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Identification of Mineral Absorption in the Meat of Freshwater Kijing (*Pilsbryoconcha exilis* Lea) Using X-Ray Fluorescence (XRF)

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ABSTRACT

The filtration ability of freshwater mussels is used as an indicator of biofiltration and has the potential to accumulate various minerals and heavy metals. This study aims to identify minerals resulting from absorption in the meat of freshwater kijing (Pilsbryoconcha exilis Lea) using the X-Ray Fluorescence (XRF) technique. Meat freshwater kijing sliced thinly and carried out the drying process below ray sun direct in 3 days with objective lower water content. Samples already dry smoothed with method pounded using mortar until smooth and filtered for get sample form flour meat tombstone. Method of quantitative identification of absorbed minerals in samples was carried out using the X-Ray Fluorescence method (ED-XRF type) Rigaku NexCG type. The XRF testing procedure is carried out in several steps. The results of the research show that qualitatively, in the XRF test, freshwater kijing meat contains 29 metal elements with the top 10 elements consisting of calcium oxide (CaO), calcium (Ca), phosphorus pentoxide (P2O5), phosphorus (P), manganese oxide. (MnO), sulfur trioxide (SO3), manganese (Mn), silicon dioxide (SiO2), aluminum oxide (AlO), magnesium oxide (MgO). Meanwhile, quantitative analysis shows that the five most abundant metal elements are CaO 48.70%, Ca 34.80%, P2O5 30.90%, P 13.50%, and MnO 4.9%. These results show that the main mineral compiler meat freshwater kijing is calcium and phosphorus. Element calcium and phosphorus lots utilized freshwater kijing for preparation shell.

1. Introduction

The river is track The flow of fresh water from upstream to the estuary is formed experience nor artificial (Government of Indonesia Regulations, 2011), and is one of the sources of water that can be obtained utilized (Rahmawati & Siwiendrayanti, 2023). Rivers are often used to supply drinking water, fish cultivation, rice irrigation needs, and tourism until transportation (Firmansyah *et al*., 2021). Indonesia has thousands of rivers with a high percentage of polluted rivers. According to (Minister of Environment and Forestry, 2021) As many as 59% of rivers in Indonesia have experienced heavy pollution. This has a serious impact on the surrounding environment, especially the ecosystem within it (Adam *et al*., 2018).

Decline aquatic biota population consequence pollution, has an impact on the content nutrients for aquatic biota that humans consume continuously. As examples of consumed aquatic biota society and experience decline population consequence pollution is freshwater muskling (Astari *et al*., 2018). Several types of deer that are often consumed and used as biofilters are *Anodontaa woodiana* Lea and *Pilsbryoconcha exilis* Lea (Faisal *et al*., 2022; Ghazali *et al*., 2015).

Freshwater kijing *Anodonta woodiana* or Taiwanese mussels are a type of freshwater shellfish from family Unionidae (Jeratthitikul *et al*., 2022). Shell This is shell originating from Taiwan, was first discovered in Indonesia in 1971 where it was accidentally brought in during the process of importing tilapia (*Tilapia nilotica*) from Taiwan. Shell This own potency economical big Because including Shellfish are commonly consumed and used as food by people (Hamidah, 2006). Apart from being material food, shellfish This own Another benefit is as an aquatic biofilter (Pramesti *et al*., 2014). This type of tombstone has a water filtration capacity of up to 40 liters per day (Apria *et al*., 2024; Rahayu, 2019). Apart from *A. woodiana*, the kijing that is often consumed by the public and used as a biofilter is *Pilsbryoconcha exilis***.** *Pilsbryoconcha exilis* is a freshwater mussel from the family Unionidae and the genus *Pilsbryoconcha* (Jeratthitikul *et al*., 2022). This shell own ability filtration (Putra *et al*., 2016), so often used as a biofiltration agent in contaminated water areas and increases the potential for contamination with dangerous minerals like metal heavy (Christakos *et al*., 2011; Fassler, 2004; Li *et al*., 2018). This shellfish is a species that people often take to make daily food. This matter because of the taste and content meat Shellfish plays an important role and are very much needed by the human body. The results of identification of the contents of kijing meat show that there are proteins and amino acids which can help the maintenance and growth and development of the body. One of them is *eicosapentaenoic acid* (EPA) and *docosahexaenoic acid* (DHA) which can increase intelligence brain (Abdullah *et al*., 2018; Ghazali *et al*., 2015; Warsidah *et al*., 2022).

