong, 2001).

Shellfish are also a rich source of high-quality lipids, particularly eicosapentaenoic and docosahexaenoic acids (Olatunji et al., 2012). The content of these fatty acids is beneficial in several human physiological processes such as fetal development (Swanson et al., 2012), improving cardiovascular health, and playing a role in the development of intelligence and vision function (Sun et al., 2018). It is predicted that global fatty acid prices will decrease in October 2023 due to an oversupply and weak demand. The European market saw a significant decrease in fatty acid prices, while the North American market experienced the smallest decline. Similarly, major suppliers and buyers in Asian markets like Indonesia and India also witnessed a drop in fatty acid prices (Kutcher, 2023). As one step in responding to this situation, the potential of shellfish as a source of fatty acids can be utilized. The aim of this research is to identify the commercial species found in the ponds of Lorok Semarang, analyze their water quality, examine the morphometry of shellfish, and analyze the content of amino acids and fatty acids in the shellfish. Through this research, it is hoped that it can provide an understanding of the potential and benefits of shellfish nutrition as an effort to fulfill global nutritional needs.

MATERIALS & METHODS

Identification of Shells

Shellfish identification was carried out in the Fish and Environmental Resources Management laboratory, Aquatic Resources Management study program, Faculty of Fisheries and Marine Sciences, Diponegoro University. Identification using references from (Dharma, 1988; Dharma, 1992; Poutiers, 1998; Dharma, 2005).

Water Quality Analysis

The water sampling location was the same as the shellfish sampling location. This collection is based on information from fishermen who usually harvest shellfish in the shellfish habitat. Sampling was conducted in the three shellfish habitats, with each location replicated three times. The first sampling point was carried out at the *A. granosa* habitat location. At this location, there are many floating net cages. The second sampling location is the *P. viridis* habitat. Many cultivated *P. viridis* and several fish cages were found at the sampling location. The third sampling location was the *M. meretrix* habitat. This location borders a mangrove area, and there are several fish cages.

The selection of sampling stations was carried out using the purposive random sampling method based on information from fishermen at the location. Water sampling was carried out directly in the field using a bottle 125mL. Control samples and samples were taken 3 times to ensure the accuracy of measurements and testing. On the same day, samples were placed in a coolbox and measurements were made in the laboratory to verify the existence of nitrate and its concentration. The samples were analyzed in the Fish Resources and Environmental Management laboratory, Aquatic Resources Management study program, Faculty of Fisheries and Marine Sciences, Diponegoro University by conducting ion chromatography tests on water samples (Rezaie-Boroon et al., 2023).

Morphometrics of Shells

Sampling of shellfish as many as 50 samples of each type of shellfish and taken randomly. Measurement of length using calipers or calipers with an accuracy of 0.05mm and the total weight of the shellfish was weighed with an analytical scale with an accuracy of 0.1g. The total length of the shellfish measured is the length of the shell from the anterior end to the posterior end (López-Rocha et al., 2018).

Amino Acid Content Analysis

Amino acid measurements were performed using the UPLC-PDA method. HPLC analysis to determine the total amino acid composition is a conventional method. The sample was first treated with acid hydrolysis (6N, HCl) to free amino acids from the protein. Tryptophan is destroyed by oxidation during acid hydrolysis. Therefore, base hydrolysis is required to measure tryptophan. In this study, acid and base hydrolysis were carried out in less than 30 minutes using the microwave digestion method. This is much faster than traditional hydrolysis of up to 24 hours at 110°C. The automated pretreatment capabilities of the autosampler enable online derivatization of the amino acids resulting from the amino acid extraction to accelerate and simplify the analysis. This online derivatization uses o-phthalaldehyde (OPA) as the primary amino acid and 9-fluorenyl methyl chloroformate (FMOC) as the secondary amino acid to produce fluorescent substances. Fluorescence (RF) detection was used for sensitive analysis of amino acid quantification in the nmol/L range, while UV detection allowed quantification of amino acid values in µmol/L. The online derivatization method for amino acids was found to be stable, reproducible, and sensitive. Shimadzu Nexera LC-40 X3 with a photodiode array (PDA) and RF detector was used for this amino acid analysis (Liw et al., 2019). Tryptophan measurement was performed by ion exchange chromatography method. The method involves the separation and quantification of tryptophan (released from protein by alkaline hydrolysis with NaOH) using isocratic ion exchange chromatography with o-phythalaldehyde derivatization followed by fluorescence detection. In this procedure, the chromatographic separation of tryptophan and the internal standard α-methyltryptophan was completed in 15min without interference from other compounds. The accuracy of this method is 1 to 4 relative standard deviations (Ravindran and Bryden, 2005). Cystine and methionine measurements were carried out using LC-MS/MS referring to the Commission Regulation (EC) No. 152/2009 Laying Down the Methods of Sampling and Analysis for the Official Control of Feed: Annex III Point F. Determination of Amino Acids (except Tryptophane) (Dahl-Lassen et al., 2018).

