



**UTILIZATION OF ULTRASOUND FOR THE SYNTHESIS OF CALCIUM
HYDROXYAPATITE NANOPARTICLES FROM COCKLE (*Anadara granosa*)
SHELLS TO IMPROVE SURIMI GEL PROPERTIES**

By

MOHAMAD RAIS BIN HASAN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

September 2024

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granosa*) SHELLS TO IMPROVE SURIMI GEL PROPERTIES**

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September 2024

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Seafood loss can be reduced by reusing the waste from the industry. This study uses ultrasound to clean and transform cockle (*Anadara granosa*) shells into hydroxyapatite nanoparticles (HAp), as an ingredient to improve surimi gel properties. This can produce a sustainable surimi ingredient while minimizing waste generated by the industry. The effectiveness of ultrasonic cleaning was tested using continuous (0.18 W/cm², 0.35 W/cm², 0.41 W/cm²) and pulsed (0.35 W/cm², 1:1 On-Off power ratio) modes for 15 and 25 min. The cleaning efficacy was assessed on the whiteness index (WI), morphology, and chemical composition of the shells, as well as the chemical composition and turbidity of the wash water. The clean shells were then used to extract the HAp, where ultrasonic treatment was done for 15 min. The HAp was evaluated on yield percentage, WI, morphology, chemical composition, crystallography, thermal, and surface properties. For the application, the ideal combination of components in the surimi formulation was assessed based on water-holding capacity (WHC), expressible moisture content (EMC), and cooking loss rate (CLR). Using this predetermined

formulation, HAp at varying concentrations (0.1%, 0.5%, 1.0%, and 1.5%) was then added. The gels were assessed on WHC, EMC, CLR, rheology, texture profile analysis, microstructure, mineral composition, and thermal properties. The effective erosion for the cleaning was found at power intensity between 0.35 and 0.41 W/cm² at 37 kHz for 15 min. In pulsed mode, efficacy increased with a 25-min treatment. High-intensity ultrasonic treatment did not impact yield percentage of HAp, WI, or particle shape, but did reduce particle size and distribution range. Crystallinity, crystallite size, and calcium content were also enhanced. It showed a higher specific surface area but lower thermal stability compared to commercial HAp. For the application, the ideal combination of surimi components was found at 3% NaCl, 89.9% paste, and 7.10% water. The addition of HAp to the surimi did not improve moisture retention. Instead, a more compact gel structure and enhanced textural qualities were seen with 0.1% HAp. Ultrasonic treatment during pretreatment and extraction improved the cleaning effectiveness and particle properties of HAp. The produced HAp can be a sustainable ingredient that improves the gel characteristics of surimi.

Keywords: Cockle shells, hydroxyapatite, seafood waste, surimi gel, sustainable food ingredient

SDG: Goal 12: Responsible Consumption and Production

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Kedoktoran Falsafah

**PENGUNAAN ULTRABUNYI UNTUK SINTESIS NANOPARTIKEL
KALSIUM HIDROKSIAPATIT DARI CENGKERANG KERANG
(*Anadara granosa*) UNTUK MENINGKATKAN
CIRI GEL SURIMI**

Oleh

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Kehilangan makanan laut boleh dikurangkan dengan menggunakan semula sisa dari industri. Kajian ini menggunakan ultrabunyi untuk membersihkan dan mengubah cangkering kerang (*Anadara granosa*) kepada nanopartikel hidroksyapatit (HAp), sebagai bahan untuk meningkatkan sifat gel surimi. Ini dapat menghasilkan bahan surimi yang mampan, selain sisa dari industri dikurangkan. Kadar pembersihan ultrasonik diuji menggunakan mod berterusan (0.18 W/cm^2 , 0.35 W/cm^2 , 0.41 W/cm^2) dan berhenti-henti (0.35 W/cm^2 , 1:1 On-Off nisbah kuasa) selama 15 dan 25 minit. Kadar pembersihan dinilai pada indeks keputihan (WI), morfologi, dan komposisi kimia cengkerang serta komposisi kimia dan kekeruhan air basuhan. Cengkerang bersih digunakan untuk mengekstrak HAp, di mana rawatan ultrasonik dilakukan selama 15 minit. HAp dinilai berdasarkan kadar hasil, WI, morfologi, komposisi kimia, kristalografi, sifat haba dan permukaan. Untuk aplikasi, gabungan sesuai komponen surimi dinilai pada kapasiti pegangan air (WHC), kandungan lembapan keluar (EMC), dan kadar kehilangan masak (CLR). Menggunakan formulasi ini, HAp

pada kepekatan yang berbeza-beza (0.1%, 0.5%, 1.0%, dan 1.5%) kemudiannya ditambah. Gel dinilai dari segi WHC, EMC, CLR, reologi, analisis profil tekstur, mikrostruktur, komposisi mineral, dan sifat terma. Hakisan yang berkesan untuk mencuci adalah pada intensiti kuasa antara 0.35 dan 0.41 W/ cm² pada 37 kHz selama 15 minit. Rawatan ultrasonik berintensiti tinggi tidak memberi kesan kepada kadar hasil HAp, WI, atau bentuk, tetapi mengurangkan saiz zarah dan julatnya. Kandungan kalsium, saiz dan kehabluran kristal dipertingkatkan. Ia mempamerkan kawasan permukaan yang tinggi namun kestabilan haba yang rendah berbanding HAp komersial. Untuk aplikasi, gabungan ideal komponen surimi didapati pada 3% NaCl, 89.9% surimi, dan 7.10% air. Penambahan HAp pada surimi tidak meningkatkan pengekatan lembapan. Sebaliknya, struktur gel yang lebih padat dan kualiti tekstur yang dipertingkatkan dilihat dengan 0.1% HAp. Rawatan ultrasonik semasa prarawatan dan pengestrakan meningkatkan kadar pembersihan dan sifat zarah HAp. HAp yang dihasilkan adalah bahan lestari yang meningkatkan ciri-ciri gel surimi.

Kata kunci: Bahan makanan yang mampan, cengkerang kerrang, hidroksiapatit, gel surimi, sisa makanan laut

SDG: Matlamat 12: Penggunaan dan Pengeluaran yang Bertanggungjawab

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LIST OF ABBREVIATIONS

AA	Acetic acid
ACP	Amorphous calcium phosphate
ANOVA	Analysis of variance
APC	Aerobic plate count
ASC	Acidified sodium chloride
BET	Brunauer-Emmett-Teller
CA	Citric acid
CaCO ₃	Calcium carbonate
CFU	Colony-forming unit
ClO ₂	Chlorine dioxide
CLR	Cooking loss rate
CPC	Cetylpyridinium chloride
Ca/P	Calcium-to-phosphorus ratio
DDT	Dichlorodiphenyltrichloroethane
DSC	Differential scanning calorimetry
EI	Electromagnetic irradiation
EDTA	Ethylenediaminetetraacetic acid
EDS	Energy dispersive X-ray spectroscopy
EMC	Expressible Moisture Content
FE-SEM	Field-emission electron microscopy
FTIR	Fourier transform infrared spectroscopy
FVP	Flammulina velutipes polysaccharide
GHz	Giga hertz
GL	Epsilon-(gamma-glutamyl)-lysine

HAp	Hydroxyapatite
HBC	Heterotrophic bacterial count
HCl	Hydrochloric acid
HNO ₃	Nitric acid
HPP	High-pressure processing
hr	Hour
H ₂ O ₂	Hydrogen peroxide
H ₃ PO ₄	Phosphoric acid
ICP-MS	Inductive coupled plasma mass spectroscopy
ISP	Innovative seafood product
J/g.°C	Joule per gram celcius
KG	Konjac glucomannan
kHz	Kilo hertz
Ksp	Solubility product constant
LA	Lactic acid
LED	Light-emitting diode
MHz	Mega mertz
min	Minute
MPa	Mega Pascal
MSZW	Meta stable zone width
NaHCO ₃	Sodium bicarbonate
NaOCl	Sodium hypochlorite
Na ₂ HPO ₄	Disodium hydrogen phosphate
NA	Not available
ND	Not detected

NTU	Nephelometric turbidity units
OCp	Octa calcium phosphate
PBC	Psychrophilic bacterial counts
Qsp	Solubility product quotient
RONS	Reactive oxygen and nitrogen species
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SEM	Scanning electron microscopy
SPSS	Statistical package for the social sciences
STP	Sodium tripolyphosphate
TBARS	Thiobarbituric acid reactive substances
TCP	Tricalcium phosphate
TGase	Transglutaminase enzyme
TSPP	Tetrasodium pyrophosphate
TSP	Trisodium phosphate
WHC	Water-holding capacity
WI	Whiteness index
W/cm ²	Watt per centimetre square
XRD	X-ray diffraction
(NH ₄) ₃ PO ₄	Ammonium phosphate

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

During seafood processing, various fish parts, including shells, heads, skin, and unused meat, are often discarded as waste. This results in a significant amount of seafood loss and waste. In Selangor Malaysia, seafood processors range from small-scale to expanding industrial-scale operations. Although small-scale processing can result in inefficiencies and increased waste, the industry is committed to improving production efficiency and sustainability. This can be achieved through waste valorization. The discarded waste can be transformed into innovative seafood products (ISP), such as fish protein hydrolysate (Agustin et al., 2023), fish calcium (Hasan et al., 2021a), fish gelatin (Islam et al., 2020), fish oils (Fuente et al., 2022), chitin (Huang et al., 2022), and minced fish products (Surasani et al., 2022). Extensive studies have been conducted on transforming seafood shells into hydroxyapatite (HAp) to reduce waste from the industry. For example, researchers have successfully extracted HAp from mussel and cockle shells, and have shown that this material possesses desirable properties for use as a wastewater purifier and bone graft substitute (Mtavangu et al., 2022; Karunakaran et al., 2020). Although HAp is a promising material for various applications, there has been limited focus on the particle characteristics. Specifically, the lack of attention given to its shape and size hinders its effective application in several domains. Furthermore, the efficiency rate of utilizing these resources for HAp and its potential applications in food are still largely unknown. Therefore, it is crucial to address these gaps to ensure the exploitation process is efficient and sustainable.

According to the Food and Agriculture Organization of the United Nations (2022), 40% of global fishery and aquaculture production is lost or wasted due to inefficiencies in processing chains. In 2018, around nine million tonnes of fish products were globally discarded from a total of 100 million tonnes (Ritchie and Roser, 2021). This discarded biomass includes fish and other marine organisms, such as shells, which are frequently discarded without utilization. These represent a significant loss of resources and potential opportunities for sustainable management. Cockles are the most abundantly produced shellfish in Malaysia, with consistent annual production exceeding 10,000 tonnes from 2018-2022 (Department of Fisheries Malaysia, 2022). This has resulted in an increase in discarded shells at processing facilities. According to the World Population Review (2024), Malaysia generated more than 91 kg of food waste per capita in 2024, totaling 2.9 million tonnes annually. This waste originated from industrial sources, food services, and households. It was reported that Malaysians produced 15,000 tonnes of food waste daily, of which 3,000 tonnes were still edible (Malaysia Kini, 2016).

Seafood shells are considered a promising source for the production of HAp. By valorizing these shells, the waste and reliance on direct fish stock exploitation can be reduced, thereby contributing to resource sustainability within the seafood industry. Common seafood shells exploited for HAp production include clams (Sindhya et al., 2022), crabs (Hsu et al., 2023), mussels (Agalya et al., 2022), oysters (Wang et al., 2022), scallops (Islami et al., 2023), and snails (Cheng et al., 2023). However, recent efforts have faced challenges related to inefficiency, resulting in particle properties that are not suitable for specific applications. Key production steps, including shells collection, pretreatment, extraction, and separation, are essential, but the efficiency of

pretreatment and extraction is often overlooked. Common pretreatment methods like washing, boiling, and ultrasonic cleaning lack evidence of effectiveness, and extraction techniques receive insufficient attention regarding particle properties. These steps are crucial for achieving the desired particle quality for intended applications. Various ingredients, including proteins (Singh et al., 2022), salt-alternative compounds (Wijayanti et al., 2021b), enzymes (Li et al., 2022), fiber (Buda et al., 2021), and polysaccharides, have been found to enhance surimi gel formation. However, finding sustainable sources for these ingredients remains a challenge. Surimi is commonly used for imitation crab, fish sausage, and fish balls, with its texture adjustable through various ingredients. Recent studies show that adding proteins like bean seed and soy isolate enhances gel strength and water-holding capacity (WHC) (Xu et al., 2023; Priyadarshini et al., 2022). Additionally, salt-alternative compounds such as calcium (Ca) improve WHC, gel strength, sensory acceptance, and texture (Murthy et al., 2021; Wijayanti et al., 2021b). However, a sustainable approach to these practices requires further research.