Consumption freshwater kijing from waters polluted can bring less impact good for health , so need done analysis mineral content for minimize impact bad (Astari *et al*., 2018; Hermi *et al*., 2023). This matter can do with identification uptake by shellfish. Lots of research previously discussed this shellfish, but studies of macro and micromineral absorption in mussel meat have not been identified. One of the mineral analysis techniques in kijing meat that can be used is X-Ray Fluorescence (XRF) (Carolina & Crime, 2020; Santhiarsa, 2015). The XRF method can be used for both qualitative and quantitative analysis of liquids, powders, and solid materials. XRF instrumentations can be divided into two categories: (1) Wavelength Dispersive X-ray Fluorescence (WDXRF), (2) Energy Dispersive X-ray Fluorescence (EDXRF). The main factor distinguishing these technologies is the method used to separate the spectrum emitted by the atoms in the sample (Wulandari *et al*., 2022). This research aims to identify minerals resulting from absorption in the meat of the *Pilsbryoconcha exilis* mussel using XRF techniques. With mineral analysis, in an effort to identify the mineral composition in this species. It is hoped that the data obtained will provide new insights regarding the nutritional aspects of the *Pilsbryoconcha exilis* mussel.

2. Materials and Methods

As for material research used that is freshwater kijing *Pilsbryoconcha exilis* obtained from pool cultivation, Fish Cultivation Center (BBI), Fisheries Service, East Lombok Regency, West Nusa Tenggara showed in Figure 1. Meat freshwater kijing sliced thinly and carried out the *drying* process below ray sun direct in 3 days with objective lower water content. Samples already dry smoothed with method pounded using mortar until smooth and filtered for get sample form flour meat tombstone Figure 2.

A B C

Figure 1. Freshwater kijing Sample Preparation (A) Kijing *Pilsbryoconcha exilis;* (B) Removal of the gill organs of the kijing; (C) Kijing Gill Dry Sample

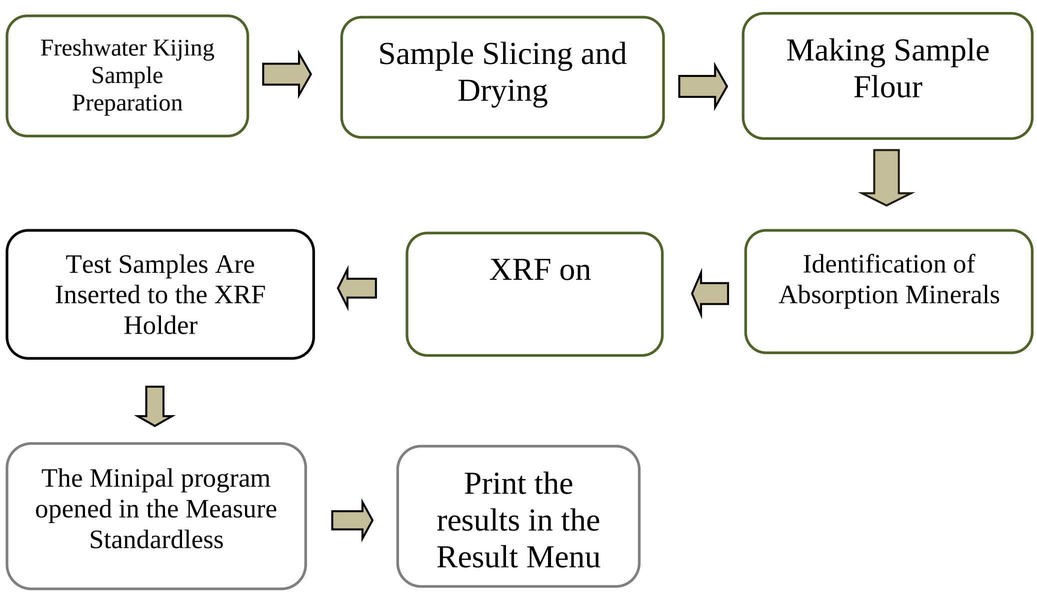

Figure 2. Procedure Meat Mineral Preparation and Identification Freshwater kijing