Analysis of Fatty Acid Content

The GC FID technique was used in the analysis of the profile and quantification of fatty acids in the form of methyl esters (fatty acid methyl esters, FAMEs). The lipid fraction was extracted using the Folch method with several modifications (FOLCH, LEES and SLOANE STANLEY, 1957). All samples were homogenized and 4g of homogenate was weighed into a 50mL tube. Folch's solution (chloroform: methanol, 2: 1, v/v) was added to the tube, followed by the addition of 0.73% NaCl solution. The samples were vortexed for 1-2min and centrifuged at 3500rpm for 15 min at 4°C. After collecting the lipid fraction (bottom layer), the flask was weighed and dried using a rotary evaporator (Heidolph Instruments GmbH & Co., Schwabach, Germany). The total lipid content (g/100g) was determined gravimetrically. Fatty acid methyl esters (FAMEs) were obtained by transmethylation (high temperature esterification) of the lipid fraction in the analytical sample. According to ISO 12966-2-2017, the process was achieved by mixing methanol with sulfuric acid (9:1, v/v) (Preview, 2017)/ISO 12966-2-2017). The fatty acid composition of the study samples was analyzed using a gas chromatograph equipped with a split/splitless injector and a flame ionization detector (GC-FID, Dani Master GC, Dani Instrument, Milan, Italy). The instrument was equipped with a ZB-Wax column (Phenomenex, Torrance, CA, USA) with a length of 30m, an internal diameter of 0.25mm, and a film thickness of 0.25µm. The operating conditions were as follows: The column oven temperature ranged from 50°C (holding time 2min) to 240°C (holding time 15 min) with a heating rate of 3°C/min. The injector and detector temperatures were set at 240°C. Helium gas was used as the carrier gas and was flowed at a constant linear velocity of 30cm/s. The injection volume was 1L, and the split ratio was 1:50. Clarity Chromatography v4. 0.2 software (DataApex, Prague, Czech Republic) was used for data acquisition and management. Each sample was analyzed in triplicate using analytical blanks. FAMEs of nutritional concern were identified by comparing their retention times with reference compounds in two mixtures (Supelco SP2560 and DB FastAME mixtures) (Nava et al., 2023).

RESULTS & DISCUSSION

Tambaklorok is a coastal area in Semarang City, Central Java. It is situated in Semarang Bay, specifically in Tanjung Mas Village, North Semarang District (Linninga et al., 2023). Initially, the Central Java Fisheries and Maritime Service utilized the Tambaklorok coastal area as a transportation route and port. However, the local community also utilized the area as the Tanjung Mas industrial area (Khusnia et al., 2019). In addition to the port, there are facilities such as PLTU PT. Indonesia Power, various industries, and residential centres in the area (Rahayu et al., 2020). The waters of Tambaklorok have the potential to provide significant benefits for human life, as well as for the utilization of marine natural resources. Shellfish are marine organisms that offer substantial advantages, particularly for the fishermen in Tambaklorok. Some examples of shellfish found in the waters of Tambak Lorok are *Anadara granosa*, *Perna viridis*, *Meretrix meretrix*, *Paphia undulata*, *Amusium pleuronectes*, and others.

Identification of Shells

Three types of shellfish were identified at the Tambaklorok location in Semarang: *Anadara granosa* (Linnaeus, 1758), *Perna viridis* (Linnaeus, 1758), and *Meretrix meretrix* (Linnaeus, 1758), as depicted in Fig. 1.