Despite growing interest in sustainable seafood processing, significant waste from shellfish, especially cockle shells, remains underutilized. Converting these Ca-rich shells into HAp through ultrasonication presents a sustainable solution. The enhanced surface properties of HAp promote better integration into the surimi protein network, potentially improving the gel's functionality (Mtavangu et al., 2022). The research gaps for each objective are extensively evaluated in the literature review section. First, although methods such as boiling, chemical immersion, and ultrasonic cleaning have been studied, recent research still leaves their effectiveness uncertain (Anggraini et al., 2021; Mtavangu et al., 2022; Cheng et al., 2023; Ahmed et al., 2022; El-Bassyouni et

al., 2020). Second, although ultrasound can enhance HAp particle characteristics (Agalya et al., 2022), its underutilization limits understanding of its mechanisms and efficiency. This research aims to demonstrate its effectiveness in converting cockle shells into HAp for surimi. Third, the thermal and surface properties of HAp derived from seafood shells, particularly regarding its suitability for food applications, remain undetermined. Fourth, although various additives have been used to enhance surimi gel properties, the crucial interactions and optimal combinations of the basic ingredients remain insufficiently explored. Last, research on the potential effects of HAp derived from seafood shells in food applications is unknown. Therefore, this study aims to address these gaps by utilizing ultrasound in the pretreatment and extraction of HAp to enhance the quality of surimi gel. Research has demonstrated that Ca compounds can enhance the gel and nutritional qualities of surimi (Wijayanti et al., 2021b; Murthy et al., 2021), and HAp is expected to provide similar benefits.

Research suggests that converting seafood waste into HAp can help reduce seafood loss (Mtavangu et al., 2022; Anggraini et al., 2021). However, the resource-intensive methods currently used to produce application-specific HAp particles pose efficiency challenges. Studies have investigated various methods for the pretreatment and extraction of HAp from seafood shells. However, the currently employed methods are often ineffective, leading to compromised particle quality and limiting their applications, which ultimately hinders the efficient utilization of seafood shells (El-Bassyouni et al., 2020; Hariani et al., 2020). This current research highlights the potential of ultrasound as an effective tool for obtaining this ingredient from cockle shells. Ultrasound treatment can be utilized as an assistance tool during pre-treatment and extraction steps to clean the shells and alter particle properties, respectively.

Operating at frequencies beyond human hearing, the cavitation implosion from ultrasound generates a destructive effect, potentially aiding in cleaning and particle size reduction. In recent years, ultrasound has gained significant attention in the seafood industry due to its potential to enhance various processing techniques. The application of ultrasound in seafood processing can enhance the preservation of nutrients, texture, and flavor, while also improving safety by reducing microbial load (Ma et al., 2023; Sun et al., 2023). Studies have shown that ultrasound can help achieve the desired particle characteristics of HAp (Wijayanti et al., 2021a; Yu et al., 2020). The addition of Ca compounds in surimi has been shown to improve the structural integrity of the gel by creating cross-linked networks (Wijayanti et al., 2021b). Therefore, this study assesses the utilization of cockle shells as a potential sustainable surimi ingredient by turning them into HAp via ultrasound.

1.2 Research Objectives

Based on the hypothesis, the research objectives are as follows:

1. To determine the impact of ultrasonic cleaning on cockle (*Anadara granosa*) shells during pretreatment.
2. To evaluate the impact of ultrasound in assisting extraction of HAp via a one-step process.
3. To assess the thermal and surface characteristics of the produced HAp.
4. To optimize components of surimi in gel formulation via custom mixture design.
5. To assess the effects of HAp addition on the gel characteristics of surimi.

1.3 Significance of the Study

Seafood production can be improved through the adoption of a circular processing system. This innovative approach involves converting discarded shells into sustainable surimi ingredients, thereby minimizing waste in the industry. This valorization can alleviate pressure on fishery stocks and support sustainability initiatives. This is a crucial step towards creating a more sustainable and efficient seafood industry. Ultrasound pretreatment and extraction improve shells cleaning and particle characteristics, respectively. These enhancements may contribute to the theoretical framework. Cavitation implosion can dislodge impurities from the shells through erosion, while the turbulence of the acoustic wave flow carries them away. These bubbles not only aid in cleaning but also during extraction by facilitating particle fragmentation into smaller clusters (Wijayanti et al., 2021; Yu et al., 2020). This occurrence leads to secondary nucleation, yielding an improvement in crystallinity, crystallite size, and Ca content. The turbulence effect also disperses the particles during extraction, ensuring uniformity in size and shape. The resulting uniform and nano-sized particles that have many reactive sites can effectively integrate with protein molecules (Yin et al., 2014). This can promote network formation, enhancing surimi texture properties such as hardness, gumminess, chewiness, and solid-like behavior. By converting non-edible seafood portions into useful ingredients for surimi products, the local seafood sector can create additional income sources. This approach would not only improve market competitiveness but also address waste management issues, benefiting local communities. The cost-effective and customizable gel properties of surimi offer valuable guidance for manufacturers interested in sustainable seafood practices. Together, these can improve the current seafood practices by exploiting

various discarded portions using ultrasound in a sustainable manner, contributing to a reduction in seafood losses.

1.4 Structure of the Thesis

The thesis is structured in a format following Layout Style 2, comprising eight chapters. Out of these, five chapters are experimental and form the core findings of the research. Figure 1.1 illustrates the structure of the thesis.



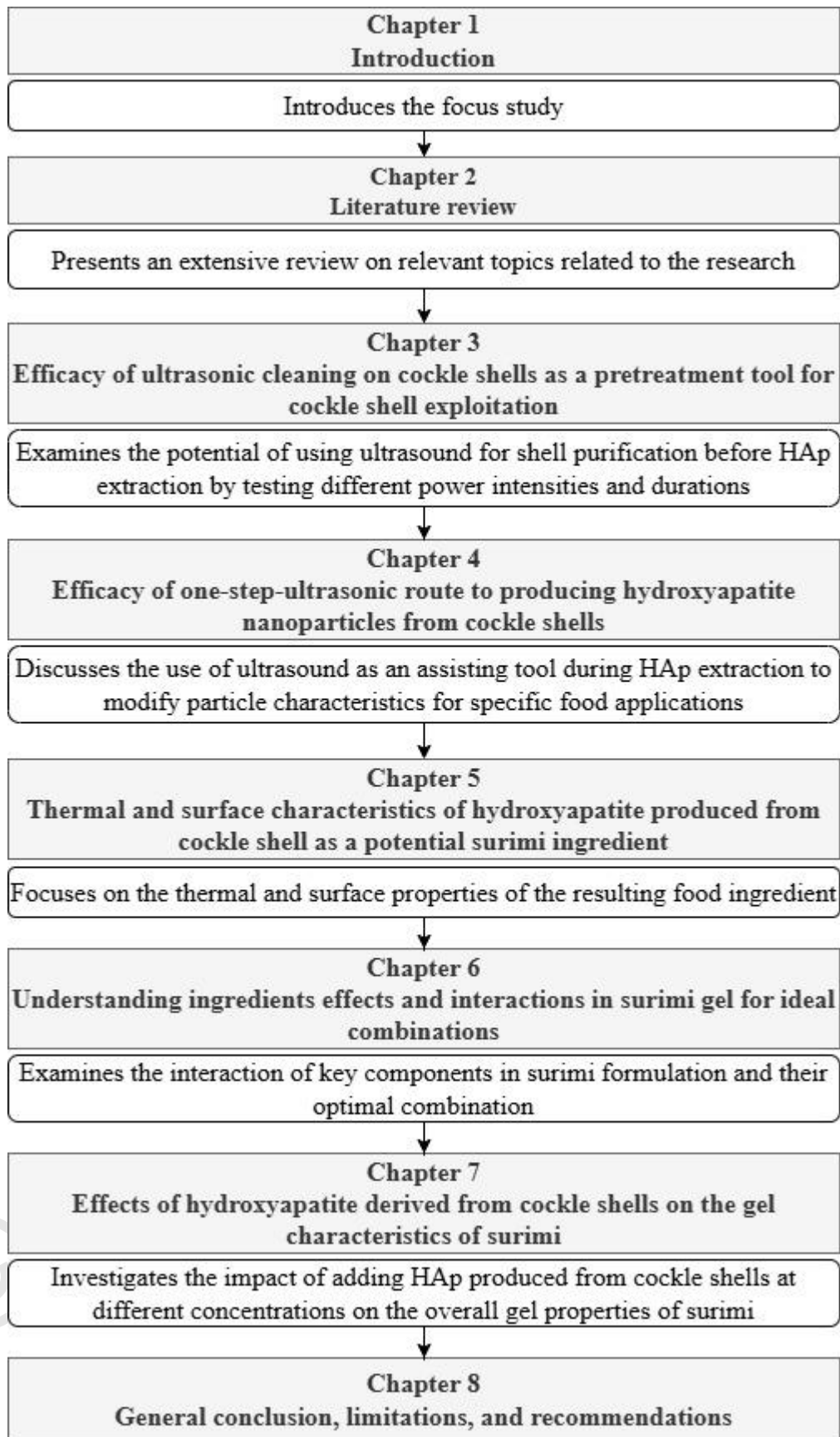


Figure 1.1: Structure of the thesis.

REFERENCES

- Abd El-Al, M. S., Saeed, A. M., Hammad, A. A., Swailam, H. M. and Abouzeid, M. A. (2022). Gamma-irradiation induced effects on histamine-forming bacteria isolated from the chilled mackerel fish. *Egyptian Journal of Aquatic Biology and Fisheries*, 26(3): 869-883.
- Abdel-Rahman, G., Ahmed, M. and Marrez, D. (2018). Reduction of heavy metals content in contaminated vegetables due to the post-harvest treatments. *Egyptian Journal of Chemistry*, 61(6): 225 - 235.
- Aboudamia, F. Z., Kharroubi, M., Neffa, M. Aatab, F., Hanoune, S., Bouchdoug, M., and Jaouad, A. (2020). Potential of discarded sardine scales (*Sardina pilchardus*) as chitosan sources. *Journal of the Air and Waste Management Association*, 70(11): 1186–1197.
- Acosta, E. (2009). Bioavailability of nanoparticles in nutrient and nutraceutical delivery. *Current Opinion in Colloid and Interface Science*, 14(1): 3–15.
- Afriani, F., Evi., J., Rafsanjani, R. A., Amelia, R., Hudatwi, M. and Tiandho, Y. (2021). Synthesis of 3D-porous scaffold from cockle shells waste-based hydroxyapatite with addition silica from tin tailings. *IOP Conference Series: Earth and Environmental Science*, 926(2021): 1-5.
- Agalya, P., Suresh Kumar, G., Prabu, K. M., Cholan, S., Karunakaran, G. and Hakami, J. (2022). One-pot ultrasonic-assisted synthesis of magnetic hydroxyapatite nanoparticles using mussel shell biowaste with the aid of trisodium citrate. *Ceramics International*, 48(19): 28299– 28307.
- Aguirre, M., Owens, C., Miller, R. and Alvarado, C. (2018). Descriptive sensory and instrumental texture profile analysis of Woody breast in marinated chicken. *Poultry Science*, 97(4): 1456-1461.
- Agustin, V., Putra, M. M. P. and Husni, A. (2023). Impact of enzymatic hydrolysis on antioxidant activity of snakehead fish (*Channa striata*) head protein hydrolysate. *Jurnal Ilmiah Perikanan Dan Kelautan*, 15(1): 44–56.
- Ahmed, J., Habeebullah, S. F., Thomas, L., Mulla, M. Z., Jacob, H. and Alagarsamy, S. (2021). Effect of high-pressure treatment and refrigerated storage on the amino acid profile, color, and texture of hammour (*Epinephelus coioides*) fillets. *Journal of Food Processing and Preservation*, 45(12): 1-11.
- Ahmed, H. Y., Safwat, N., Shehata, R., Althubaiti, E. H., Kareem, S., Atef, A., Qari, S. H., Aljahani, A. H., Al-Meshal, A. S., Youssef, M. and Sami, R. (2022). Synthesis of natural nano-hydroxyapatite from snail shells and its biological activity: Antimicrobial, Antibiofilm, and Biocompatibility. *Membranes*, 12(4): 1-17.

