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Food Technology–Driven Utilization of Seaweed Waste as a Source of Health-Promoting Bioactive Compounds

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Abstract: This community engagement activity focused on the utilization of native seaweed, particularly *Kappaphycus alvarezii*, as a source of bioactive compounds with the potential to enhance functional food products developed by small and medium enterprises (SMEs) in Kampung Nelayan Merah Putih, Ekas Buana Village, East Lombok. The activity was conducted on 22 January 2026 and centred on the delivery of the module entitled *"Exploring Kappaphycus alvarezii as a Sustainable Source of Bioactive Compounds for Functional Food Innovation."* The session was delivered directly by Prof. Wan Rosli Bin Wan Ishak, accompanied by Prof. Haslina Ahmad and collaborators from the Synthesis and Bioactive Materials research group of USM–UPM. The programme included theoretical presentations on the bioactive composition of *K. alvarezii*, opportunities for the sustainable utilization of processing by-products, and an introduction to the concept of algae-based functional foods tailored for coastal SMEs. Participants were also invited to visit a local seaweed production facility to gain a deeper understanding of the supply chain, raw material quality, and the potential conversion of processing waste into value-added products. The expected outcomes include enhanced technical and entrepreneurial capacities among SME actors, improved ability to design algae-based functional food products, and the strengthening of an environmentally sustainable local supply chain. The long-term impact will be assessed through improvements in production efficiency, the adoption of basic food safety and quality practices (GMP/SSOP), and the potential increase in income among coastal SME practitioners. Overall, this initiative highlights the value of international–local partnerships in advancing sustainable tropical food innovation.

Keywords: Bioactive compounds; Community engagement; East Lombok; Functional food; *Kappaphycus alvarezii*; Seaweed waste.

Introduction

Kappaphycus alvarezii is a red seaweed widely cultivated commercially in tropical coastal regions, primarily for the production of carrageenan, which functions as a thickening agent, emulsifier, and stabilizer in a wide range of food and pharmaceutical products. In addition to carrageenan, this alga contains various bioactive compounds that may contribute to health benefits through antioxidant and anti-inflammatory mechanisms, as well as modulation of the gut microbiota. The utilization of algal bioactive compounds in functional foods has become a major focus of global research due to their potential health benefits and their capacity to add value to tropical food production without relying on expensive imported resources (Pacheco-Quito et al., 2020; Keyimu & Abuduli, 2019; Fu et al., 2022).

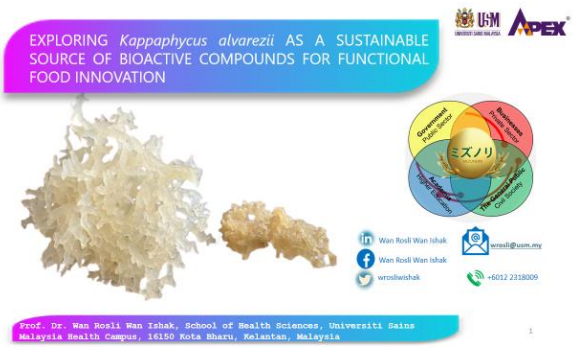

Figure 1. Presentation slide on *Kappaphycus alvarezii* for functional food innovation.

At the regional level, East Lombok possesses coastal natural resources that can be leveraged to improve the livelihoods of coastal communities through the diversification of food products. The sustainable utilization of algae can reduce pressure on other natural resources while providing employment opportunities for local small and medium enterprises (SMEs). The relationship between the design of bioactive compound utilization from algae and the quality of functional food products has been discussed in international literature. For instance, studies on the role of carrageenan and algal polysaccharides in food systems and bioactive applications demonstrate that these compounds have the potential to improve the functional profile of food products while providing additional health benefits (Chin et al., 2019). Furthermore, research on seaweed processing waste indicates that by-products can serve as valuable sources of bioactive compounds through environmentally friendly extraction techniques, thereby contributing to the development of a circular economy in coastal areas (Wen et al., 2025).

Kampung Nelayan Merah Putih in Ekas Buana Village was selected as the location for this community service programme due to its proximity to fishing activities and the emerging seaweed industry in the area. Observations of the local market indicate growing interest in algae-based functional food products that can be produced at the SME scale with relatively limited capital. This programme aligns with literature emphasizing the importance of context-based strategies for utilizing algal bioactive compounds to enhance the quality of tropical food products while maintaining the sustainability of local raw-material supply chains (Firdaus et al., 2020). Beyond technical aspects, the programme also highlights socio-economic dimensions, including the empowerment of SME actors, improved market access, and the adoption of basic food quality practices to ensure the safety and quality of algae-based functional food products in coastal regions.