A. granosa has two thick, elliptical shells that are the same on both sides, with approximately 20 ribs. The shell shape is rounded and slightly oval, and may have a rough or uneven surface. The surface of the shell has radial ribs (Zainuddin, 2018). The white shell is covered with a periostracum that is brownish-yellow to blackish-brown. Adult clams typically measure 6cm in size. The shell of *A. granosa* is gray-brown or yellowish with fine radial markings or lines. The shell of *A. granosa* is typically smaller than *P. viridis*, measuring around 5cm in length. It has a shorter and less prominent tassel (byssus) than other species, which helps it adhere to surfaces like rocks and other shells. The inner shell of *A. granosa* has a unique hinge structure with more hinge teeth and a distinct shape. The outer surface of the shell is rough, often with small bumps, giving it a somewhat uneven appearance. Blood clams, also known as *A. granosa*, are shellfish commonly found in Indo-Pacific waters, including Indonesian waters (Shao et al., 2016).

Table 1: Water Quality of Tambak Lorok Waters

No.	Parameter	Unit	Station 1	Station 2	Station 3	Quality standards
	Physics					
1	Water color		Murky green	Murky green	Murky green	
2	Brightness	cm	30	50	40	
3	Temperature	°C	29.1	29.3	29.5	Natural
4	Current speed	m/sec	0.3	1.2	0.2	
5	Depth	cm	300.5	300	200	
6	Substrat		Clay mud	Mud and shells	Mud	
7	*Chemistry*					
	Dissolved oxygen	mg/L	5.6	5.6	5.7	>5
8	pH		7.6	7.6	7.5	7-8.5
9	Salinity	ppt	30	31	30	Natural
10	Nitrate	mg/L	1.6	1.5	1.3	0.06

Note* Sea water quality standards, Republic of Indonesia government regulation number 22 of 2021.

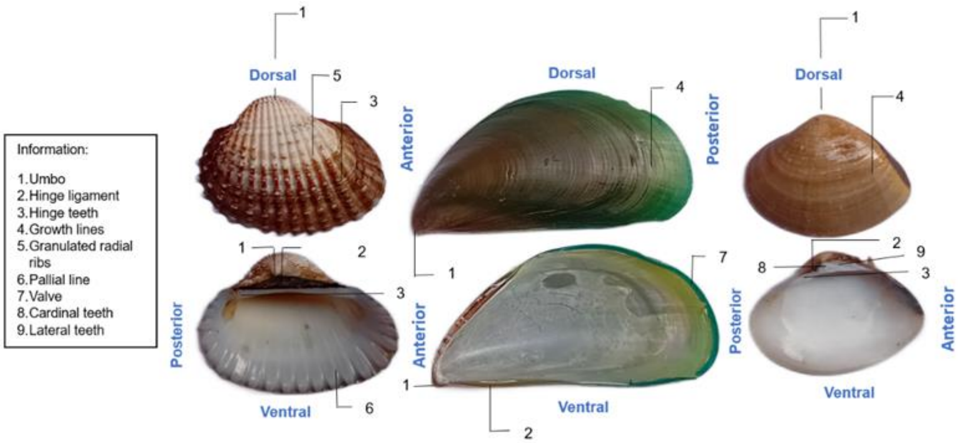

Fig. 1: *A. granosa* (Linnaeus, 1758), *P. viridis* (Linnaeus, 1758) and *M. meretrix* (Linnaeus, 1758).

P. viridis, commonly called the green mussel or green-lipped mussel, is a type of bivalve mollusk from the Mytilidae family. It consists of two shell pieces connected by a dorsal ligament. The shell is narrower from front to back, with a concave ventral margin. It typically has an oval or elliptical shape with a slightly wavy or mottled surface and fewer noticeable papillae along the mantle edge. The shell is bright green with a golden or yellowish hue. Juveniles are typically characterized by bright green and red colors, while adult shells are less bright and browner. One distinctive feature that sets it apart from other crustacean species is its brown or black tufts (byssus) that allow it to attach to surfaces such as rocks and other shells. The length of the *P. viridis* shell can reach around 80-100mm. This species is usually found in warm tropical coastal waters, especially in the Indo-Pacific region, such as the coastlines of Southeast Asia, Australia, and New Zealand (Namesis, 2024).