- Ahmed, M. A. and Mohamed, A. A. (2024). Advances in ultrasound-assisted synthesis of photocatalysts and sonophotocatalytic processes: A review. *iScience*, 27(1): 1-19.
- Allen, G. R. (1985). An Annotated and Illustrated Catalogue of Lutjanid Species Known to Date. In W. Fischer (Ed.), *FAO Species Catalogue. Vol. 6. Snappers of the World* (pp. 208). Rome: Food and Agriculture of United Nations.
- Alenyorege, E. A., Ma, H., Ayim, I., Lu, F. and Zhou, C. (2019). Efficacy of sweep ultrasound on natural microbiota reduction and quality preservation of Chinese cabbage during storage. *Ultrasonics Sonochemistry*, 59: 1-10.
- Alexandre, E. M. C., Brandão, T. R. S. and Silva, C. L. M. (2012). Efficacy of non-thermal technologies and sanitizer solutions on microbial load reduction and quality retention of strawberries. *Journal of Food Engineering*, 108(3): 417–426.
- Al-Juboori, R. A., Aravinthan, V. and Yusaf, T. (2015). Impact of pulsed ultrasound on bacteria reduction of natural waters. *Ultrasonics Sonochemistry*, 27(2015): 137-147.
- Amiri, A., Sharifian, P. and Soltanizadeh, N. (2018). Application of ultrasound treatment for improving the physicochemical, functional and rheological properties of myofibrillar proteins. *International Journal of Biological Macromolecules*, 111: 139–147.
- Amorim, M. O., Júnior, J. C. C. S., Ruiz, Y. L. and Andrade, J. C. S. (2021). Synthesis and characterization of niobium-doped fish scale-derived hydroxyapatite by physical ultrasound interference. *Cerâmica*, 67(381): 23-27.
- Anese, M., Maifreni, M., Bot, F., Bartolomeoli, I. and Nicoli, M. C. (2015). Power ultrasound decontamination of wastewater from fresh-cut lettuce washing for potential water recycling. *Innovative Food Science and Emerging Technologies*, 32: 121–126.
- Anggraini, R., Sari, M., Aminatun, Suciati, T., Dahlan, K. and Yusuf, Y. (2021). Nanostructure of carbonated hydroxyapatite precipitation extracted from pearl shells (*Pinctada maxima*) by pH treatment. *Digest Journal of Nanomaterials and Biostructures*, 16(4): 1619-1625.
- Ansari, M. H. and Ibrahim, M. H. I. (2017). Thermal characteristic of waste-derived hydroxyapatite (HA) reinforced ultra-high molecular weight polyethylene (UHMWPE) composites for fused deposition modeling (FDM) process. *IOP Conference Series: Materials Science and Engineering*, 165(2017): 1-17.
- AOAC International. (2000). Official Methods of Analysis. (17th Ed.): Gaithersburg, MD. 950.46.

- Arruda, H. S., Silva, E. K., Pereira, G. A., Angolini, C. F. F., Eberlin, M. N., Meireles, M. A. and Pastore, G. M. (2019). Effects of high-intensity ultrasound process parameters on the phenolic compounds recovery from araticum peel. *Ultrasonics Sonochemistry*, 50: 82–95.
- Astala, R. and Stott, M. J. (2008). First-principles study of hydroxyapatite surfaces and water adsorption. *Physical Review B*, 78(7): 1-11.
- Atitallah, B. A., Hentati, F., Dammak, M., Hadrich, B., Fendri, I., Ayadi, M., Michaud, P., Abdelkafi, S. and Barkallah, M. (2019). Effect of Microalgae incorporation on quality characteristics and functional and antioxidant capacities of ready-to-Eat fish burgers made from common carp (*Cyprinus Carpio*). *Applied Sciences*, 9(9): 1-12.
- Awad, S. B. (2011). High-Power Ultrasound in Surface Cleaning and Decontamination. In H. Feng, G. Barbosa-Canovas, and J. Weiss. (Ed.), *Ultrasound Technologies for Food and Bioprocessing* (pp. 545-558). New York: Springer.
- Bakare, A. H., Adeola, A. A., Otesile, I., Obadina, A. O., Afolabi, W. A., Adegunwa, M. O., Akerele, R. A., Bamgbose, O. O. and Alamu, E. O. (2020). Nutritional, texture, and sensory properties of composite biscuits produced from breadfruit and wheat flours enriched with edible fish meal. *Food Science and Nutrition*, 8(11): 6226-6246.
- Bharane, P. R., Bethi, C. M. and Kudre, T. G. (2020). Effect of Catla catla Roe protein isolate on textural and sensorial properties of surimi gel from *Piaractus brachypomus*. *Journal of Food Measurement and Characterization*, 14(3): 1391-1401.
- Boziaris, I. S., Parlapani, F. F. and Mireles DeWitt, C. A. (2021). High pressure processing at ultra-low temperatures: Inactivation of foodborne bacterial pathogens and quality changes in frozen fish fillets. *Innovative Food Science and Emerging Technologies*, 74: 1-10.
- Buamard, N., Singh, A., Zhang, B., Hong, H., Singh, P. and Benjakul, S. (2023). Ethanolic extract of duea ching fruit: Extraction, characterization and its effect on the properties and storage stability of sardine Surimi gel. *Foods*, 12(8): 1-18.
- Buda, U., Priyadarshini, M. B., Majumdar, R., Mahanand, S., Patel, A. and Mehta, N. (2021). Quality characteristics of fortified silver carp surimi with soluble dietary fiber: Effect of apple pectin and konjac glucomannan. *International Journal of Biological Macromolecules*, 175: 123-130.
- Bulina, N. V., Makarova, S. V., Baev, S. G., Matvienko, A. A., Gerasimov, K. B., Logutenko, O. A. and Bystrov, V. S. (2021). A study of thermal stability of hydroxyapatite. *Minerals*, 11(12): 1-15.

- Chatzisyneon, E. (2016). Inactivation of bacteria in seafood processing water by means of UV treatment. *Journal of Food Engineering*, 173: 1–7.
- Chen, K., Zhang, T., Chen, Xgalottalotta., He, Y.-J., and Liang, X. (2018). Model construction of micro-pores in shale: A case study of Silurian Longmaxi formation shale in Dianqianbei area, SW China. *Petroleum Exploration and Development*, 45(3): 412–421.
- Chen, J., Deng, T., Wang, C., Mi, H., Yi, S., Li, X. and Li, J. (2020). Effect of hydrocolloids on gel properties and protein secondary structure of silver carp surimi. *Journal of the Science of Food and Agriculture*, 100(5): 2252–2260.
- Chen, B., Huang, J., Liu, Y., Liu, H., Zhao, Y. and Wang, J. J. (2021). Effects of the curcumin-mediated photodynamic inactivation on the quality of cooked oysters with *Vibrio parahaemolyticus* during storage at different temperature. *International Journal of Food Microbiology*, 345: 1–11.
- Cheng, M., Hu, L., Pan, P., Liu, Q., Zhang, Z., Wang, C., Liu, M. and Chen, J. (2023). Abalone shell-based magnetic macroporous hydroxyapatite microspheres with good reusability for efficient dye adsorption. *Colloids and Surfaces B: Biointerfaces*, 231: 1–8.
- Chow, R., Blindt, R., Chivers, R. and Povey, M. (2003). The sonocrystallisation of ice in sucrose solutions. Primary and secondary nucleation. *Ultrasonics*, 41(8): 595–604.
- Chudasama, N. A., Sequeira, R. A., Moradiya, K. and Prasad, K. (2021). Seaweed polysaccharide-based products and materials: An assessment on their production from a sustainability point of view. *Molecules*, 26(9): 1–19.
- Citradewi, P. W., Hidayat, H., Purwiandono, G., Fatimah, I. and Sagadevan, S. (2021). *Clitorea ternatea*-mediated silver nanoparticle-doped hydroxyapatite derived from cockle shell as antibacterial material. *Chemical Physics Letters*, 769: 1–8.
- Dalvi, S. V. and Yadav, M. D. (2015). Effect of ultrasound and stabilizers on nucleation kinetics of curcumin during liquid antisolvent precipitation. *Ultrasonics Sonochemistry*, 24: 114–122.
- Daud, Z., Abubakar, M. H., Kadir, A. A., Latiff, A. A. A., Awang, H., Halim, A. A. and Marto, A. (2017). Batch study on cod and ammonia nitrogen removal using granular activated carbon and cockle shells. *International Journal of Engineering*, 30(7): 937–944.
- Daupor, H., Ricky, W.A., Pongsaton, A., Isma-ae, C. and Acharee, S. (2022). Synthesis of Hydroxyapatite from Budu Waste by Calcination Method. *Iranian Journal of Chemistry & Chemical Engineering*, 41(12): 4203–4212.
- Department of Fisheries Malaysia (2022). Annual Fisheries Statistics 2022 (Volume 1). Retrieved from <https://www.dof.gov.my/sumber/perangkaan-perikanan-i/>

- Dhanaraj, K. and Suresh, G. (2018). Conversion of waste sea shell (*Anadara granosa*) into valuable nanohydroxyapatite (nHAp) for biomedical applications. *Vacuum*, 152: 222-230.
- Dikici, A., Özpolat, E., Bozatli, S. B., Koluman, A., Patir, B. and Çalicioğlu, M. (2021). Investigating the effect of decontaminants on microbiological and chemical properties of rainbow trouts. *Turkish Journal of Veterinary and Animal Sciences*, 45(4): 691-699.
- Dodds, J., Espitalier, F., Louisnard, O., Grossier, R., David, R., Hassoun, M., Baillon, F., Gatumel, C. and Lyczko, N. (2007). The effect of ultrasound on crystallisation-precipitation processes: Some examples and a new segregation model. *Particle and Particle Systems Characterization*, 24(1): 18-28.
- Dumetz, A. C., Chockla, A. M., Kaler, E. W. and Lenhoff, A. M. (2008). Effects of pH on protein–protein interactions and implications for protein phase behavior. *Biochimica et Biophysica Acta (BBA) - Proteins and Proteomics*, 1784(4): 600-610.
- Eddin, A. S., Adegoke, S., Issa, A. T., Wilson, C. and Tahergorabi, R. (2020). Physicochemical changes of surimi gels with addition of different particle sizes of citrus peel fiber. *Journal of Aquatic Food Product Technology*, 29(10): 1029–1040.
- Eddin, A. S., Adegoke, S. C., Ibrahim, S. A. and Tahergorabi, R. (2021). Fortification of surimi gels with camel milk. *Journal of Aquatic Food Product Technology*, 30(5): 535–548.
- El-Bassyouni, G. T., Eldera, S. S., Kenawy, S. H. and Hamzawy, E. M. (2020). Hydroxyapatite nanoparticles derived from mussel shells for in vitro cytotoxicity test and cell viability. *Heliyon*, 6(6): 1-10.
- Ensminger, D. and Bond, L. J. (2012). Ultrasonic: A Broad Field. In L. L. Faulkner. (Ed.), *Ultrasonics Fundamentals, Technologies, and Applications* (pp. 1-25). U.S.A.: CRC Press.
- Esua, O. J., Cheng, J. and Sun, D. (2020). Antimicrobial activities of plasma-functionalized liquids against foodborne pathogens on grass carp (*Ctenopharyngodon Idella*). *Applied Microbiology and Biotechnology*, 104(22), 9581-9594.
- Esua, O. J., Cheng, J. and Sun, D. (2021a). Optimisation of treatment conditions for reducing *Shewanella putrefaciens* and *Salmonella Typhimurium* on grass carp treated by thermoultrasound-assisted plasma functionalized buffer. *Ultrasonics Sonochemistry*, 76: 1-11.
- Esua, O. J., Cheng, J. and Sun, D. (2021b). Novel technique for treating grass carp (*Ctenopharyngodon idella*) by combining plasma functionalized liquids and ultrasound: Effects on bacterial inactivation and quality attributes. *Ultrasonics Sonochemistry*, 76: 1-14.