Several studies have confirmed the potential of *K. alvarezii* as a source of bioactive compounds with positive health effects when extracted and incorporated into functional food formulations. For example, studies on algal polysaccharides and their applications in drug delivery systems, as well as their antioxidant properties, demonstrate that algal bioactive compounds can enhance nutritional stability and health-promoting properties in processed food products (Pacheco-Quito et al., 2020). Meanwhile, studies on the application of algal bioactive compounds in functional food formulation and technology transfer strategies suggest that community training, cross-institutional collaboration, and the adoption of Good Manufacturing Practices (GMP) and Sanitation Standard Operating Procedures (SSOP) are crucial for improving the reliability of production processes in coastal SMEs. In this context, the present community service initiative functions not only as a platform for knowledge transfer but also as a means of fostering a sustainable algae-based food innovation ecosystem in East Lombok.

The literature on algal bioactive compounds further highlights that carrageenan, polysaccharides, phenolic compounds, and other bioactive constituents in algae can provide antioxidative and anti-inflammatory benefits, as well as modulate the gut microbiota. Consequently, tropical algae represent a promising candidate for the development of functional foods. In addition, existing studies emphasize the importance of contextualizing tropical marine resources, designing robust quality systems and supply chains, and implementing GMP/SSOP practices to ensure the consistent quality of algae-based functional food products at the SME level. Within the framework of this community service programme, the evaluation of technology transfer impacts, institutional collaboration, and the adoption of environmentally friendly practices form an integral part of efforts to utilize *K. alvarezii* sustainably for functional food development in coastal communities of East Lombok.

Methodology

The methodology was implemented in a structured single-paragraph format consisting of several integrated activities. The programme began with the delivery of the module entitled *"Exploring Kappaphycus alvarezii as a Sustainable Source of Bioactive Compounds for Functional Food Innovation"* by Prof. Wan Rosli Bin Wan Ishak, followed by an interactive question-and-answer session with participants. This was complemented by a field visit to a local seaweed production facility aimed at mapping the supply chain and identifying opportunities for converting seaweed processing waste into functional food products. In addition, observations were conducted to assess basic food quality practices within SME environments, particularly regarding the implementation of Good Manufacturing Practices (GMP) and Sanitation Standard Operating Procedures (SSOP). The entire sequence of activities was designed to strengthen both the technical capacity and entrepreneurial skills of SME actors in East Lombok.

Figure 2. Training session on *Kappaphycus alvarezii* for functional food innovation.

Result and Discussion

This community service programme successfully enhanced the knowledge and capacity of SME actors in Kampung Nelayan Merah Putih regarding the utilization of *Kappaphycus alvarezii* as a source of bioactive compounds for functional food development. The training module entitled *"Exploring Kappaphycus alvarezii as a Sustainable Source of Bioactive Compounds for Functional Food Innovation"*, combined with case-based interactive discussions and direct observation of local seaweed production facilities, significantly improved participants' technical literacy regarding algal bioactive components, including polysaccharides, phenolic compounds, and other bioactive substances, as well as the mechanisms through which these compounds can be converted into value-added functional food products. The evaluation of participants' technical independence indicated an increased ability among partners to plan and implement algae-based food production processes, as well as improved capacity to conduct basic quality assessments of raw materials and final products prior to scaling up production (Suciyati, 2019; Arifin et al., 2025; Srihidayati et al., 2018; Anfas et al., 2022; Fitrianti et al., 2023; Erniati et al., 2016). These findings align with previous literature emphasizing that community-based training and technology transfer can enhance the capacity of coastal SMEs to transform local raw materials into sustainable value-added products (Mayomi & Aderinola, 2024).

Figure 3. Examples of seaweed-based products developed from *Kappaphycus alvarezii*.

The programme also encouraged diversification of algae-based processed products, moving beyond the sale of raw seaweed toward ready-to-consume products with higher market value. Implementation results revealed the potential conversion of *K. alvarezii* into various processed products, including seaweed crackers, algae-based chips and snacks, seaweed dodol (traditional confectionery), seaweed noodles, as well as other processed food products such as cream crackers, packaged snack foods, and functional food products. Similar studies and practices in various coastal regions have demonstrated that seaweed product diversification can increase farmers' income by tens to hundreds of percent within relatively short training and mentoring periods, depending on product type and target markets (Puspaningrum et al., 2023; Anfas et al., 2022; Ekayana, 2016; Fahruddin et al., 2024; Halim et al., 2025). For instance, seaweed crackers produced with appropriate algal proportions have shown positive consumer acceptance and broad market potential, with physicochemical characteristics meeting established standards and achieving high scores in consumer sensory evaluations (Putra et al., 2024; Heriawan et al., 2021). Meanwhile, studies on seaweed noodles and seaweed dodol indicate that technical training and marketing assistance can significantly improve production capacity and market access for coastal SMEs (Sakaria & Annisa, 2023; Sanger et al., 2024).