Meretrix meretrix shells are generally elliptical or oval with slightly curved edges. The shell's length ranges from 17.2 to 39.1mm and 1.92 to 18.51g but can vary based on environmental factors and the shell's age (Keith et al., 2018). The shell is smooth with clearly visible concentric lines. The shell color can vary from cream to light brown, often with a less striking colored pattern. The shell has a hinge line on the back that allows the shell to open and close. These hinges are generally more straightforward than shellfish living in rocky environments. *M. meretrix* feet are flexible, extendable structures for digging and moving in the sand. These legs are slightly flat and can be elongated to help the clam dig into the sand substrate. These feet also help in the process of adjusting position in the sand. *M.meretrix* has an inhalant siphon used to draw water into the shell. This functions to supply oxygen and food particles to the shellfish's body. The soft body parts of shellfish that are not protected by the shell include internal organs such as the digestive organs, gonads and respiratory system. The mantle membrane is the tissue that lines the shell's inside and produces the shell. This coat also functions to protect the shellfish's body organs. The adductor muscles function to open and close the shell. In the *M. meretrix*, these muscles are located on either side of the shell's inside, allowing the clam to close tightly as a defense mechanism. This clam species is a dynamic burrower and a suspension-feeding species that develops well in intertidal zones with sloppy or silty substrate sorts such as mangroves and estuaries (Keith et al., 2018; Zhang et al, 2022). The Asiatic hard clam (*M. meretrix*) is broadly dispersed within the Indo-Pacific locale (Poutiers, 1998; Keith et al., 2020).

Water Quality Analysis

The results showed that the physical parameters varied (Table 1). The measurements of chemical parameters reveal that the nitrate content has exceeded the seawater quality standards set for biota life, specifically falling within the range of 1.3-1.6mg/L. Nitrate serves as an indicator of water fertility, which is visually evident from the cloudy green color of the water at all research locations. The high concentration of nitrate at all research stations indicates that the research location is in close proximity to ports, industrial areas, and residential locations. This proximity leads to a significant amount of waste from human activities, which in turn causes the release of nitrate content in sediment and enriches nutrients in the water column (Rahayu et al., 2020; Clasrisa et al., 2023).

Table 2: Amino acid content in all species

No	Amino acid	Amino acid content (%)		
Essential amino acid		*A. granosa* (%)	*P. viridis* (%)	*M. meretrix* (%)
1	Phenylalanine	6.36	6.62	5.20
2	Icoleucine	4.26	4.40	3.70
3	Valine	5.55	5.18	4.33
4	Lysine	5.33	4.84	3.76
5	Leucine	6.62	7.38	6.10
6	Threonine	5.23	5.86	4.92
7	Histidine	2.81	3.10	2.82
8	Thryptophan	1.04	0.99	1.35
9	Methionine	1.22	1.40	1.64
Non-essential amino acid				
10	Serine	5.67	5.60	4.30
11	Glutamate	9.31	11.86	7.24
12	Alanine	6.12	6.35	6.86
13	Arginine	6.91	7.46	5.15
14	Glycine	10.30	5.70	7.53
15	Aspartic acid	7.66	8.09	5.95
16	Tyrosine	5.23	4.33	3.44
17	Proline	4.31	3.75	3.10
18	Cysteine	5.21	7.08	22.60

Morphometric Analysis

The analysis results of the relationship between shell length and total weight of *A. granosa* (Linnaeus, 1758), *P. viridis* (Linnaeus, 1758), and *M. meretrix* (Linnaeus, 1758) from Tambaklorok Waters indicate that the b values are 0.8716, 1.427 and 2.5593, respectively. This suggests that the growth of green mussels in these waters is negatively allometric (<3), where the growth in shell length is more dominant than the growth in weight, as shown in Fig. 2. The analysis results indicated a significant relationship between the shell length and total weight of *A. granosa, P. viridis*, and *M. meretrix* in Tambaklorok waters. Moreover, the growth of these three species appeared to be positively correlated with shell length. This suggests that there are environmental factors affecting the growth and adaptation of these species in these waters. The research findings can be valuable for guiding future research and policymaking concerning water resource management. According to (Ubay et al., 2023), the allometric growth of *P. viridis* (Linnaeus 1758) with a negative b value of <3 in these waters is strongly influenced by water quality. Notonegoro and Pratiwi (2022) conducted similar research and found that the relationship between shell length and total shell weight in *A. granosa* (Linnaeus, 1758) exhibited negative allometry with a b value of 2.1328. This was attributed to the influence of water temperature, food availability, production activities, and the substrate composition, which consists of mud and sandy mud.