- Esua, O. J., Sun, D., Ajani, C. K., Cheng, J. and Keener, K. M. (2022). Modelling of inactivation kinetics of *Escherichia coli* and *Listeria monocytogenes* on grass carp treated by combining ultrasound with plasma functionalized buffer. *Ultrasonics Sonochemistry*, 88: 1-11.
- Fang, C., Tang, W., Wu, S., Wang, J. and Gao, Z. (2020). Ultrasound-assisted intensified crystallization of L-glutamic acid: Crystal nucleation and polymorph transformation. *Ultrasonics Sonochemistry*, 68: 1-12.
- Fatimah, I., Hidayat, H., Purwiandono, G., Khoirunisa, K., Zahra, H. A., Audita, R. and Sagadevan, S. (2022). Green synthesis of antibacterial nanocomposite of silver nanoparticle-doped hydroxyapatite utilizing *Curcuma longa* leaf extract and land snail (*Achatina fulica*) shell waste. *Journal of Functional Biomaterials*, 13(2): 1-10.
- Food and Agriculture Organization of the United Nations. (2006). Defining and Setting Programme Goals. In L. Allen, B. Benoist, O. Dairy and R. Hurrell. (Ed.), *Guidelines on Food Fortification with Micronutrients* (pp. 139-177). France: World Health Organization.
- Food and Agriculture Organization of the United Nations. (2009). Food balance sheet data. Retrieved from <http://faostat3.fao.org/home/index.html>
- Food and Agriculture Organization of the United Nations. (2022). *World review. The state of world fisheries and aquaculture 2022: Towards blue transformation* (pp. 1-91). Rome: Food and Agriculture of the United Nations.
- Food and Drug Administration (2004). Juice HACCP hazards and controls guidance (First edition. Available at: <https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-juice-hazard-analysis-critical-control-point-hazards-and-controls-guidance-first> (Accessed on October 2023).
- Fuchs, F. J. (2015). Ultrasonic Cleaning and Washing of Surfaces. In A. Juan, Gallego-Jua' rez and F. Karl. (Ed.), *Power Ultrasonics Applications of High-intensity Ultrasound* (pp. 577-609). Jamestown, NY, USA: Woodhead Publishing Series.
- Fuente, B., Pinela, J., Calhelha, R. C., Heleno, S. A., Ferreira, I. C. F. R., Barba, F. J., Berrada, H., Caleja, C. and Barros, L. (2022). Sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) head oils recovered by microwave-assisted extraction: Nutritional quality and biological properties. *Food and Bioproducts Processing*, 136: 97-105.
- Galotta, A., Rubenis, K., Locs, J. and Sglavo, V. M. (2023a). Dissolution-precipitation synthesis and cold sintering of mussel shells-derived hydroxyapatite and hydroxyapatite/chitosan composites for bone tissue engineering. *Open Ceramics*, 15: 1-15.

- Galotta, A., Kristaps Rubenis, Locs, J. and Sglavo, V. M. (2023b). Dissolution-precipitation synthesis and cold sintering of mussel shells-derived hydroxyapatite and hydroxyapatite/chitosan composites for bone tissue engineering. *Open Ceramics*, 15: 1-13.
- Gani, A., Benjakul, S. and Ul Ashraf, Z. (2020). Nutraceutical profiling of surimi gel containing β -glucan stabilized virgin coconut oil with and without antioxidants after simulated gastro-intestinal digestion. *Journal of Food Science and Technology*, 57(8): 3132-3141.
- Gao, Y., Fukushima, H., Deng, S., Jia, R., Osako, K. and Okazaki, E. (2018). Effect of pH and heating conditions on the properties of Alaska Pollock (*Theragra chalcogramma*) surimi gel fortified with fish oil. *Journal of Texture Studies*, 49(6): 595-603.
- Gao, R., Wang, X., Shi, T., Wijaya, G. Y., Bai, F., Wang, J., Jin, W. and Yuan, L. (2021). Enhanced physical properties of reduced-salt surimi gels from Amur sturgeon (*Acipenser schrenckii*) by L-arginine and L-histidine. *Journal of Food Processing and Preservation*, 45(11): 1-11.
- Gore, S. B., Xavier, K. M., Nayak, B. B., Tandale, A. T., and Balange, A. K. (2022). Technological effect of dietary oat fiber on the quality of minced sausages prepared from Indian major carp (*Labeo rohita*). *Bioactive Carbohydrates and Dietary Fibre*, 27: 1-8.
- Guenneugues, P., and Ianelli, J. (2014). Surimi Resources and Market. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 26–53). Boca Raton, FL: CRC Press.
- Gündüz, H. and Öztürk, F. (2020). Prevalence of *Listeria spp.* in seafood samples and control of *Listeria monocytogenes* using LISTEX™ P100 bacteriophage applications in smoked rainbow trout. *Journal of Agricultural Sciences*, 27(4): 493-499.
- György, S., Károly, Z., Fazekas, P., Németh, P., Bódis, E., Menyhárd, A., Kótai, L. and Klébert, S. (2019). Effect of the reaction temperature on the morphology of nanosized HAp. *Journal Thermal Analysis Calorimetry*, 138: 145-151.
- Hajfathalian, M., Jorjani, S. and Ghelichi, S. (2020). Characterization of fish sausage manufactured with combination of sunflower oil and fish oil stabilized with fish roe protein hydrolysates. *Journal of Food Science and Technology*, 57(4): 1439-1448.
- Hamada, H. M., Abed, F., Tayeh, B. A., Jawahery, M. S. A., Majdi, A. and Yousif, S. T. (2023). Effect of recycled seashells on concrete properties: A comprehensive review of the recent studies. *Construction and Building Materials*, 376: 1-16.

- Han, S., Jo, J. Y., Park, S. R., Choi, C. and Ha, S. (2021). Impact of chlorine dioxide and electron-beam irradiation for the reduction of murine norovirus in low-salted “jogaejeotgal”, a traditional Korean salted and fermented clam. *International Journal of Food Microbiology*, 342: 1-7.
- Han, Q., Wang, Y., Chu, Q. and Bao, B. (2022). Effect of extracts derived from Brown algae (*Sargassum horneri*) on the gel property and moisture distribution of Hairtail Surimi gel (*Trichiurus haumela*). *Foods*, 11(3): 1-16.
- Hariani, P. L., Riyanti, F., Fatma, F., Rachmat, A. and Herbanu, A. (2020). Removal of Pb (II) using hydroxyapatite from golden snail shell (*Pomacea canaliculata* L.) modified with silica. *Molekul*, 15(2): 130-139.
- Hasan, M. R., Mohd Yasin, N. S., Ghazali, M. S. M. and Mohtar, N. F. (2020). Proximate and morphological characteristics of nano hydroxyapatite (Nano HAp) extracted from fish bone. *Journal of Sustainability Science and Management*, 15(8): 9-21.
- Hasan, M. R., Sabri M. G. M. and Mohtar, N. F. (2021a). Correlation of heating profile with calcination temperature for the extraction of nano hydroxyapatite (Nano-HAp) derived from bone. *Journal of Mechanical Engineering and Sciences*, 15(1): 7792–7806.
- Hasan, M. R., Ghazali, M. S. M. and Mohtar, N. F. (2021b). Nitrogen sorption isotherms of biologically synthesized non-stoichiometric hydroxyapatite nanoparticles (HAp NPs) extracted from fish bones. *Global Journal of Science Frontier Research: C Biological Science*, 21: 1-14.
- Hazurina, N. O., Bakar, B. H. A., Don, M. M. and Johari, M. A. M. (2013). Cockle shell ash replacement for cement and filler in concrete. *Malaysian Journal of Civil Engineering*, 25(2): 201-211.
- He, Y., Zhao, X., Chen, L., Zhao, L. and Yang, H. (2021). Effect of electrolysed water generated by sodium chloride combined with sodium bicarbonate solution against listeria innocua in broth and on shrimp. *Food Control*, 127: 1-12.
- Hembrick-Holloman, V., Samuel, T., Mohammed, Z., Jeelani, S. and Rangari, V. K. (2020). Ecofriendly production of bioactive tissue engineering scaffolds derived from egg- and sea-shells. *Journal of Materials Research and Technology*, 9(6): 13729-13739.
- Herbanu, A., Ana, I. D., Ardhani, R. and Siswomihardjo, W. (2023). Fibrous PVA matrix containing strontium-substituted Hydroxyapatite nanoparticles from golden Apple snail (*Pomacea canaliculata* L.) shells for bone tissue engineering. *Bioengineering*, 10(7): 1-19.
- Homayonpour, P., Jalali, H., Shariatifar, N. and Amanlou, M. (2021). Effects of nano-chitosan coatings incorporating with free /nano-encapsulated cumin (*Cuminum cyminum* L.) essential oil on quality characteristics of sardine fillet. *International Journal of Food Microbiology*, 341: 1-10.

- Hou, Y., Xia, S., Ma, C., Xue, C. and Jiang, X. (2023). Effects of the soy protein to wheat gluten ratio on the physicochemical and structural properties of Alaska Pollock surimi-based meat analogs by high moisture extrusion. *Food Research International*, 173: 1-8.
- Hsu, H., Wu, S., Lin, C. and Ho, W. (2023). Characterization of Hydroxyapatite/Chitosan composite coating obtained from crab shells on low-modulus ti-25nb-8Sn alloy through hydrothermal treatment. *Coatings*, 13(2): 1-18. H
- Hu, J., Huang, W., Wang, Y., Jin, J., Li, Y., Chen, J., Zheng, Y. and Deng, S. (2023). Atmospheric cold plasma: A potential technology to control *Shewanella putrefaciens* in stored shrimp. *International Journal of Food Microbiology*, 390: 1-10.
- Huang, Y., Sido, R., Huang, R. and Chen, H. (2015). Application of water-assisted pulsed light treatment to decontaminate raspberries and blueberries from *Salmonella*. *International Journal of Food Microbiology*, 208: 43-50.
- Huang, K., Wrenn, S., Tikekar, R. and Nitin, N. (2018). Efficacy of decontamination and a reduced risk of cross-contamination during ultrasound-assisted washing of fresh produce. *Journal of Food Engineering*, 224(2): 95-104.
- Huang, J., Ye, B., Wang, W., Li, J., Yi, S., Li, X., Xu, Y. and Mi, H. (2020). Incorporation effect of inulin and microbial transglutaminase on the gel properties of silver carp (*Hypophthalmichthys molitrix*) surimi. *Journal of Food Measurement and Characterization*, 15(1): 1-11.
- Huang, Y., Chang, W. and Hsu, C. (2021). Inactivation of norovirus by atmospheric pressure plasma jet on salmon sashimi. *Food Research International*, 141: 1-11.
- Huang, W-C., Zhao, D., Xue, C. and Mao, X. (2022). An efficient method for chitin production from crab shells by a natural deep eutectic solvent. *Marine Life Science & Technology*, 4(3): 384-388.
- Huang, P., Cheng, Y., Hsieh, H., Ko, W., Lu, W. and Li, P. H. (2023). Effects of transglutaminase on the physicochemical properties of surimi and kamaboko prepared by thermal and low level-pressure treatments. *LWT- Food Science and Technology*, 183(1): 1-14.
- Husein, R. and Abdullah, N. (2021). Effect of temperature and long storage against profile amino acid and value protein carbonyls fish snapper (*Lutjanus sp*). *IOP Conference Series: Earth and Environmental Science*, 681(1): 1-6.
- Hussain, S., Shah, Z. A., Sabiruddin, K. and Keshri, A. K. (2023). Characterization and tribological behaviour of Indian clam seashell-derived hydroxyapatite coating applied on titanium alloy by plasma spray technique. *Journal of the Mechanical Behavior of Biomedical Materials*, 137(2023): 1-15.