Furthermore, Quantitative identification of absorbed minerals in samples was carried out using the *X-Ray Fluorescence method* (ED-XRF type) Rigaku NexCG type Figure 3. The XRF testing procedure is carried out in several steps. The first step is to prepare the XRF tool, by turning on the XRF, turning the HT On (X-Ray On) key, opening the Minipal program on the computer and waiting around 10-15 minutes or until the tool is completely ready to be used. The next step is powder and solid sample preparation. This is done by preparing *a holder* that has been fitted with special plastic for XRF and inserting the test sample into the holder. The final step, namely measurement, is carried out by inserting the sample into the XRF tool, opening the Minipal program in the Measure Standardless menu, and filling in the name of the sample to be measured in *the Sample Ident* and *Measure* (according to the sample order). After a few minutes the analysis results will be displayed in the *Results menu* and print the desired analysis results

Figure 3. XRF with type X- rays. XRF

3. Results and Discussion

Results of X -*Ray Fluorescence spectrophotometer analysis* to meat freshwater kijing *P. exilis* in Table 1.

Table 1. Mineral absorption in kijing meat

No	Compound Names	XRF Results
1	Calcium oxide	√
2	Calcium	√
3	Phosphorus pentoxide	√
4	Phosphor	√
5	Manganese oxide	√
6	Sulfur trioxide	√
7	Manganese	√
8	Silicon dioxide	√
9	Aluminum oxide	√
10	Magnesium oxide	√
11	Sulfur	√
12	Ferric oxide sulfur	√
13	Magnesium	√
14	Aluminum	√
15	Silicone	√
16	Chloride	√
17	Iron	√
18	Potassium oxide	√
19	Potassium	√
20	Zinc oxide	√
21	Zinc	√
22	Scandium oxide	√
23	Strontium oxide	√
24	Strontium	√

No	Compound Names	XRF Results
25	Scandium	√
26	Tetraterbium heptaoxide	√
27	Titanium dioxide	√
28	Terbium	√
29	Titanium	√

X-Ray quantitative analysis results *Fluorescence* of the meat of the mussel *P.exilis* against 130 minerals. Identified exists 29 types of minerals contained in different percentages. Based on the data obtained in the table, 29 types of minerals were identified including calcium oxide, calcium, phosphorus pentoxide, phosphorus, manganese oxide, sulfur trioxide, manganese, silicon dioxide, aluminum oxide, magnesium oxide, sulfur, ferric oxide sulfur, magnesium, aluminum, Silicon, Chloride, Iron, Potassium oxide, Potassium, Zinc oxide, Zinc, Scandium oxide, Strontium oxide, Strontium, Scandium, Tetraterbium heptaoxide, Titanium dioxide, Terbium, and Titanium. There are several types of metal minerals such as Ca, Mg, Mn, Al, Fe, K, Zn, Tb, and Ti (Charanworapan *et al*., 2013). Where in this case Fe, Mn, and Zn are included category metal heavy (Adam *et al*., 2018, 2022; Risjani *et al*., 2022). This type of heavy metal is included in the micronutrient category that is needed by deer, but can be used in certain amounts dangerous for (Utami *et al*., 2018). Based on the results of XRF analysis, the 10 dominant minerals contained in kijing meat can be seen in Table 2.

Table 2. Percentage Dominant Mineral Absorption in Meat Freshwater Kijing

No	Chamical Compounds	Formulas	Value
1	Calcium oxide	CaO	48.70%
2	Calcium	Ca	34.80%
3	Phosphorus pentoxide	P_2O_5	30.90%
4	Phosphor	P	13.50%
5	Manganese oxide	MnO	4.90%
6	Sulfur trioxide	SO_3	3.80%
7	Manganese	M N	3.80%
8	Silicon dioxide	SiO_2	2.60%
9	Aluminum oxide	Al_2O_3	2.30%
10	Magnesium oxide	MgO	2.10%