Results of Analysis of Amino Acid Content

The results of amino acid research indicated that there are 18 essential and non-essential amino acids (Table 2) present in *A. granosa* (Linnaeus, 1758), *P. viridis*, and *M. meretrix* (Linnaeus, 1758). Specifically, there were 9 essential amino acids (phenylalanine, isoleucine, valine, lysine, leucine, threonine, histidine, tryptophan, and methionine) and 9 non-essential amino acids (serine, glutamate, alanine, glycine, aspartic acid, tyrosine, proline and cysteine).

The shellfish species *P. viridis* (Linnaeus, 1758) had the highest and lowest essential amino acid compositions, with Leucine at 7.38% and Tryptophan at 0.99%, respectively. The shellfish species *M. meretrix* (Linnaeus, 1758) had the highest and lowest non-essential amino acid compositions, with cysteine at 22.60% and proline at 2.88%, respectively. The amino acid content in shellfish is very beneficial for body health, especially the essential amino acids that the human body cannot produce independently. In *P. viridis*, there is a high content of the amino acid leucine, which helps in building muscle and reducing body fat (Pedroso et al., 2015). On the other hand, in *M. meretrix*, the high content of the amino acid cysteine can strengthen the immune system (Li & Wu 2022). This indicates that consuming shellfish can offer various health benefits, depending on the type of shellfish consumed. Furthermore, the differences in amino acid composition in each type of shellfish can provide nutritional variations for the body.

The highest and lowest amino acid contents in *A. granosa* (Linnaeus, 1758) are 10.30% glycine and 1.22% methionine, respectively. The dominant type of free amino acid is known to vary among osmotically compatible shellfish species. It has been shown that glycine is the major free amino acid in the softshell clam *Mya arenaria* (Haider et al., 2019). Although the glycine content in Tambaklorok waters is relatively low, it is still lower than the 0.6% glycine content found in *A. antiquate* (Abdullah et al., 2017). Non-essential amino acids present in animal muscle tissue include alanine, glycine, and glutamic acid (Krug et al., 2009). Glycine, along with glutamic acid and aspartic acid, can contribute unique flavors to fishery products. Glycine is an active flavor component and is

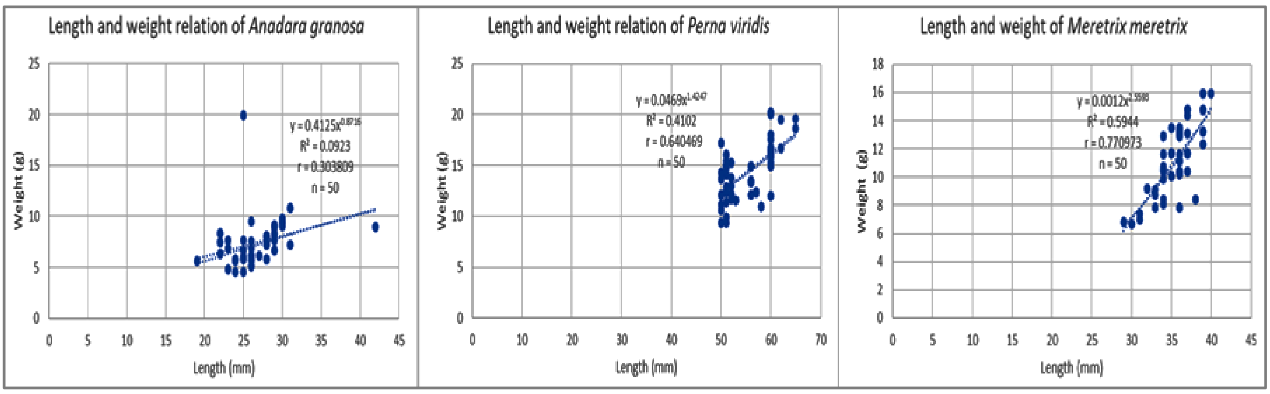

Fig. 2: Relationship between length (m) and total weight (mm) of *A. granosa, P. viridis* and *M. meretrix.*