- Hwang, I. M., Lee, H-W., Lee, H. M., Yang, J-S., Seo, H. Y., Chung, Y-J. and Kim, S. H. (2021). Determination of toxic elements and arsenic species in salted foods and sea salt by ICP-MS and HPLC-ICP-MS. *ACS Omega*, 6(30): 19427-19434.
- Intannia, W., Charlena, C. and Suparto, I. H. (2023). Hydroxyapatite-ZnO Biomimetic toothpaste formulation from rice snail shell waste. *Science and Technology Indonesia*, 8(3): 486-493.
- Irfan, M., Suprajaa, P. S., Praveen, R. and Reddy, B. M. (2021). Microwave-assisted one-step synthesis of nanohydroxyapatite from fish bones and mussel shells. *Materials Letters*, 282(8): 1-4.
- Islam, M. R., Yuhi, T., Ura, K. and Takagi, Y. (2020). Optimization of extraction of gelatin from the head of kalamtra sturgeon (*huso dauricus* × *acipenser scherenkii* × *acipenser transmontanus*). *Applied Sciences*, 10(19): 1-15.
- Islam, M., Amin, S., Brown, C., Juraimi, A., Uddin, M. and Arshad, A. (2022). Determination of the most efficient household technique for the reduction of pesticide residues from raw fish muscles. *Foods*, 11(9): 1-15.
- Islami, D. M., Wulandari, N. Jamarun, Syukri, and V. Sisca. (2023). *In-situ* hydrothermal method for graphene oxide/hydroxyapatite synthesis from scallop shells. *RASAYAN Journal of Chemistry*, 16(01): 456-462.
- Ismail, R., Laroybafih, M. B., Fitriyana, D. F., Sri Nugroho, Santoso, Y. I., Hakim, A. J., Al Mulqi, M. S. and Bayuseno, A. P. (2021). The effect of hydrothermal holding time on the characterization of hydroxyapatite synthesized from green mussel shells. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 80(1): 84-93.
- Jamarun, N., Amelia, D., Rahmayeni, Septiani, U. and Sisca, V. (2023). The effect of temperature on the synthesis and characterization of hydroxyapatite-polyethylene glycol composites by in-situ process. *Hybrid Advances*, 2(14): 1-7.
- Jannat-Alipour, H., Rezaei, M., Shabanpour, B. and Tabarsa, M. (2019). Edible green seaweed, *Ulva intestinalis* as an ingredient in surimi-based product: Chemical composition and physicochemical properties. *Journal of Applied Phycology*, 31(4): 2529-2539.
- Jia, R., Katano, T., Yoshimoto, Y., Gao, Y., Nakazawa, N., Osako, K. and Okazaki, E. (2020). Effect of small granules in potato starch and wheat starch on quality changes of direct heated surimi gels after freezing. *Food Hydrocolloids*, 104(1): 1-8.
- Jia, Y., Mao, Z., Huang, W. and Zhang, J. (2022). Effect of temperature and crystallinity on the thermal conductivity of semi-crystalline polymers: A case study of polyethylene. *Materials Chemistry and Physics*, 287: 1-8.

- Jiang, Q., Han, J., Gao, P., Yu, L., Xu, Y. and Xia, W. (2018). Effect of heating temperature and duration on the texture and protein composition of bighead carp (*Aristichthys nobilis*) muscle. *International Journal of Food Properties*, 21(1): 2110-2120.
- Jiao, X., Su, R., Zhu, H., Yan, B., Wang, Q., Cao, H., Huang, J., Zhao, J., Zhang, H. and Fan, D. (2021). Effect of lipase incorporation on gelling properties of catfish (*Clarias lazera*) surimi and its mechanism. *Journal of the Science of Food and Agriculture*, 101(11): 4498-4505.
- Jordens, J., Gielen, B., Braeken, L. and Gerven, V. T. (2014). Determination of the effect of the ultrasonic frequency on the cooling crystallization of paracetamol. *Chemical Engineering and Processing: Process Intensification*, 84: 38-44.
- Jordens, J., Gielen, B., Xiouras, C., Hussain, M. N., Stefanidis, G. D., Thomassen, L. C. J., Braeken, L. and Gerven, V.T. (2019). Sonocrystallisation: Observations, theories and guidelines. *Chemical Engineering and Processing - Process Intensification*, 139: 130–154.
- Jubaedah, D., Marsi, M., Wijayanti, M. and Rahmani, S. (2020). Combination cockle shells (*Anadara granosa*) and calcite lime to improve swamp water pH for catfish (*Pangasius sp.*) Culture. *Omni-Akuatika*, 16(1): 48-52.
- Jung, S., Yeo, D., Wang, Z., Woo, S., Seo, Y., Hossain, M. I. and Choi, C. (2023). Viability of SARS-Cov-2 on lettuce, chicken, and salmon and its inactivation by peracetic acid, ethanol, and chlorine dioxide. *Food Microbiology*, 110: 1-9.
- Karunakaran, G., Cho, E.-B., Kumar, G. S., Kolesnikov, E., Janarthanan, G., Pillai, M. M., Rajendran, S., Boobalan, S., Sudha, K. G. and Rajeshkumar, M. P. (2020). Mesoporous Mg-doped hydroxyapatite nanorods prepared from bio-waste blue mussel shells for implant applications. *Ceramics International*, 46(18): 28514–28527.
- Keratimanoch, S., Takahashi, K., Kuda, T., Okazaki, E., Geng, J. and Osako, K. (2022). Effects of tyndallization temperature on the sterility and quality of kamaboko. *Food Chemistry*, 366(3): 1-7.
- Kim, J-S., Peters, G., and Christina, A. M. D. (2014). Food-Grade Coproducts from Surimi Processing. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 341-359). Boca Raton, FL: CRC Press.
- Korkmaz, K. and Tokur, B. (2022). Optimization of hydrolysis conditions for the production of protein hydrolysates from fish wastes using response surface methodology. *Food Bioscience*, 45(1): 1-8.
- Kraithong, S., Lee, S. and Rawdkuen, S. (2018). Physicochemical and functional properties of Thai organic rice flour. *Journal of Cereal Science*, 79: 259-266.

- Kumar, G. S., Girija, E. K., Venkatesh, M., Karunakaran, G., Kolesnikov, E. and Kuznetsov, D. (2017). One-step method to synthesize flower-like hydroxyapatite architecture using mussel shell bio-waste as a calcium source. *Ceramics International*, 43(3): 3457-3461.
- Kumar, S. C., Dhanaraj, K., Vimalathithan, R. M., Ilaiyaraja, P. and Suresh, G. (2020). Hydroxyapatite for bone-related applications derived from sea shell waste by simple precipitation method. *Journal of Asian Ceramic Societies*, 8(2): 416-429.
- Lagnika, C., Zhang, M., Nsor-Atindana, J. and Bashari, M. (2012). Effects of ultrasound and chemical treatments on white mushroom (*Agaricus bisporus*) prior to modified atmosphere packaging in extending shelf-life. *Journal of Food Science and Technology*, 51(12): 3749-3757.
- Lall, S. P. and Tibbetts, S. M. (2009). Nutrition, feeding, and behavior of fish. *Veterinary Clinics of North America: Exotic Animal Practice*, 12(2): 361–372.
- Lanier, T. C., Yongsawatdigul, J., and Carvajal-Rondanelli, P. (2014b). Surimi Gelation Chemistry. In J. W. Park. (Ed.). *Surimi and Surimi Seafood* (pp. 101-139). Boca Raton, FL: CRC Press.
- Lee, H. S., Kim, N. and Min, S. C. (2022). Inactivation of Salmonella in steamed fish cake using an in-package combined treatment of cold plasma and ultraviolet-activated zinc oxide. *Food Control*, 135(9): 1-9.
- Li, J., Ma, L., Liao, X., Liu, D., Lu, X., Chen, S., Ye, X. and Ding, T. (2018). Ultrasound-induced *Escherichia coli* O157:H7 cell death exhibits physical disruption and biochemical Apoptosis. *Frontiers in Microbiology*, 9: 1-10.
- Li, Q., Yi, S., Wang, W., Xu, Y., Mi, H., Li, X. and Li, J. (2022). Different thermal treatment methods and TGase addition affect gel quality and flavour characteristics of *Decapterus maruadsi* Surimi products. *Foods*, 11(1): 1-21.
- Lin, W., Han, Y., Liu, F., Huang, H., Li, L., Yang, S., Yang, X. and Wu, Y. (2020). Effect of lipid on surimi gelation properties of the three major Chinese carp. *Journal of the Science of Food and Agriculture*, 100(13): 4671-4677.
- Lin, D., Lin, H., Haung, S., Liu, S. and Chen, W. C. (2021). Effect of pH on the in vitro biocompatibility of surfactant-assisted synthesis and hydrothermal precipitation of rod-shaped nano-hydroxyapatite. *Polymers*, 13(17): 1-15.
- Ling, L., Liu, Y., Zhang, X., Aziz, T., Shahzad, M., Sameeh, M. Y., Wang, Y., Cai, C. and Zhu, Y. (2023). Effect of *Flammulina velutipes* polysaccharides on the physicochemical properties of catfish surimi and myofibrillar protein oxidation during frozen storage. *Frontiers in Nutrition*, 10: 1-11.
- Liu, Y., Ma, J. and Zhang, S. (2015). Synthesis and thermal stability of selenium-doped hydroxyapatite with different substitutions. *Frontiers of Materials Science*, 9(4): 392–396.

- Liu, Z., Yuan, Y., Qin, Y., Feng, A., He, Y., Zhou, D., Dong, X., Shen, X., Cao, J. and Li, C. (2021a). Sweet potato starch addition together with partial substitution of tilapia flesh effectively improved the golden pompano (*Trachinotus blochii*) surimi quality. *Journal of Texture Studies*, 52(2): 197-206.
- Liu, X., Zhang, M., Meng, X., Bai, Y. and Dong, X. (2021b). Effect of plasma-activated water on *Shewanella putrefaciens* population growth and quality of Yellow River carp (*Cyprinus Carpio*) fillets. *Journal of Food Protection*, 84(10): 1722-1728.
- Liu, C., Chen, S., Yang-Zhou, C., Zhang, Q. and Michael, R. N. (2021c). Application of nano-hydroxyapatite derived from oyster shell in fabricating superhydrophobic sponge for efficient oil/water separation. *Molecules*, 26(12): 1-13.
- Lu, Y., Zhu, Y., Ye, T., Nie, Y., Jiang, S., Lin, L. and Lu, J. (2022). Physicochemical properties and microstructure of composite surimi gels: The effects of ultrasonic treatment and olive oil concentration. *Ultrasonics Sonochemistry*, 88: 1-11.
- Luo, Z., Chang, G., Liu, Y., Ni, K., Zhou, T., Lv, X., Yu, J., Bai, J. and Wang, X. (2022). Inactivation of suspended cells and biofilms of the Gram-negative bacteria by electron beam irradiation and possible mechanisms of action. *LWT-Food Science and Technology*, 172: 1-11.
- Luo, Z., Ni, K., Zhou, Y., Chang, G., Yu, J., Zhang, C., Yin, W., Chen, D., Li, S., Kuang, S., Zhang, P., Li, K., Bai, J. and Wang, X. (2023). Inactivation of two SARS-Cov-2 virus surrogates by electron beam irradiation on large yellow croaker slices and their packaging surfaces. *Food Control*, 144(2): 1-11.
- Ma, K. K., Greis, M., Lu, J., Nolden, A. A., McClements, D. J. and Kinchla, A. J. (2022). Functional performance of plant proteins. *Foods*, 11(4): 1-23.
- Ma, J., Meng, L., Wang, S., Li, J. and Mao, X. (2023). Inactivation of *Vibrio parahaemolyticus* and retardation of quality loss in oyster (*Crassostrea gigas*) by ultrasound processing during storage. *Food Research International*, 168: 1-8.
- MacDonald, G. A., Carvajal-Rondanelli, P. A., and Lanier, T. C. (2014). Stabilization of Proteins in Surimi. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 193-227). Boca Raton, FL: CRC Press.
- Malaysia Kini. (2016). Battling food waste. Malaysia Kini. Retrieved from <http://www.malaysiakini.com/letters/359487>
- Manan, W. N. A. and Aziz, N. A. (2018). Optimization of soil pH by using calcium carbonate (CaCO₃) obtained from seashell waste. *GADING Journal for Science and Technology*, 1(1): 81-84.