In level molecular the mineral composition in mussels can be influenced by a number of factors, including their living environment, food patterns, and internal biological processes. Based on the data in Table 2. Quantitatively, the 3 most abundant minerals in kijng meat are CaO 48.70%, Ca 34.80%, and P_2O_5 30.90%, followed by other minerals such as P 13.50%, MnO 4.9 %, SO_3 3.8 %, Mn 3.8 %, SiO_2 2.6 %, Al_2O_3 2.3 %, and MgO 2.1 %. In this table, the values for CaO 48.70%, Ca 34.80%, and P_2O_5 30.90% have very dominant amounts compared to the others, especially CaO. Calcium oxide (CaO) is an important element for mussels, especially in the formation of mussel shells. This element is the result of the decomposition of $CaCO_3$ in the shell into CaO and CO_2 (Sidauruk *et al*., 2022). Generally, CaO is found in mussel shells. In the results of the quantitative XRF analysis, this element was identified as being present in the sample, with the largest percentage. The presence of CaO in the sample is thought to be the result of absorption by kijing which originates from the decomposition of elements in the shells of other kijing. According to Retno *et al*., (2012), this element has the potential to act as an adsorbent because it has dehydrator properties. That's why this element is often used as an ingredient to reduce levels metal heavy (Rahmaniah *et al*., 2024). Some of them include the metals Manganese (Mn), Zinc

(Zn), Iron (Fe), especially Mn (Sudarmawan *et al*., 2020). Similar to CaO, another element that plays a role in shell formation is calcium (Ca). Calcium is the element with the second highest percentage value after CaO. This is due to the many important roles that require calcium in deer. Apart from shell formation, calcium also plays a role in contraction muscle (Szent-Györgyi, 1975). Mussel muscles which are moved by calcium will regulate functional activities, body metabolism and body movement activities of clams. Adequate calcium availability will accelerate the growth and development of kerrang (Shita & Sulistiyani, 2010). Calcium, which plays a role in the shell nutrition process, is always related to phosphorus. Based on table 2 data, phosphorus ranks in the third largest percentage after calcium. This element is one of the main elements that make up the shell of the kijing. This mineral is a compound high in ATP which acts as an energy supplier for cellular activities both in the contraction process muscles (Lestari et al., 2019), nerves until metabolism brain (Scabra *et al*., 2021).

One of the heavy metals that is often found in waters is manganese (Mn). Manganese (Mn) is one of the essential microminerals that is important for creature life (Kurniawati *et al*., 2017). In research data, manganese was identified as found in kijing meat. This metal is found in two forms, namely MnO and Mn, with contents of 4.9% and 3.8%. This element plays a very important role in living things. In animals, Mn regulates thirty-six enzymes involved in protein, carbohydrate and fat metabolism (Kurniawati *et al*., 2017). Based on WHO data (2002), several enzymes involved in this metabolic process are *manganese superoxide dismutase* and *pyruvate carboxylase*. This enzyme plays a role in activating the enzymes *kinase*, *decarboxylase*, *transferase* , and *hydrolase* (Hartini, 2012). Individuals who lack manganese intake can experience several adverse effects such as impaired growth, impaired bone formation, and internal problems system reproduction (Rahayu, 2019). However, in excessive amounts, this metal can be toxic to humans nerves center (Kurniawati *et al*., 2017). The presence of the Mn element in kijing is thought to come from absorbed water and plankton. This proves that there is Mn metal content in water, although in different percentages. Based on Minister of Health Decree number 907 of 2002, the standard for drinking water quality in Indonesia is that the maximum manganese content in water is 0.1 mg/L (Hartini, 2012). Meanwhile, the Turkish Guidlines maximum manganese metal in fish is 20 mg/Kg (Gultom *et al*., 2020). This proves that there is an attachment for mineral absorption in the meat of the *P. axilis mussel*. Absorption minerals will be used optimally both metabolically and in shell formation.

4. Conclusion

Research result shows the absorption of minerals in meat freshwater kijing using X-Ray Fluorescence There are 29 absorption minerals. Mineral elements from the top 10 consists from calcium oxide (CaO), calcium (Ca), phosphorus pentoxide (P_2O_5), phosphorus (P), manganese oxide (MnO), sulfur trioxide (SO_3), manganese (Mn), silicon dioxide (SiO_2), aluminum oxide (AlO), magnesium oxide (MgO). Mineral constituents of meat biggest are calcium and phosphorus. quantitative analysis shows that the five most abundant metal elements are CaO 48.70%, Ca 34.80%, P2O5 30.90%, P 13.50%, and MnO 4.9%. These results show that the main mineral compiler meat freshwater kijing is calcium and phosphorus. Element calcium and phosphorus lots utilized freshwater kijing for preparation shell.