Table 3: Fatty fat content (%) in all species

No	Fatty Acids		*A. granosa*	*P. viridis*	*M. meretrix*
	Saturated				
1	Stearic Acid	C18:0	6.54	6.41	3.68
2	Heptadecanoic acid	C17:0	2.76	2.78	1.77
3	Palmitic acid	C16:0	23.69	16.29	19.26
4	Tricosanoid acid	C23:0			4.73
5	Myristic Acid	C14:0	3.09		2.8
6	Pentadecanoic acid	C15:0		0.65	0.54
7	Arachidic acid	C20:0			0.68
8	Lauric acid	C12:0		0.32	
9	Tricosanoic acid	C23:0			
	Total saturated fatty acid		36.08	26.44	33.46
	Monounsaturated				
10	Oleic Acid	C18:1	9.73	5.34	10.03
11	Palmitoleic acid	C16:1	7.13	19.98	7.88
12	Heptadecanoic acid	C17:1		2.91	
13	Pentadecanoid acid	C15:1		0.74	
14	Mirystoleic acid	C14:1		4.31	
15	Erucid acd	C22:1		10.22	
16	Eicosenoic acid	C20:1	1.19	0.41	0.84
	Total monounsaturated fatty acid		18.05	43.91	18.74
	Polyunsaturated				
17	Eicopentanoic acid	C20:5	13.77	9.32	16.32
18	Linolenic acid (ω3)	C18:3	1.02	0.71	1.08
19	Docosadienoic acid	C22:2	10.4	3.96	7.48
20	Linoleic acid	C18:2	5.23	6	4.08
21	Arachidonic acid	C20:4	5.13	3.03	3.48
22	Docosahexaeonic acid	C22:6	10.32	5.71	13.73
23	Linolenic acid (ω6)	C18:3		0.93	
24	Eicosadienoic acid	C20:2			1.63
	Total polyunsaturated acid		45.87	29.65	47.8

known to provide sweet properties to various aquatic foods (Pratama et al., 2018). Methionine was discovered to be low in *A. granosa* (Linnaeus, 1758), specifically at 1.22%. Methionine aids in breaking down fat to prevent the accumulation of fat in the arteries. It contains sulfur, which is crucial for the body's natural antioxidants. Methionine also plays a role in the production of another amino acid, cysteine. According to FAO/WHO (1985), the body's requirement for methionine is 0.42%. However, the methionine content in *A. granosa* (Linnaeus, 1758) in this study was still relatively high compared to the 0.25% methionine content found in *A. antiquata* meat (Abdullah et al., 2017). Methionine and cysteine are the only sulfur-containing amino acids that are considered proteinogenic among the various sulfur-containing amino acids. They are classified as essential and semi-essential amino acids. Both methionine and cysteine play crucial roles as primary sources of sulfur for numerous biochemical reactions in cells. Cancer cells utilize excess cystine to elevate intracellular cysteine levels for catabolic functions. Many cancer cell lines express the Na+-independent cystine/glutamate antiporter xCT, which is encoded by the SLC7A11 gene (Sayin et al., 2017). The highest and lowest amino acid contents in *P. viridis* (Linnaeus, 1758) are 11.86% for glutamate and 1.22% for tryptophan, respectively.

In this study, the glutamate content in *A. antiquata* was 1.74% lower than that in *P. viridis* (Linnaeus, 1758), which was 11.86%. Glutamic acid plays a crucial role in determining the taste of seafood. The most commonly found amino acids in marine mollusks are glutamate, aspartate, glycine, alanine, and taurine (Derby et al., 2007). Glutamate contributes to the umami taste when its concentration in food exceeds the taste threshold (Sayin et al., 2017). In addition to providing umami taste, glutamate can help prevent excessive alcohol intake, accelerate the healing of intestinal wounds, improve mental health, and reduce depression (Mandila and Hidajati 2013). The lowest amino acid content in *P. viridis* (Linnaeus, 1758) is tryptophan, specifically 0.99%. Tryptophan is an essential amino acid in both plant and animal foods and is not synthesized by the body. Tryptophan was not detected in *P. viridis* (Linnaeus, 1758) sourced from the waters of Cirebon (Januar et al., 2020).