- Meiron, O. E., Bar-David, E., Aflalo, E. D., Shechter, A., Stepensky, D., Berman, A. and Sagi, A. (2011). Solubility and bioavailability of stabilized amorphous calcium carbonate. *Journal of Bone and Mineral Research*, 26, 364–372.
- Mi, H., Su, Q., Chen, J., Yi, S., Li, X. and Li, J. (2021). Starch-fatty acid complexes improve the gel properties and enhance the fatty acid content of *Nemipterus virgatus* surimi under high-temperature treatment. *Food Chemistry*, 362(1): 1-8.
- Milinic, J., Mata, P., Diniz, M. and Noronha, J. P. (2021). Umami taste in edible seaweeds: The current comprehension and perception. *International Journal of Gastronomy and Food Science*, 23: 1-9.
- Millan-Sango, D., Garroni, E., Farrugia, C., Van Impe, J. F. M. and Valdramidis, V. P. (2016). Determination of the efficacy of ultrasound combined with essential oils on the decontamination of *Salmonella* inoculated lettuce leaves. *LWT-Food Science and Technology*, 73(3): 80-87.
- Mirzapour-Kouhdasht, A., Moosavi-Nasab, M., Krishnaswamy, K. and Khalesi, M. (2020). Optimization of gelatin production from barred mackerel by-products: Characterization and hydrolysis using native and commercial proteases. *Food Hydrocolloids*, 108: 1-14.
- Misyura, S. (2018). Evaporation and heat transfer of aqueous salt solutions during crystallization. *Applied Thermal Engineering*, 139: 203-212.
- Mtavangu, S. G., Mahene, W., Machunda, R. L., van der Bruggen, B. and Njau, K. N. (2022). Cockle (*Anadara granosa*) shells-based hydroxyapatite and its potential for defluoridation of drinking water. *Results in Engineering*, 13: 1-16.
- Murthy, L. N., Phadke, G. G., Jeyakumari, A. and Ravishankar, C. N. (2020). Effect of added calcium and heat setting on gel forming and functional properties of *Sardinella fimbriata* surimi. *Journal of Food Science and Technology*, 58(2), 427-436.
- Ngouoko, J. J. K., Tajeu, K. Y., Fotsop, C. G., Tamo, A. K., Doungmo, G., Temgoua, R. C. T., Kamgaing, T. and Tonle, I. K. (2022). Calcium carbonate originating from snail shells for synthesis of hydroxyapatite/l-lysine composite: Characterization and application to the electroanalysis of toluidine blue. *Crystals*, 12(9): 1-17.
- Nisa, A., Sari, M. and Yusuf, Y. (2022). Fabrication and characterization of HA-oyster shell based on biopolymer-propolis as an agent of dental enamel remineralization material. *Materials Research Express*, 9(11): 1-12.
- Nikolaev, A. L., Gopin' A.V., Severin, A.V., Rudin, V.N., Mironov, M.A. and Dezhkunov, N.V. (2018). Ultrasonic synthesis of hydroxyapatite in non-cavitation and cavitation modes. *Ultrasonics Sonochemistry*, 44: 390-397.

- Noviyanti, A. R., Akbar, N., Deawati, Y., Ernawati, E. E., Malik, Y. T. Fauzia, R. P. and Risdiana (2020). A novel hydrothermal synthesis of nanohydroxyapatite from eggshell-calcium-oxide precursors. *Heliyon*, 6(4): 1-6.
- Ntzimani, A., Semenoglou, I., Dermesonlouoglou, E., Tsironi, T. and Taoukis, P. (2022). Surface decontamination and shelf-life extension of gilthead sea bream by alternative washing treatments. *Sustainability*, 14(10): 1-17.
- OECD/FAO (2023). OECD-FAO Agricultural Outlook 2023-2032, OECD Publishing, Paris.
- Olivia, M., Oktaviani, R. and Ismeddiyanto. (2017). Properties of concrete containing ground waste cockle and clam seashells. *Procedia Engineering*, 171: 658–663.
- Ooizumi, T. (2014). Manufacture of Kamaboko, Chikuwa, Tempura, and Hanpen. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 271-283). Boca Raton, FL: CRC Press.
- Öztürk, F., Gündüz, H. and Sürengil, G. (2021). The effects of essential oils on inactivation of *Listeria monocytogenes* in rainbow trout cooked with sous-vide. *Journal of Food Processing and Preservation*, 45(10): 1-10.
- Pal, A., Metya, A. K., Roy Chowdhury, A. and Sinha, A. (2020). Structural and mechanical behavior of Mechanochemically synthesized nanocrystalline hydroxyapatite from *Mercenaria* clam shells. *Transactions of the Indian Ceramic Society*, 79(4): 175-181.
- Pang, S., Su, F. Y., Green, A., Salim, J., McKittrick, J. and Jasiuk, I. (2021). Comparison of different protocols for demineralization of cortical bone. *Scientific Reports*, 11(1): 1-10.
- Popović, N. T., Lorencin, V., Strunjak-Perović, I. and Čož-Rakovac, R. (2023). Shell waste management and utilization: Mitigating organic pollution and enhancing sustainability. *Applied Sciences*, 13(1): 1-18.
- Park, J. W., Nozaki, H., Suzuki, T., and Beliveau, J-L. (2014a). Manufacture of Surimi: Harvest to Frozen Block. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 55-99). Boca Raton, FL: CRC Press.
- Park, J. W., Ooizumi, T., and Hunt, A. L. (2014b). Ingredient Technology for Surimi and Surimi Seafood. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 453-495). Boca Raton, FL: CRC Press.
- Park, S. Y., Mizan, M. F. R., and Ha, S. (2016). Inactivation of *Cronobacter sakazakii* in head lettuce by using a combination of ultrasound and sodium hypochlorite. *Food Control*, 60: 582–587.
- Pati, K., Chowdhury, S., Dora, K. C., Murmu, P. and Nath, S. (2022). Effects of zinc oxide nano particle on fortified tilapia mince during refrigerated storage (4 ± 1 °C). *Journal of Food Science and Technology*, 59(10): 3976-3988.

- Piao, X., Li, J., Zhao, Y., Guo, L., Zheng, B., Zhou, R. and Ostrikov, K. (2022). Oxidized cellulose nanofibrils-based surimi gel enhancing additives: Interactions, performance and mechanisms. *Food Hydrocolloids*, 133(2): 1-12.
- Piao, X., Huang, J., Sun, Y., Zhao, Y., Zheng, B., Zhou, Y., Yu, H., Zhou, R. and Cullen, P. J. (2023). Inulin for surimi gel fortification: Performance and molecular weight-dependent effects. *Carbohydrate Polymers*, 305(7): 1-10.
- Poowakanjana, S., and Park, J. W. (2014). Comminution Process for Surimi and Surimi Seafood Paste. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 229-243). Boca Raton, FL: CRC Press.
- Prasad, R. and Dalvi, S. V. (2020). Sonocrystallization. Monitoring and controlling crystallization using ultrasound. *Chemical Engineering Science*, 226(6): 1-30.
- Priyadarshini, B., Majumdar, R. K., Parhi, J., Maurya, P. K., Roy, D. and Saha, A. (2016). Gel properties of sutchi catfish (*Pangasius hypophthalmus*) surimi as affected by selected washing process and number of washing cycles. *Food Science and Technology International*, 22(3): 266–274.
- Priyadarshini, B., Xavier, K. M., Nayak, B. B., Dhanapal, K. and Balange, A. K. (2017). Instrumental quality attributes of single washed surimi gels of tilapia: Effect of different washing media. *LWT - Food Science and Technology*, 86(3): 385–392.
- Priyadarshini, M. B., Balange, A., Xavier, M. and Nayak, B. B. (2022). Effect of spray-dried cluster bean seed protein extract on the gel properties of single washed Nile tilapia surimi. *Journal of Food Processing and Preservation*, 46(11): 1-11.
- Qin, L., Fu, Y., Yang, F., Chang, Z., Zou, C., Gao, H., Jiang, D. and Jia, C. (2022). Effects of polysaccharides autoclave extracted from *Flammulina velutipes* mycelium on freeze-thaw stability of surimi gels. *LWT- Food Science and Technology*, 169(2022): 1-10.
- Qiu, J., Cai, L., Xiong, S., You, J., Yin, T. and An, Y. (2023). Characterization of aroma profiles and volatile organic compounds in silver carp surimi gel by GC-IMS, SPME-GC-MS, and sensory evaluation: Affected by okara insoluble dietary fiber with varied particle sizes. *Food Chemistry Advances*, 2(38): 1-11.
- Quan, T. H. and Benjakul, S. (2019). Impact of salted duck egg albumen powder on proteolysis and gelling properties of sardine surimi. *Journal of Texture Studies*, 50(5): 434-442.
- Ram, U. B., Sujatha, V., Vidhya, S., Jayasree, R. and Mahalaxmi, S. (2023). Oyster shell-derived nano-hydroxyapatite and proanthocyanidin pretreatment on dentinal tubule occlusion and permeability before and after acid challenge—an in vitro study. *Journal of Materials Science: Materials in Medicine*, 34(4): 1-17.

- Ramisetty, K. K., Gogate, P. R. and Pandit, A. B. (2013). Ultrasound-assisted antisolvent crystallization of benzoic acid: effect of process variables supported by theoretical simulations. *Industrial and Engineering Chemistry Research*, 52(49): 17573–17582.
- Ritchie H. and Roser M. (2021). Fish and overfishing. Our World in Data. Retrieved from <https://ourworldindata.org/fish-and-overfishing>
- Rosenthal, A. J. (2010). Texture profile analysis - How important are the parameters? *Journal of Texture Studies*, 41(5): 672-684.
- Roslan, M. R., Nasir, N. F., Mohammad, N. F., Meng, C. E., Mohamed, M. S. and Abdullah, M. N. (2021). The influences of sintering process on the characteristics of *Corbiculacea* (Etok) shells-based hydroxyapatite powder. *Journal of Physics: Conference Series*, 2071(1): 1-7.
- Roslan, M. R., Nasir, N. F., Mohammad, N. F., Daud, F. D., Ee Meng, C. and You, B. C. (2023). Nano hydroxyapatite (Nano-HA) based on *Pholas orientalis* shells and degradation analysis. *International Journal of Nanoelectronics and Materials*, 16(2): 283-300.
- Salim, I., Kamadjaja, M. J. and Dahlan, A. (2022). Tumor necrosis factor- α and osterix expression after the transplantation of a hydroxyapatite scaffold from crab shell (*Portunus pelagicus*) in the post-extraction socket of *Cavia cobaya*. *Dental Journal*, 55(1): 26-32.
- Sang, S., Chen, X., Qin, Y., Tong, L. and Ou, C. (2022). A study on the effects of calcium lactate on the gelling properties of large yellow croaker (*Pseudosciaena crocea*) surimi by low-field nuclear magnetic resonance and raman spectroscopy. *Foods*, 11(20): 1-12.
- Scientific Committee on Consumer Safety (2023). Final Opinion. Opinion on hydroxyapatite (nano) SCCS/1648/22. EU: European Commission.
- Sha, S., Zhang, L., Liu, H., Chen, J., Che, Y., Zhang, F. and Song, C. (2021). Synthesis and visible-light photocatalytic degradation of $\text{Ag}_3\text{PO}_4/\text{AgBr}$ /hydroxyapatite ternary nanocomposites prepared from oyster shells. *RSC Advances*, 11(26): 15598-15607.
- Shahroom, A., Shapawi, R., Mustafa, S., Abd Halid, N. F., Estim, A. and Daning Tuzan, A. (2023). Effects of eggshell and seashell powder as natural dietary calcium supplements on growth, molting frequency, and carapace calcium composition of juvenile red claw crayfish, *Cherax quadricarinatus*. *PeerJ Life and Environment*, 11: 1-18.
- Sharma, S., Majumdar, R., Mehta, N. and Nirmal, N. (2022). Effects of pineapple peel Ethanolic extract on the physicochemical and textural properties of surimi prepared from silver carp (*Hypophthalmichthys molitrix*). *Foods*, 11(20), 1-21.