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6. References

Abdullah, A., Nurjanah, & Wardhani, Y. K. (2018). Karakteristik Fisik Dan Kimia Tepung Cangkang Kijing Lokal. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *13*(1), 48–57.

https://doi.org/10.17844/jphpi.v13i1.1215.

Adam, M. A., Maftuch, M., Kilawati, Y., & Tahirah, S. N. (2018). Analysis of Heavy Metal Pollutant in Wangi River Pasuruan and Its Impact on Gambusia affinis. *Jurnal Pembangunan Dan Alam Lestari*, *9*(2), 120–128. https://doi.org/10.21776/ub.jpal.2018.009.02.09

Adam, M. A., Soegianto, A., Melissa, C., Khumaidi, A., Ramli, R., Ernawati, E., Mei, I., & Insivitawati, E. (2022). CD4 cell activation with the CD8 marker and metallothionein expression in the gills of cadmium-exposed mosquito fish (Gambusia affinis Baird and Girard 1853) juveniles. *Emerging Contaminants*, *8*, 280–287. https://doi.org/https://doi.org/10.1016/j.emcon.2022.05.002

Apria, R., Awaludin, M., Diniarti, N., & Dewi, Y. (2024). Strategies for Effective Plankton Management in Kijing Taiwanese (Anodonta woodiana , Lea): A Study on Stocking Density and Aquaculture Techniques. *Indonesian Journal of Limnology*, *05*(01), 1–10. https://doi.org/10.51264/inajl.v5i1.60

Astari, D. F., Solichin, A., & Widyorini, N. (2018). Analisis Kelimpahan, Pola Distribusi, Dan Nisbah Kelamin Kerang Kijing (Anodonta woodiana) Di Inlet Dan Outlet Danau Rawapening Jawa Tengah. *Journal of Maquares*, *7*(2), 227-236. https://doi.org/10.14710/marj.v7i2.22546

Carolina, N., & Crime, S. (2020). *Technical Procedure for Micro X-Ray Fluorescence (μ-XRF) Spectrometry* (Trace Evid). Trace Evidence Section Forensic Scientist Manager.

Charanworapan, C., Suddhiprakarn, A., Kheoruenromne, I., Wiriyakitnateekul, W., & Gilkes, R. J. (2013). An evaluation of three Thai phosphate rocks for agronomic use based upon their chemical and mineralogical properties. *Soil Science and Plant Nutrition*, *59*(4), 522–534. https://doi.org/10.1080/00380768.2013.810546

Christakos, S., Dhawan, P., Porta, A., Mady, L. J., & Seth, T. (2011). Vitamin D and Intestinal Calcium Absorption. *Molecular and Cellular Endocrinology*, *347*(1–2), 25–29. https://doi.org/10.1016/j.mce.2011.05.038

Faisal, E., Bahja, & Stevi Indriastuti Maharadi. (2022). Utilization Of Gravestone (Pilsbryoconcha Exilis) A Local Food Ingredients Source Of Protein. *Jurnal Pengabdian Masyarakat: Svasta Harena*, *2*(1), 1–4. https://doi.org/10.33860/jpmsh.v2i1.485

Fassler, C. R. (2004). *The American Mussel Crisis: Effects on the world pearl industry* .

Firmansyah, Y. W., Setiani, O., & Darundiati, Y. H. (2021). Kondisi Sungai di Indonesia Ditinjau dari Daya Tampung Beban Pencemaran: Studi Literatur. *Jurnal Serambi Engineering*, *6*(2), 1879–1890. https://doi.org/10.32672/jse.v6i2.2889

Ghazali, T. M., Desmelati, & Karnila, R. (2015). Pemanfaatan Daging Kijing Air Tawar (Pilsbryoconcha exilis) pada Pembuatan Bakso Terhadap Penerimaan Konsumen. *Jurnal Online Mahasiswa*, 1–10.

Gultom, S. P. (2020). Penentuan Status Cemaran Logam Mangan Pada Daging Kerang Kepah *(Polymesoda erosa).* Skripsi Universitas Jambi.