Figure 4. Interactive discussion between trainers and SME participants.

From an economic perspective, the diversification of algae-based processed products has strong potential to increase the income of SMEs in the coastal areas of East Lombok through higher product value, improved packaging, and more effective marketing strategies. Previous studies indicate that empowerment programmes such as DIPORLA (*Diversifikasi Produk Olahan Rumput Laut*) can enhance partners' capacity in seaweed processing, packaging improvement, and market expansion, resulting in significant income increases—sometimes doubling revenue within the programme evaluation period. Similar community empowerment initiatives have also shown that improvements in production capacity and business management can substantially increase seaweed farmers' income, supported by increased turnover and broader market opportunities through more targeted distribution strategies. The adoption of basic food quality practices and GMP/SSOP within SME facilities can further enhance product credibility in local and regional markets, thereby expanding market access and improving opportunities for business financing. Nevertheless, several challenges remain, including variability in raw material quality, limited access to efficient processing equipment, and the need for clearer quality guidelines. These issues require improvements in seaweed raw material standardization and sustained capacity-building for production systems.

Product quality, food safety, and compliance with quality standards were also key priorities in the implementation of this programme. The adoption of basic quality principles such as Good Manufacturing Practices (GMP) and Sanitation Standard Operating Procedures (SSOP) within SME facilities provides a fundamental framework for ensuring food safety and maintaining consistent product quality in algae-based processed foods within coastal communities. Existing literature and community service case studies demonstrate that training in GMP/SSOP, HACCP, and standardized production procedures for algae-based foods can strengthen production process integrity, reduce contamination risks, and increase consumer trust in seaweed-based products in both local and regional markets. Field observations highlighting variations in raw material quality further emphasize the need for simple yet effective quality guidelines to maintain product

consistency at the coastal SME level. In this context, the involvement of educational and research institutions in technology transfer is essential to provide continuous assistance, ensuring that food quality practices can be sustained and improved over time. The adoption of relevant quality standards not only enhances product quality but also strengthens the reputation of SMEs as reliable partners within regional and national supply chains (Moenaert et al., 2023).

Figure 5. Field observation of local seaweed processing activities.

Cross-institutional collaboration also played a crucial role in the broader success of this community service programme. Partnerships among universities, research institutions, and coastal communities have been shown to enhance technology adoption, knowledge transfer, and the commercialization capacity of tropical algae-based processed products. Technical literacy, food quality training, and marketing support through partnership networks provide substantial opportunities for SMEs to expand product lines, improve market access, and build supply chains that are more resilient to economic and environmental fluctuations. Studies on community partnership programmes demonstrate that cross-institutional collaboration improves SME capacity, accelerates technology adoption, and enhances overall programme performance, including the willingness to adopt environmentally friendly practices and more innovative product designs. The outcomes of this programme are expected to serve as a foundation for implementing similar initiatives in other coastal regions with high seaweed potential while maintaining economic and environmental sustainability through green supply chains and the optimal utilization of local resources (Bikovens et al., 2018).

Conclusion

This community service programme demonstrated that the training module *"Exploring Kappaphycus alvarezii as a Sustainable Source of Bioactive Compounds for Functional Food Innovation"* can enhance the technical and entrepreneurial capacity of SMEs in Kampung Nelayan Merah Putih to design algae-based functional food products with health-relevant bioactive components. Field observations and interactive discussions also revealed opportunities to improve the quality of algae-based functional food products and to integrate seaweed processing waste, where applicable, as an added-value component within the local supply chain. These findings are consistent with existing literature highlighting the health benefits of algal bioactive compounds and the importance of quality-oriented design and environmentally responsible practices in ensuring the safety and sustainability of tropical functional food products.

Recommendations

The following recommendations are proposed for future implementation:

1. Expansion of raw material quality standardization and functional food formulations based on algae for SMEs in East Lombok.
2. Strengthening training programmes on GMP/SSOP, HACCP, and standard operating procedures for algae-based food production.
3. Expansion of research–industry partnerships to support innovation in algae-based functional food products, including environmentally friendly packaging and the adoption of green supply chains.
4. Implementation of continuous community service programmes that map upstream–downstream supply chains to strengthen local and regional market access.
5. Evaluation of medium-term health and economic impacts through consumer feedback and further studies on the effectiveness of bioactive compounds in algae-based functional food products.

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