The highest and lowest amino acid contents in *M. meretrix* (Linnaeus, 1758) are 22.60% cysteine and 1.35% tryptophan, respectively. Cysteine and tryptophan were not found in *M. meretrix* from Muara Angke Jakarta (Abdullah et al., 2017). Tryptophan was found in *Solen regularis* from the waters of Tanjung Solok Jambi in the amount of 1,098mg/kg (Trisyani, 2019). Tryptophan is a precursor of the vitamin niacin and a neurotransmitter of serotonin. Dietary tryptophan and its metabolites from tryptophan appear to have the potential to contribute to the therapy of autism, cardiovascular disease, cognitive function, chronic kidney disease, depression, inflammatory bowel disease, multiple sclerosis, sleep, social function, and microbial infections (Friedman, 2018).

Results of Analysis of Fatty Acid Content

The results of the fatty acid research showed that there are a total of 23 fatty acids (Table 3). These include 8 saturated fatty acids: stearic acid, heptadecanoic acid, palmitic acid, tricosanoic acid, myristic acid, pentadecanoic acid, arachidic acid, and lauric acid; 7 monounsaturated fatty acids: oleic acid, palmitoleic acid, heptadecanoic acid, pentadecanoic acid, myrystoleic acid, erucic acid, and eicosenoic acid; and 8 polyunsaturated fatty acids: eicopentanoic acid, linolenic acid (ω3), docosadienoic acid, linoleic acid, arachidonic acid, docosahexaenoic acid, linolenic acid (ω6), and eicosadienoic acid. The species *A. granosa* (Linnaeus, 1758) had the highest and lowest fatty acid contents of palmitic acid at 23.69% and linoleic ω3 at 1.02%, respectively. In the *A. granosa* species found in the waters of the Southeast Coast of India, the palmitic acid content was found to be 27.42% (Periyasamy & Murugan, 2016). The species *P. viridis* (Linnaeus, 1758) had the highest and lowest fatty acid contents of palmitoleic acid at 19.98% and laucid acid at 0.32%, respectively. The species *M. meretrix* (Linnaeus, 1758) had the highest and lowest fatty acid contents of palmitic acid at 19.26% and pentadecanoic acid at 0.54% (Fig. 3).

The species *A. granosa* (Linnaeus, 1758) had the highest percentage of saturated fatty acids at 36.08%, while the species *P. viridis* (Linnaeus, 1758) had the lowest at 26.44%. The species *P. viridis* (Linnaeus, 1758) had the highest percentage of monounsaturated fatty acids (MUFA) at 43.91%. In contrast, the species *A. granosa* (Linnaeus, 1758) had the lowest monounsaturated fatty acids (MUFA) percentage at 18.05%. The species *M meretrix* (Linnaeus, 1758) had the highest amount of polyunsaturated fatty acids (PUFA) at 47.80%, while the species *P. viridis* (Linnaeus, 1758) had the lowest amount of polyunsaturated fatty acids (PUFA) at 29.65% (Fig. 4).

