

**SHORT COMMUNICATION**

**Seaweed-based edible coating with palmarosa essential oil to extend the shelf life of papaya (*Carica papaya* L.): physicochemical and yeast–mold evaluation**

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**ABSTRACT**

*Papaya (*Carica papaya* L.) is a climacteric fruit with rapid postharvest deterioration. This study evaluated the effect of seaweed-based edible coating incorporated with palmarosa essential oil on weight loss and yeast–mold growth during storage. The experiment followed a factorial randomized block design with two factors: temperature (room and cold) and seaweed source (*Gracilaria* from Tegal and Yogyakarta). Fruits were stored for 15 days, and quality parameters were periodically evaluated. Weight loss increased progressively in all treatments, with higher values under room temperature. At day 15, weight loss reached 21.68% (Tegal) and 24.52% (Yogyakarta) under room temperature, while lower values were observed under cold storage (6.60% and 6.28%, respectively). Yeast–mold counts also increased during storage, with higher counts under room temperature compared to cold storage. At day 10, microbial counts reached 175.67 and 173.33 CFU/cm<sup>2</sup> under room temperature, while lower counts (42.67 and 31.33 CFU/cm<sup>2</sup>) were observed under cold storage. The results indicate that storage temperature plays a dominant role in reducing quality deterioration, while edible coating contributes to maintaining physicochemical and microbiological stability.*

**Keywords:** Edible coating, *Gracilaria* sp, palmarosa essential oil, papaya, postharvest quality, yeast–mold contamination

Papaya (*Carica papaya* L.) is a widely consumed tropical fruit valued for its nutritional composition, desirable sensory attributes, and economic importance. However, papaya is classified as a climacteric fruit, undergoing rapid postharvest ripening characterized by increased respiration rate, ethylene production, tissue softening, and high susceptibility to microbial spoilage. These physiological changes result in a short shelf life, typically limited to 4–5 days at ambient temperature, leading to substantial postharvest losses during transportation and

marketing (Escamilla-García *et al.*, 2018; Monzón-Ortega *et al.*, 2018).

To mitigate postharvest deterioration, edible coatings have gained increasing attention as an environmentally friendly and safe strategy to extend fruit shelf life. Edible coatings function as semi-permeable barriers that reduce moisture loss, regulate gas exchange, delay respiration, and suppress microbial growth on fruit surfaces (Garcia *et al.*, 2014; Valdés *et al.*, 2017). Edible coatings derived from natural polymers have been widely applied to reduce deterioration by forming semi-permeable barriers and

limiting microbial growth. Seaweed-derived polysaccharides, especially from red algae such as *Gracilaria* spp., represent a promising natural resource for edible coating development. *Gracilaria* species are rich in phycocolloids, mainly agar-type sulfated galactans, which provide strong gelling and film-forming properties. Beyond their structural functionality, *Gracilaria* polysaccharides may exhibit intrinsic bioactivities that enhance the physicochemical and biological performance of edible coatings. Nevertheless, the functional quality of seaweed-based coatings can vary depending on environmental conditions and geographical origin, which influence polysaccharide composition and gelling efficiency (Wang *et al.*, 2024). The incorporation of essential oils into edible coatings has been shown to further enhance preservative efficacy due to their antimicrobial and antioxidant activities. The application of essential oils derived from medicinal and aromatic plants as natural preservatives has been widely recognized as an effective and sustainable post-harvest strategy (Kumar *et al.*, 2023). Palmarosa essential oil (*Cymbopogon martinii*), rich in geraniol, exhibits strong antifungal and antibacterial properties and has demonstrated effectiveness against postharvest fungal pathogens (Rathore, 2024; da Rocha Neto *et al.*, 2019; Kou *et al.*, 2023). When integrated into polysaccharide-based coatings, palmarosa essential oil may improve barrier properties while simultaneously inhibiting fungal growth on fruit surfaces.

Despite growing interest in seaweed-based edible coatings and essential oil incorporation, studies evaluating the combined use of *Gracilaria* spp. from different geographical origins with palmarosa essential oil for papaya preservation remain limited. Therefore, this study aims to evaluate the effectiveness of a seaweed-based edible coating incorporated with palmarosa essential oil in improving physicochemical quality and reducing microbial growth in papaya during storage.