Hamidah, A. (2006). Pengaruh Penggunaan Berbagai Jenis Ikan sebagai Inang terhadap Kelangsungan Hidup Glochidia Kijing Taiwan (*Anodonta woodiana* Lea). *Biota*, *XI* (3), 185–189.

Hartini, E. (2012). Cascade Aerator dan Bubble Aerator dalam Menurunkan Kadar Mangan Air Sumur Gali. *Jurnal Kesehatan Masyarakat*, *8*(5), 42–50. https://doi.org/10.15294/kemas.v8i1.2258.

Hermi, R., Mursawal, A., Ali, M., Heriansyah, Munandar, Akbardiansyah, Syahril, A., Lubis, F., & Hasibuan, M. (2023). Morfometrik Kerang *Sinanodonta woodiana* di Perairan Lamnaga Kecamatan Meureboh Kabupaten Aceh Barat Provinsi Aceh. *Journal of Aceh Aquatic Science*, *7*(1), 1–8.

Jeratthitikul, E., Paphatmethin, S., Sutcharit, C., Ngor, P. B., Inkhavilay, K., & Prasankok, P. (2022). Phylogeny and biogeography of Indochinese freshwater mussels in the genus Pilsbryoconcha Simpson, 1900 (Bivalvia: Unionidae) with descriptions of four new species. *Scientific Reports*, *12*(1), 1–14. https://doi.org/10.1038/s41598-022-24844-9

Kurniawati, S. D., Santjoko, H., & Husein, A. (2017). *P*asir Vulkanik sebagai Media Filtrasi dalam Pengolahan Air Bersih Sederhana untuk Menurunkan Kandungan Besi (Fe), Mangan (Mn) dan Kekeruhan Air Sumur Gali. *Sanitasi: Jurnal Kesehatan Lingkungan*, 9(1), 20–25. https://doi.org/10.29238/sanitasi.v9i1.746

Lestari, S. M., Soedradjad, R., Soeparjono, S., & Satiawati, T. C. (2019). The Application Phosphate Solubization Bacteria and Rock Phosphate on the Physiological Characteristics of Tomato (*Solanum lycopersicum* L.). *Jurnal Bioindustri*, *02*(01), 319–333.

Li J., Wu X., Bai Z. (2018) Freshwater pearl culture. In J.-F. Gui et al., Eds., Aquaculture in China: Success Stories and Modern Trends, John Wiley & Sons Ltd., New York, http://dx.doi.org/10.1002/9781119120759.ch3_1

Menteri Lingkungan Hidup dan Kehutanan. (2021). Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor 8 Tahun 2021 tentang Tata Hutan dan Penyusunan Rencana Pengelolaan Hutan, serta Pemanfaatan Hutan di Hutan Lindung dan Hutan Produksi. *Indonesia, Kementerian Lingkungan Hidup Dan Kehutanan*, 1–911.

Peraturan Pemerintah RI. (2011). Sungai. In *38 Tahun 2011*. Menteri Hukum dan HAM Republik Indonesia.

Pramesti, D. T., Haeruddin, & Rudiyanti, S. (2014). Biokonsentrasi Bahan Organik Pada Berbagai Ukuran Cangkang Kijing (*Anodonta woodiana*) di Balai Benih Ikan Siwarak Ungaran Semarang. *Management of Aquatic Resources Journal (MAQUARES)*, 3(4), 250-256. https://doi.org/10.14710/marj.v3i4.7106

Putra, S., Arianto, A., Efendi, E., Hasani, Q., & Yulianto, H. (2016). Efektifitas Kijing Air Tawar (Pilsbryoconcha exilis) sebagai Biofilter dalam Sistem Resirkulasi Terhadap Laju Penyerapan Amoniak dan Pertumbuhan Ikan Lele Sangkuriang (Clarias gariepinus). *E-Jurnal Rekayasan Dan Teknologi Budidaya Perairan*, *4*(2), 497–506.

Rahayu, S. Y. S. (2019). *Detoksifikasi Logam Berat di Perairan dan Fortifikasi Makanan Ringan dengan Nanokalsium dari Kerang Air Tawar Famili Unionidae*. Lembaga Penelitian dan Pengabdian pada Masyarakat, Universitas Pakuan.