- Shi, P., Liu, M., Fan, F., Yu, C., Lu, W. and Du, M. (2018). Characterization of natural hydroxyapatite originated from fish bone and its biocompatibility with osteoblasts. *Materials Science and Engineering: C*, 90: 706-712.
- Shi, T., Arief Wijaya, G. Y., Yuan, L., Sun, Q., Bai, F., Wang, J. and Gao, R. (2020). Gel properties of Amur sturgeon (*Acipenser schrenckii*) surimi improved by lecithin at reduced and regular-salt concentrations. *RSC Advances*, 10(51), 30896-30906.
- Sindhya, A., Johnson Jeyakumar, S., Jothibas, M. and Pugalandhi, P. (2022). Synthesis and characterization of nanohydroxyapatite (nHAp) from *Meretrix meretrix* clam shells and its in-vitro studies for biomedical applications. *Vacuum*, 204: 1-17.
- Singh, A., Prabowo, F. F., Benjakul, S., Pranoto, Y. and Chantakun, K. (2020). Combined effect of microbial transglutaminase and ethanolic coconut husk extract on the gel properties and in-vitro digestibility of spotted golden goatfish (*Parupeneus heptacanthus*) surimi gel. *Food Hydrocolloids*, 109: 1-10.
- Singh, A., Benjakul, S., Prodpran, T. and Nuthong, P. (2021). Effect of Psyllium (*Plantago ovata* forks) husk on characteristics, rheological and textural properties of threadfin bream Surimi gel. *Foods*, 10(6), 1-17.
- Singh, A., Buamard, N., Zhou, A. and Benjakul, S. (2022). Effect of sodium bicarbonate on textural properties and acceptability of gel from unwashed Asian sea bass mince. *Journal of Food Science and Technology*, 59(5): 3109-3119.
- Singer, A., Barakat, Z., Mohapatra, S., and Mohapatra, S. S. (2019). Nanoscale Drug-Delivery Systems: *In Vitro* and *In Vivo* Characterization. In S.S. Mohapatra, S. Ranjan, N. Dasgupta, R. K. Mishra and S. Thomas (Ed.), *Nanocarriers for Drug Delivery* (pp. 395-419). USA: Elsevier.
- Soegianto, A., Putranto, T. W. C., Lutfi, W., Almirani, F. N., Hidayat, A. R., Muhammad, A., Firdaus, R. A., Rahmadhani, Y. S., Fadila, D. A. N. and Hidayati, D. (2020). Concentrations of metals in tissues of cockle *Anadara granosa* (Linnaeus, 1758) from East Java coast, Indonesia, and potential risks to human health. *International Journal of Food Science*, 2020: 1–9.
- Song, C., Lin, Y., Hong, P., Liu, H. and Zhou, C. (2022a). Low-content pre-emulsified safflower seed oil enhances the quality and flavor of the *Nemipterus Virgatus* Surimi gel. *Gels*, 8(2): 1-16.
- Song, C., Lin, Y., Hong, P., Liu, H. and Zhou, C. (2022b). Compare with different vegetable oils on the quality of the *Nemipterus virgatus* surimi gel. *Food Science and Nutrition*, 10(9): 2935-2946.

- Sousa, T. C., Silva, E. L., Ferreira, V. C., Madruga, M. S. and Silva, F. A. (2022). Oxidative stability of green weakfish (*Cynoscion virescens*) by-product surimi and surimi gel enhanced with a *Spondias mombin* L. waste phenolic-rich extract during cold storage. *Food Bioscience*, 50(Part A): 102021.
- Sricharoen, P., Limchoowong, N., Nuengmatcha, P. and Chanthai, S. (2020). Ultrasonic-assisted recycling of Nile tilapia fish scale biowaste into low-cost nano-hydroxyapatite: Ultrasonic-assisted adsorption for Hg^{2+} removal from aqueous solution followed by “turn-off” fluorescent sensor based on Hg^{2+} -graphene quantum dots. *Ultrasonics Sonochemistry*, 63: 1-11.
- Stanislavov, A. S., Sukhodub, L. F., Sukhodub, L. B., Kuznetsov, V. N., Bychkov, K. L. and Kravchenko, M. I. (2018). Structural features of hydroxyapatite and carbonated apatite formed under the influence of ultrasound and microwave radiation and their effect on the bioactivity of the nanomaterials. *Ultrasonics Sonochemistry*, 42(12): 84-96.
- Stec, M. and Synowiec, P. M. (2022). The use of ultrasound-assisted precipitation for the production of micro-sized crystals with narrow CSD. *Chemical Engineering and Processing*, 173: 1-17.
- Sughanthy, S. A. P., Ansari, M. N. M. and Atiqah, A. (2020). Dynamic mechanical analysis of polyethylene terephthalate/hydroxyapatite biocomposites for tissue engineering applications. *Journal of Materials Research and Technology*, 9(2): 2350-2356.
- Sun, R., Xu, W., Xiong, L., Jiang, N., Xia, J., Zhu, Y., Wang, C., Liu, Q., Ma, Y. and Luo, H. (2023). The combined effects of ultrasound and plasma-activated water on microbial inactivation and quality attributes of crayfish during refrigerated storage. *Ultrasonics Sonochemistry*, 98(5): 1-14.
- Sun, X., Li, Q., Ding, N., Liang, S., Mubango, E., Zheng, Y., Yu, Q., Dai, R., Tan, Y., Luo, Y. and Hong, H. (2024). Cryoprotective effect of fistular onion stalk polysaccharide on frozen surimi derived from bighead carp: Physicochemical properties and gel quality during storage. *Food Hydrocolloids*, 148(8): 1-13.
- Surasani, V. K. R., Raju, C. V., Singh, A. and Joshi, S. (2022). Quality changes in fish sausages supplemented with pangas protein isolates as affected by frozen storage and casing material. *Journal of Food Science and Technology*, 59(6): 2127-2140.
- Suzuki, T., and Tsuchiya, T. (2014). Nutrition and Health Benefits of Surimi Seafood. In J. W. Park. (Ed.), *Surimi and Surimi Seafood* (pp. 603-627). Boca Raton, FL: CRC Press.
- Szałaj, U., Świdarska-środa, A., Chodara, A., Gierlotka, S. and Łojkowski, W. (2019). Nanoparticle size effect on water vapour adsorption by hydroxyapatite. *Nanomaterials*, 9(7): 1-20.

- Tao, L., Tian, L., Zhang, X., Huang, X., Long, H., Chang, F., Li, T. and Li, S. (2020). Effects of γ -polyglutamic acid on the physicochemical properties and microstructure of grass carp (*Ctenopharyngodon idellus*) surimi during frozen storage. *LWT - Food Science and Technology*, 134(7), 1-8.
- Tappi, S., Nissen, L., Casciano, F., Antonelli, G., Chiarello, E., Picone, G., Laurita, R., Capelli, F., Gherardi, M., Maccaferri, C., Gianotti, A., Bordoni, A., Espmark, Å. M., Capozzi, F. and Rocculi, P. (2023). Effect of cold plasma generated with different gas mixtures on safety, quality and nutritional aspects of fresh sea bream fillets. *Innovative Food Science and Emerging Technologies*, 89: 1-9.
- Teerakapibal, R., Li, H., Linehan, B. and Nordstrom, F. L. (2020). Material impurity distribution of lattice-incorporated impurities in salicylic acid. *Crystal Growth and Design*, 20(3): 1716-1728.
- Tönsuaadu, K., Gross, K. A., Plūduma, L. and Veiderma, M. (2012). A review on the thermal stability of calcium apatites. *Journal of Thermal Analysis and Calorimetry*, 110(2): 647-659.
- Trakoolwannachai, V., Kheolamai, P. and Ummartyotin, S. (2019). Characterization of hydroxyapatite from eggshell waste and polycaprolactone (PCL) composite for scaffold material. *Composites Part B: Engineering*, 173(1): 1-7.
- Tsai, Y., Hwang, C., Kao, J., Ou, T., Chang, T., Lee, S. and Lee, Y. (2022). Cooking and pasteurizing evaluation of barramundi (*Lates calcarifer*) meats subjected to an emerging microwave-assisted induction heating (MAIH) technology. *Innovative Food Science and Emerging Technologies*, 80(11): 1-10.
- Vikash and Kumar, V. (2020). Ultrasonic-assisted de-agglomeration and power draw characterization of silica nanoparticles. *Ultrasonics Sonochemistry*, 65: 1-13.
- Wang, Y., Zhang, P. and Chen, J. Z. Y. (2018). Formation of three-dimensional colloidal crystals in a nematic liquid crystal. *Soft Matter*, 14(32): 6756-6766.
- Wang, H., Yan, K. and Chen, J. (2021). Preparation of hydroxyapatite microspheres by hydrothermal self-assembly of marine shell for effective adsorption of Congo red. *Materials Letters*, 304: 1-4.
- Wang, H., Xing, H., Yan, K., Han, D. and Chen, J. (2022). Oyster shell derived hydroxyapatite microspheres as an effective adsorbent for remediation of Coomassie brilliant blue. *Advanced Powder Technology*, 33(2): 1-8.
- Wang, Y., Yan, H., Zhuang, Y., Tian, Y. and Yang, H. (2023). Effect of soy protein isolate, egg white protein and whey protein isolate on the flavor characteristics of silver carp (*Hypophthalmichthys molitrix*) surimi. *LWT- Food Science and Technology*, 186: 1-14.