Fresh papaya fruits (*Carica papaya* L., California variety) were obtained from a

local farm in Boyolali, Central Java, Indonesia and selected based on uniform size, maturity, and absence of defects. Papaya fruits were collected on 12 December 2025 at 08:00 AM. The experiment was conducted in 2025 at the Laboratory of Natural Product Formulation and Technology and the Microbiology Laboratory, Sekolah Tinggi Ilmu Kesehatan Nasional, Indonesia. Seaweed (*Gracilaria* sp.) samples were collected from the coastal waters of Yogyakarta Province and Tegal Regency, Central Java, Indonesia. Seaweed extract was used as the coating base, and palmarosa essential oil was obtained from a commercial supplier PT Rumah Atsiri Indonesia (batch number: 02044501). Other materials included acetic acid, triethanolamine (TEA), Tween® surfactant, Potato Dextrose Agar (PDA), sodium chloride solution, and distilled water. All chemicals used were of analytical grade.

Fresh *Gracilaria* sp. seaweed samples were washed thoroughly with clean water to remove adhering impurities and debris. The seaweed was sun-dried until a constant weight was achieved to reduce moisture content. The dried samples were ground using a blender and sieved through a 60-mesh sieve to obtain a fine seaweed powder, which was stored in airtight containers at room temperature ( $25 \pm 2^\circ\text{C}$ ) until further use.

The coating formulation was prepared using seaweed powder obtained from two different sources, namely Yogyakarta and Tegal. The edible coating solution was prepared by dispersing seaweed powder (2 g) in 20 mL of distilled water at  $70^\circ\text{C}$  under continuous stirring until a homogeneous gel was formed. Subsequently, Tween 80 (0.2% v/v), triethanolamine (TEA, 2% w/v), and palmarosa essential oil (0.5% v/v) were added. Distilled water was then added to make up the final volume to 100 mL, and the mixture was continuously stirred using a magnetic stirrer at 1200 rpm until a uniform gel-like emulsion was obtained.

Papaya fruits (*Carica papaya* L., cv. California) were selected at uniform maturity (25% yellow surface coloration) and free from defects., mechanical damage and

visible microbial infection. The fruits were washed with clean water and air-dried at room temperature.

The papaya fruits were randomly divided into four experimental groups, *viz.*, i. Uncoated fruits stored at room temperature ( $25 \pm 2^\circ\text{C}$ ) (control); ii. Fruits coated with edible coating and stored at room temperature ( $25 \pm 2^\circ\text{C}$ ). iii. Uncoated fruits stored under cold conditions ( $8\text{--}10^\circ\text{C}$ ).; iv. Fruits coated with edible coating and stored under cold conditions ( $8\text{--}10^\circ\text{C}$ ).

Each treatment consisted of 10 fruits with three independent replicates. The experiment was conducted in duplicate to ensure reproducibility. All samples were stored for 15 days, and observations were conducted at predetermined intervals.

The edible coating was applied by dipping the coating solution uniformly onto the surface of the papaya fruits until fully covered. Coating was applied by dipping the fruits for 2 minutes, followed by air drying at room temperature. The coated fruits were allowed to air-dry before storage. The storage conditions included room temperature ( $25 \pm 2^\circ\text{C}$ ) and cold storage ( $8\text{--}10^\circ\text{C}$ ). The observations were conducted over a storage period of 15 days. Measurements were recorded at multiple time points (day 2, 4, 5, 6, 7, 8, 11, 12, 13, 14, and 15) to monitor progressive changes in physicochemical parameters.

Weight loss was determined by measuring the difference in fruit weight before and after storage and expressed as a percentage. The weight loss was determined by measuring fruit weight at the beginning of storage ( $W_0$ ) and at each sampling interval ( $W_t$ ). The weight loss percentage was calculated using the following equation:

$$\text{Weight loss (\%)} = \frac{W_0 - W_t}{W_0} \times 100$$

It were determined using the serial dilution method. A sterile cotton swab moistened with physiological saline solution was used to sample a  $1 \times 1 \text{ cm}^2$  area of the papaya surface. The swab was transferred into 9 mL of saline solution ( $10^{-1}$  dilution), followed by serial dilutions up to  $10^{-3}$ . Aliquots (1 mL) were plated onto PDA plates and incubated at  $25 \pm 2^\circ\text{C}$  for 48–72

hours. Colony-forming units (CFU) were counted and expressed as CFU/cm<sup>2</sup>. These analyses were performed in duplicate at each sampling interval.

Observations were conducted up to 15 days for weight loss and up to 10 days for yeast–mold count. All quantitative data were expressed as mean  $\pm$  standard deviation ( $n = 3$ ) and analyzed using appropriate statistical methods at a significance level of  $p < 0.05$ . Statistical analysis was performed using one-way analysis of variance (ANOVA), followed by post hoc tests to determine significant differences among treatments. Differences were considered statistically significant at  $p < 0.05$ .

