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Effects of Seasonal Variability on the Physicochemical, Biochemical, and Nutritional Composition of Western Peninsular Malaysia *Gracilaria manilaensis*

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Abstract: This study evaluated the effect of seasonal variation on the physicochemical, biochemical, and nutritional composition of *Gracilaria manilaensis*. Sampling was designed during the main monsoon seasons in Malaysia—the Southwest monsoon (SWM) and Northeast monsoon (NEM)—to understand the intraspecific variation ($p < 0.05$). Carbohydrates, protein, and dietary fiber were found to be higher in NEM-*G. manilaensis*, whereas a higher ash content was quantified in SWM-*G. manilaensis*. No significant differences were found in crude lipid and moisture content ($p > 0.05$). Vitamin B2 was calculated as $(0.29 \pm 0.06 \text{ mg } 100 \text{ g}^{-1})$ and $(0.38 \pm 0.06 \text{ mg } 100 \text{ g}^{-1})$ for the NEM and SWM samples, respectively ($p < 0.05$). The fatty acid profile showed the dominance of saturated fatty acids (SFAs)—palmitic acids, stearic acid, and myristic acid—while the mineral contents were found to be good sources of calcium ($1750.97\text{--}4047.74 \text{ mg } 100 \text{ g}^{-1}$) and iron ($1512.55\text{--}1346.05 \text{ mg } 100 \text{ g}^{-1}$). Tryptophan and lysine were recorded as the limiting essential amino acids (EAAs) in NEM *G. manilaensis*, while leucine and phenylalanine were found to be the limiting EAAs in the SWM samples. None of the extracts exhibited antibacterial properties against the screened strains. The study concluded that seasonal changes have a great effect on the biochemical composition of *G. manilaensis*.

Keywords: *Gracilaria manilaensis*; seasonal variation; physicochemical properties; nutritional properties; mineral elements; anti-microbial; heavy metals

1. Introduction

Food security is a global concern due to the increasing human population amid dwindling natural resources in a fragile natural environment [1]. An estimated 1 billion people currently suffer from malnutrition due to insufficient dietary energy, accessibility, and micronutrient undernourishment [2,3]. However, in a renewed interest to exploit new resources to meet the growing demand for food and value-added nutritional ingredients, marine macroalgae (commonly referred to as seaweed) seem to meet the requirements [4].

The red seaweed, phylum Rhodophyta, is abundant, with nearly 6000 species globally [5]. The genus *Gracilaria* Greville (*Gracilariales*, Rhodophyta) is the second-largest commercially important agarophyte with 160 taxonomically accepted species found distributed in tropical climates and temperate regions [6,7]. It is an important source of food and agar, exceeding the capacity of the genus