Rahmaniah, Isdar, E., & Rani, S. R. A. (2024). Sintesis dan karakterisasi kitosan berbasis cangkang landak laut sebagai kandidat absorban logam berat. *Journal Online of Physics*, 9(2), 30-36. https://doi.org/10.22437/jop.v9i2.31486

Rahmawati, S. D., & Siwiendrayanti, A. (2023). Analisis Parameter Kunci Kualitas Air Sungai Kaligarang Menggunakan Metode Water Pollution Index. *HIGEIA :Journal of Public Health Research And Development*, *7*(2), 186–196.

Retno, E., Rizki, B., Dan, S., & Wulandari, N. (2012). Pembuatan Ethanol Fuel Grade Dengan Metode Adsorbsi Menggunakan Adsorbent Granulated Natural Zeolite Dan Cao. *Simposium Nasional RAPI XI* , 46–50.

Risjani, Y., Darmawan, A., Putri Renitasari, D., Lorma Ayuknita, A., Rahma, F., Effendi, S., Dzacky

Pradana, M., Rachma, A., & Awaludin Adam, M. (2022). Histopathological aberration and 17-β-estradiol imbalance in green mussel Perna viridis population cultured in Java Sea, Indonesia. *Egyptian Journal of Aquatic Research*, 49 (2), 197-203. https://doi.org/10.1016/j.ejar.2022.07.002

Santhiarsa, N. (2015). Pengujian Kandungan Unsur Logam Serat Ijuk dengan X-Ray Fluorescence Testing. *Proceeding Seminar Nasional Tahunan Teknik Mesin XIV (SNTTM XIV)*, *Material 2*(Snttm Xiv), 7–8.

Scabra, A. R., Marzuki, M., & Ismail. (2021). Pengaruh penambahan fosfor pada media budidaya terhadap laju pertumbuhan benur udang vaname (Litopenaues vannamei) di salinitas 0 ppt. *Indonesian Journal Of Aquaculture Medium*, *1*(2), 113–124. https://doi.org/10.29303/mediaakuakultur.v1i2.492

Shita, A., & Sulistyani, S. (2015). Pengaruh kalsium terhadap tumbuh kembang gigi geligi anak. STOMATOGNATIC - Jurnal Kedokteran Gigi, 7(3), 40-44.

Sidauruk, S. W., Iriani, D., Diharmi, A., Anggraini, A., & Azka, A. (2022). Physicochemical Characterization of Calcium Oxide from Freshwater Mussel (*Pilsbryoconcha* sp.) Shell. *IOP Conference Series: Earth and Environmental Science*, *1118*(1), 0–6. https://doi.org/10.1088/1755-1315/1118/1/012036

Sudarmawan, W. S., Suprijanto, J., & Riniatsih, I. (2020). Abu Cangkang Kerang Anadara granosa, Linnaeus 1758 (Bivalvia: Arcidae) sebagai Adsorben Logam Berat dalam Air Laut. *Journal of Marine Research*, *9*(3), 237–244. https://doi.org/10.14710/jmr.v9i3.26539

Szent-Györgyi, A. G. (1975). Calcium regulation of muscle contraction. *Biophysical Journal*, *15*(7), 707–723. https://doi.org/10.1016/S0006-3495(75)85849-8

Utami, R., Rismawati, W., & Sapanli, K. (2018). Pemanfaatan Mangrove untuk Mengurangi Logam Berat di Perairan. *Prosiding Seminar Nasional Hari Air Dunia 2018*, 2621–7449.

Warsidah, W., Sofiana, M. S. J., Apriansyah, A., Hartanti, L., Lestari, D., Safitri, I., & Helena, S. (2022). Proximate and Macro Minerals Content of Gastropods in the Waters of Teluk Cina Lemukutan Island West Kalimantan. *Jurnal Biologi Tropis*, *22*(4), 1210–1215. https://doi.org/10.29303/jbt.v22i4.4398

Wulandari, L., Idroes, R., Noviandy, T. R., & Indrayanto, G. (2022). *Chapter Six - Application of chemometrics using direct spectroscopic methods as a QC tool in pharmaceutical industry and their validation* (A. A. B. T.-P. of D. S. Al-Majed Excipients and Related Methodology (ed.); Vol. 47, pp. 327–379). Academic Press. https://doi.org/https://doi.org/10.1016/bs.podrm.2021.10.006