The edible coating solutions prepared using *Gracilaria* sp. from Yogyakarta and Tegal produced homogeneous dispersions with distinct visual characteristics. The formulation derived from Yogyakarta seaweed exhibited a slightly greenish-white appearance, while the Tegal-based formulation appeared white. Both formulations showed acceptable homogeneity, and comparable viscosity and density (Table 1). Slight variations in viscosity may influence the coating thickness and barrier properties, which in turn affect moisture loss and gas exchange at the fruit surface. The observed differences may be attributed to variations in polysaccharide composition and gelling strength of *Gracilaria* sp. associated with geographical origin and environmental conditions.

Weight loss increased progressively during storage in all treatments (Table 2). Fruits stored at room temperature showed higher weight loss compared to cold storage. At day 15, papaya coated with *Gracilaria* (Tegal) showed weight loss of 21.68% under room temperature and 6.60% under cold storage, while papaya coated with *Gracilaria* (Yogyakarta) showed 24.52% and 6.28%, respectively. These results indicate that storage temperature had a greater effect on reducing weight loss than differences in seaweed source.

Yeast and mold counts increased during storage (Table 3). Higher microbial counts were observed under room temperature than cold storage. At day 10, counts reached 175.67 CFU/cm<sup>2</sup> (Tegal) and 173.33 CFU/cm<sup>2</sup> (Yogyakarta) under room temperature, while lower values of 42.67 and 31.33 CFU/cm<sup>2</sup> were observed under cold storage. The calculated C.D. value (36.41) indicated significant differences between storage conditions. These findings confirm that low temperature effectively suppresses microbial growth during storage.

This study primarily evaluated the effect of edible coating on weight loss and microbial growth. However, parameters related to fruit rot and market acceptability were not included, which may limit direct determination of shelf life from a consumer perspective.

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#### CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Table 1: Physicochemical characteristics of edible coating formulations**

Formulation	Appearance	Homogeneity	Viscosity (cPs)	Density (g/mL)
<i>Gracilaria</i> (Tegal)	White	Homogeneous	1.61	1.60
<i>Gracilaria</i> (Yogyakarta)	Greenish-white	Homogeneous	1.60	1.58

Values are expressed as mean  $\pm$  standard deviation (n = 3)

**Table 2: Effect of edible coating on weight loss of papaya (%) on storage**

Storage period (days)	Room temperature <i>Gracilaria</i> (Tegal)	Cold condition (8–10°C) <i>Gracilaria</i> (Tegal)	Room temperature <i>Gracilaria</i> (Yogyakarta)	Cold condition (8–10°C) ( <i>Gracilaria</i> (Yogyakarta))
After 1st day	0.00	0.00	0.00	0.00
After 4-days	0.65	1.69	0.29	0.46
5	1.09	2.41	0.53	1.98
6	1.31	2.71	0.80	2.28
7	3.31	3.63	3.11	2.94
8	7.84	4.25	8.00	3.55
11	10.06	5.17	9.37	4.56
12	11.27	5.48	10.76	4.76
13	12.97	5.94	13.39	5.22
14	15.54	6.29	16.14	5.83
15	21.68	6.60	24.52	6.28
C.D. values	2.85	0.42	2.40	0.39

**Table-3: Effect of edible coating on yeast and mold count during storage ((CFU/cm<sup>2</sup>))**

Storage period (days)	Room temperature, <i>Gracilaria</i> (Tegal)	Cold condition (8–10 °C) <i>Gracilaria</i> (Tegal)	Room temperature, <i>Gracilaria</i> (Yogyakarta)	Cold condition (8–10 °C) <i>Gracilaria</i> (Yogyakarta)
0	–	–	–	–
2	7.33 $\pm$ 2.52	1.67 $\pm$ 1.15	10.33 $\pm$ 5.13	1.67 $\pm$ 0.58
4	29.67 $\pm$ 16.07	3.33 $\pm$ 1.53	13.33 $\pm$ 1.53	4.00 $\pm$ 1.73
6	55.33 $\pm$ 9.29	4.67 $\pm$ 1.53	34.00 $\pm$ 22.07	6.33 $\pm$ 2.08
8	96.67 $\pm$ 37.87	20.67 $\pm$ 14.22	79.33 $\pm$ 27.68	7.67 $\pm$ 2.08
10	175.67 $\pm$ 57.93	42.67 $\pm$ 14.19	173.33 $\pm$ 75.06	31.33 $\pm$ 6.11
C.D. values	36.41	36.41	36.41	36.41

Values are expressed as mean  $\pm$  standard deviation (n = 3).

C.D. = Critical Difference at p = 0.05