- Wantala, K., Khongkasem, E., Khlongkarnpanich, N., Sthiannopkao, S. and Kim, K. (2012). Optimization of As(V) adsorption on Fe-RH-MCM-41-immobilized GAC using box-behnken design: Effects of pH, loadings, and initial concentrations. *Applied Geochemistry*, 27(5): 1027-1034.
- Wasinnitiwong, N., Benjakul, S. and Hong, H. (2022). Effects of κ -carrageenan on gel quality of threadfin bream (*Nemipterus spp.*) surimi containing salted duck egg white powder. *International Journal of Biological Macromolecules*, 221(9): 61-70.
- Welker, R. W. (2012). Basics and Sampling of Particles for Size Analysis and Identification. In R. Kohli and K. L. Mithal. (Ed.), *Developments in Surface Contamination and Cleaning Series* (pp. 1-340). Kidlington, Oxford: Elsevier.
- Wei, Y., Zhang, T., Yu, F., Xue, Y., Li, Z., Wang, Y. and Xue, C. (2018). Effects of curdlan on the texture and structure of Alaska Pollock surimi gels treated at 120°C. *International Journal of Food Properties*, 21(1): 1778-1788.
- Wijayanti, I., Singh, A., Benjakul, S. and Sookchoo, P. (2021b). Textural, sensory, and chemical characteristic of threadfin bream (*Nemipterus sp.*) surimi gel fortified with bio-calcium from bone of asian sea bass (*Lates calcarifer*). *Foods*, 10(5): 976.
- Wijayanti, I., Sookchoo, P., Prodpran, T., Mohan, C., Aluko, R. E. and Benjakul, S. (2021a). Physical and chemical characteristics of Asian sea bass bio-calcium powders as affected by ultrasonication treatment and drying method. *Journal of Food Biochemistry*, 45(4): 1-10.
- Wongmaneepratip, W., Gao, X. and Yang, H. (2022). Effect of food processing on reduction and degradation pathway of pyrethroid pesticides in mackerel fillet (*Scomberomorus commerson*). *Food Chemistry*, 384(1): 1-9.
- World Health Organization (2024). Food Fortification. Retrieved from https://www.who.int/health-topics/food-fortification#tab=tab_1
- World Population Review. (2024). Food Waste by Country 2024. Retrieved from <https://worldpopulationreview.com/country-rankings/food-waste-by-country>
- Wu, Q., Wang, W., Li, X., Yi, S., Mi, H., Xu, Y. and Li, J. (2022). Gel properties of blue round scad (*Decapterus maruadsi*) mince as influenced by the addition of egg white powder. *Journal of Texture Studies*, 53(4): 563-576.
- Xiaohuang, C., Azam, M. and Islam, M. (2022). Effect of chitosan and hydroxypropyl starch complex polysaccharide on the physico-chemical properties of tilapia fish (*Oreochromis mossambicus*) gel. *Food Research*, 6(5): 340-348.
- Xiong, Z., Wang, X., Li, M., Shi, T., Jin, W., Li, J., Yuan, L. and Gao, R. (2023). Investigation of the enhancement mechanism of ethanol addition on the gel performance of heat-induced surimi. *Journal of Food Engineering*, 355: 1-9.

- Xu, Y., Lv, Y., Zhao, H., He, X., Li, X., Yi, S. and Li, J. (2022). Diacylglycerol pre-emulsion prepared through ultrasound improves the gel properties of golden thread Surimi. *SSRN Electronic Journal*, 82: 1-8.
- Xu, Y., Yu, J., Xue, Y. and Xue, C. (2023). Enhancing gel performance of surimi gels via emulsion Co-stabilized with soy protein isolate and κ -carrageenan. *Food Hydrocolloids*, 135: 1-10.
- Xue, C., Pei, Z., Wen, P., Chin, Y. and Hu, Y. (2023). Effects of pH and NaCl on the spatial structure and conformation of Myofibrillar proteins and the emulsion gel system—Insights from computational molecular dynamics on myosin of golden pompano. *Gels*, 9(4): 1-15.
- Yan, B., Jiao, X., Zhu, H., Wang, Q., Huang, J., Zhao, J., Cao, H., Zhou, W., Zhang, W., Ye, W., Zhang, H. and Fan, D. (2020). Chemical interactions involved in microwave heat-induced surimi gel fortified with fish oil and its formation mechanism. *Food Hydrocolloids*, 105: 1-9.
- Yan, W., Yin, T., Xiong, S., You, J., Hu, Y. and Huang, Q. (2021). Gelling properties of silver carp surimi incorporated with konjac glucomannan: Effects of deacetylation degree. *International Journal of Biological Macromolecules*, 191: 925-933.
- Yang, G., Lin, W., Lai, H., Tong, J., Lei, J., Yuan, M., Zhang, Y. and Cui, C. (2021). Understanding the relationship between particle size and ultrasonic treatment during the synthesis of metal nanoparticles. *Ultrasonics Sonochemistry*, 73: 1-6.
- Yapo, N. S., Aw, S., Briton, B. G., Drogui, P., Yao, K. B. and Adouby, K. (2022). Removal of fluoride in groundwater by adsorption using hydroxyapatite modified *Corbula trigona* shell powder. *Chemical Engineering Journal Advances*, 12: 1-12.
- Yin, T., Reed, Z. H. and Park, J. W. (2014). Gelling properties of surimi as affected by the particle size of fish bone. *LWT- Food Science and Technology*, 58(2): 412–416.
- Yin, T. and Park, J. W. (2014). Effects of nano-scaled fish bone on the gelation properties of Alaska Pollock surimi. *Food Chemistry*, 150(2014): 463-468.
- Yoon, W. B., Park, J. W. and Jung, H. (2022). Effects of potato protein isolated using ethanol on the gelation and anti-proteolytic properties in pacific whiting surimi. *Foods*, 11(19): 1-12.
- Yu, N., Xu, Y., Jiang, Q. and Xia, W. (2017). Textural and physicochemical properties of surimi gels prepared with potassium and calcium chloride as substitutes for sodium chloride. *International Journal of Food Properties*, 20(1): 1-14.

- Yu, C., Huang, X., Fan, Y. and Deng, Z. (2020). A new household ultrasonic cleaning method for pyrethroids in cabbage. *Food Science and Human Wellness*, 9(3): 304–312.
- Yu, T., Kuwahara, S., Ohno, T. and Iwahashi, H. (2021). Recycling salmon meat by decontamination under mild conditions using high-pressure carbon dioxide. *Waste Management*, 124(17): 102-109.
- Yu, H., Zhang, J., Zhao, Y., Li, H., Chen, Y. and Zhu, J. (2023). Effects of specific doses of E-beam irradiation which inactivated SARS-Cov-2 on the nutrition and quality of Atlantic salmon. *Food Science and Human Wellness*, 12(4): 1351-1358.
- Yuliana, I., Mahendradatta, M. and Laga, A. (2021). Effects of transglutaminase enzyme on physicochemical properties of milkfish (*Chanos chanos*) surimi gel. *Food Research*, 5(6): 49-57.
- Zakaria, N. I., Mohamad, R., Hanifah, S. A., Kamarudin, K. H. and Ahmad, A. (2021). Low-cost and eco-friendly nanoparticles from cockle shells as a potential matrix for the immobilization of urease enzyme. *Arabian Journal of Chemistry*, 14(3): 1-8.
- Zhang, L., Feng, H., Li, X., Ye, X., Jing, Y., Ouyang, T., Yu, X., Liang, R. and Chen, W. (2009). Heavy metal contaminant remediation study of western Xiamen Bay sediment, China: Laboratory bench scale testing results. *Journal of Hazardous Materials*, 172(1): 108-116.
- Zhang, L., Li, Q., Hong, H. and Luo, Y. (2020). Prevention of protein oxidation and enhancement of gel properties of silver carp (*Hypophthalmichthys molitrix*) surimi by addition of protein hydrolysates derived from surimi processing by-products. *Food Chemistry*, 316(4): 1-9.
- Zhang, L., Zhang, A., Jing, Y., Qu, P. and Wu, Z. (2021a). effect of particle size on the heat transfer performance of SiO₂–Water nanofluids. *The Journal of Physical Chemistry C*, 125(24): 13590-13600.
- Zhang, J., Yu, P., Fan, L. and Sun, Y. (2021b). Effects of ultrasound treatment on the starch properties and oil absorption of potato chips. *Ultrasonics Sonochemistry*, 70: 1-9.
- Zhang, Y., Wang, S., Guo, D., Liu, Z., Gao, J., Zhan, X., Wang, Y., Shi, C. and Xia, X. (2022). Efficacy of 405 nm light-emitting diode illumination and citral used alone and in combination for inactivation of *Vibrio parahaemolyticus* on shrimp. *Foods*, 11(14): 1-13.
- Zhang, C., He, Y., Zheng, Y., Ai, C., Cao, H., Xiao, J., El-Seedi, H., Chen, L. and Teng, H. (2023a). Effect of carboxymethyl cellulose (CMC) on some physico-chemical and mechanical properties of unrinsed surimi gels. *LWT- Food Science and Technology*, 180: 1-7.

- Zhang, C., Lu, M., Ai, C., Cao, H., Xiao, J., Imran, M., Chen, L. and Teng, H. (2023b). Ultrasonic treatment combined with curdlan improves the gelation properties of low-salt *Nemipterus virgatus* surimi. *International Journal of Biological Macromolecules*, 248(4): 1-11.
- Zhang, X., Xie, W., Liang, Q., Jiang, X., Zhang, Z. and Shi, W. (2023c). High inner phase emulsion of fish oil stabilized with rutin-grass carp (*Ctenopharyngodon idella*) myofibrillar protein: Application as a fat substitute in surimi gel. *Food Hydrocolloids*, 145(1-2): 1-12.
- Zhang, C., Chen, L., Lu, M., Ai, C., Cao, H., Xiao, J. and Teng, H. (2023d). Effect of cellulose on gel properties of heat-induced low-salt surimi gels: Physicochemical characteristics, water distribution and microstructure. *Food Chemistry: X*, 19(4): 1-9.
- Zhang, X., Pan, H., Jiang, X. and Shi, W. (2023e). Study on the mechanism of soy protein isolate to improve quality of reduced-salt *Hypophthalmichthys molitrix* surimi gel: Focus on gel quality, protein structure, and in vitro digestibility. *Food Chemistry: X*, 20(6): 1-8.
- Zhao, Y., Kong, H., Zhang, X., Hu, X. and Wang, M. (2019). The effect of Perilla (*Perilla frutescens*) leaf extracts on the quality of surimi fish balls. *Food Science & Nutrition*, 7(6): 2083-2090.
- Zhao, Y., Ojha, S., Burgess, C. M., Sun, D. and Tiwari, B. K. (2020). Influence of various fish constituents on inactivation efficacy of plasma-activated water. *International Journal of Food Science and Technology*, 55(6): 2630-2641.
- Zhao, X., Lan, W., Zhai, Y. and Xie, J. (2021). Multi-frequency ultrasound: A potential method to improve the effects of surface decontamination and structural characteristics on large yellow croaker (*Pseudosciaena crocea*) during refrigerated storage. *Ultrasonics Sonochemistry*, 79(10): 1-8.
- Zhao, X., Wang, X., Zeng, L., Huang, Q., Zhang, J., Wen, X., Xiong, S., Yin, T. and Zhang, B. (2022). Effects of oil-modified crosslinked/acetylated starches on silver carp surimi gel: Texture properties, water mobility, microstructure, and related mechanisms. *Food Research International*, 158(S1): 1-11.
- Zhou, C., Wang, X., Song, X., Wang, Y., Fang, D., Ge, S. and Zhang, R. (2020). Insights into dynamic adsorption of lead by nano-hydroxyapatite prepared with two-stage ultrasound. *Chemosphere*, 253: 1-11.
- Zhu, Y., Zhang, T., Xu, D., Wang, S., Yuan, Y., He, S. and Cao, Y. (2019). The removal of pesticide residues from pakchoi (*Brassica rape L. ssp. chinensis*) by ultrasonic treatment. *Food Control*, 95: 176-180.
- Zhu, Z., Zhang, P. and Sun, D-W. (2020). Effects of multi-frequency ultrasound on freezing rates and quality attributes of potatoes. *Ultrasonics Sonochemistry*, 60(3): 1-9.

Zhu, Y., Lu, Y., Ye, T., Jiang, S., Lin, L. and Lu, J. (2021). The effect of salt on the gelling properties and protein phosphorylation of surimi-crabmeat mixed gels. *Gels*, 8(1): 1-14.

Zhu, X., Yan, H., Cui, Z., Li, H., Zhou, W., Liu, Z., Zhang, H., Manoli, T., Mo, H., and Hu, L. (2023). Ultrasound-assisted blue light killing *Vibrio parahaemolyticus* to improve salmon preservation. *Ultrasonics Sonochemistry*, 95(5): 1-11.

Zuliantoni, Z., Suprpto, W., Setyarini, P. H. and Gapsari, F. (2022). Extraction and characterization of snail shell waste hydroxyapatite. *Results in Engineering*, 14: 1-7.