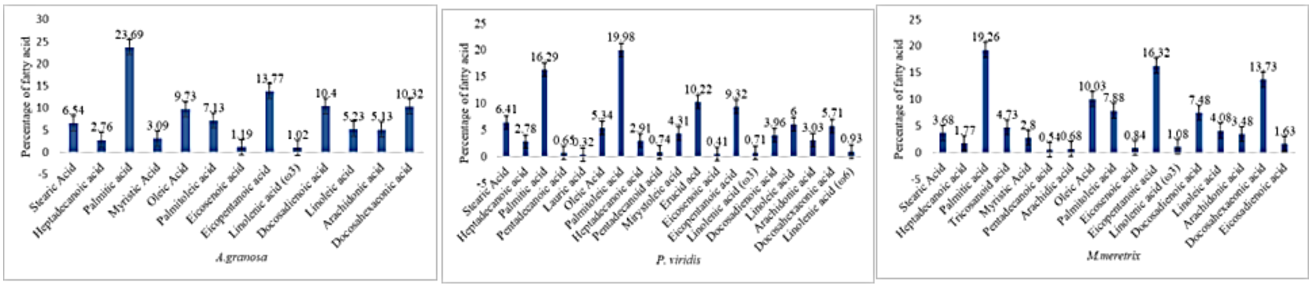

Fig. 3: Fatty acid content of *A. granosa, P. viridis* and *M. meretrix.*

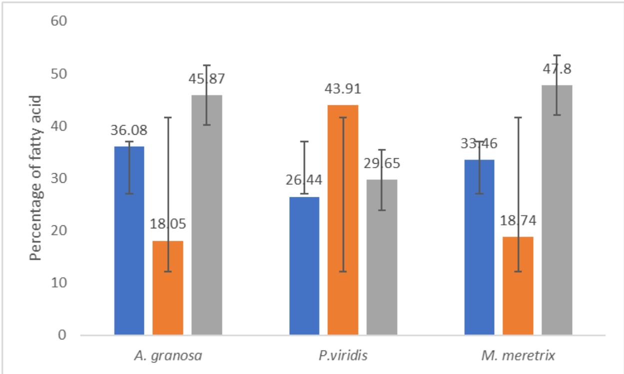

Fig. 4: Fatty acid content of SFA, MUFA, PUFA from *A. granosa, P. viridis* and *M. meretrix*.

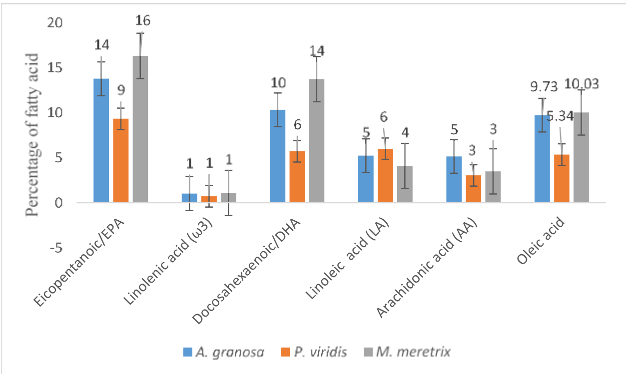

Fig. 5: Content of Omega 3, 6, and 9 fatty acids.

The analysis of fatty acids in the waters of Tambaklorok revealed that *M. meretrix* clams had the highest level of polyunsaturated fatty acids (PUFA), while *P. viridis* clams had the highest level of monounsaturated fatty acids (MUFA). *A. granosa* clams had the highest level of saturated fatty acids (SFA) as depicted in Fig. 5.

The highest compounds found in *M. meretrix* are eicopentanoic acid/EPA, docosahexaenoic acid/DHA, and oleic acid/omega 9. Sea shells are a source of high-quality lipids because they concentrate EPA and DHA from phytoplankton. Marine bivalves have a higher proportion of n-3 PUFA than land bivalves, and lipid quality also differs between cultivated and wild species. LCPUFA n-3 is important for fighting inflammation, preventing depression, reducing body weight and fat in the liver and improving mental health (Olatunji et al., 2012).

Shellfish are becoming more important because they are a great source of high-quality lipids that provide the necessary n-3 LC-PUFA for human consumption. They have positive effects on human health, regardless of the species or habitat. The nutritional value of shellfish differs depending on the species and location. Consumers only need to eat about 100g of shellfish to meet their daily requirements for n-3 LC-PUFA (Tan et al., 2021). The research results showed that the three types of bivalves had high n-3 content. Among them, *M. meretrix* (Linnaeus, 1758) had the highest n-3 fatty acid content compared to *A. granosa* and *P. viridis*. Therefore, it is highly recommended for cultivation.

Conclusion

Based on the research results, it can be concluded that Tambalorok Semarang has three types of commercial shellfish: *A. granosa, P. viridis, and M. meretrix*. The water quality does not meet the standards required for marine life, particularly due to high nitrate levels. The growth of shell length is more prominent than weight growth in mussels. The amino acid composition differs among the three shellfish species, varying highest and lowest levels. Additionally, the fatty acid content varies, with *A. granosa* having the highest saturated fatty acids at 36.08% and *P. viridis* having the lowest at 26.44%. Meanwhile, *M. meretrix* has the highest content of polyunsaturated fatty acids, specifically 47.80%. The species *P. viridis* (Linnaeus, 1758) had the lowest polyunsaturated fatty acid (PUFA) content at 29.65%. Tambaklorok Semarang has varying nutritional content and nutraceutical profiles based on the type of commercial shellfish present.

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