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Lime Juice Marination with Local Spices: A Low-Cost Approach to Fresh Shrimp Preservation

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ABSTRACT

This study aimed to evaluate the effect of lime juice marination on the shelf life and sensory quality of shrimp (*Penaeus* spp.) as a low-cost preservation method. Fresh shrimp samples, each weighing 10–12 g, with a total sample weight of 3 kg, were sourced from the Segiri Traditional Market in Samarinda, East Kalimantan, Indonesia. The shrimp were manually peeled, cleaned, and marinated with freshly squeezed lime juice, followed by the addition of salt, shallots, chili, and basil leaves. The marinated products were then stored at room temperature (±27 °C) and under refrigeration (4 °C) to monitor changes in sensory attributes and spoilage indicators. The results showed that lime juice extended the shrimp's shelf life to approximately 12 hours at room temperature and up to 2–3 days under refrigeration, without visible signs of spoilage such as off-odor, discoloration, or slime formation. The observed improvements in shelf life and sensory quality were attributed to the antimicrobial effects of citric acid and the synergistic bioactive compounds present in the added spices. This method provides a practical and culturally relevant approach to enhancing the safety, sensory acceptability, and marketability of shrimp, particularly in regions with limited access to refrigeration.

INTRODUCTION

Shrimp is one of Indonesia's most valuable fishery commodities, playing a crucial role in both domestic consumption and international trade **(Rindayati & Akbar, 2022)**. Fresh shrimp is widely valued for its high-quality protein, essential amino acids, and low-fat content **(Dayal *et al.*, 2013; Bhatti *et al.*, 2025)**, making it an important component of many diets across the archipelago. However, due to its high moisture content, neutral pH, and rich nutrient profile, shrimp is highly perishable. Without proper handling or preservation, fresh shrimp undergoes rapid spoilage **(Das & Mishra, 2023)**, which is often first detected through changes in sensory attributes such as off-odors, discoloration, sliminess, and loss of firmness. These degradations are not only undesirable for consumers but also pose economic risks for producers and vendors along the supply chain. Previous studies have shown that microbial contamination, such as *Escherichia*

coli, is a common problem in fish muscle and handling environments, emphasizing the need for simple and effective preservation methods **(Sharef *et al.*, 2025)**.

To address these challenges, various preservation techniques have been employed, including freezing **(Zulfikar, 2016)**, refrigeration **(Herawati *et al.*, 2020)**, and the use of chemical preservatives. However, in many regions—especially rural and coastal areas where cold chain infrastructure is limited—simple and low-cost preservation methods are more practical and sustainable. One such method involves the use of organic acids, particularly from natural sources like citrus fruits, which are abundant and affordable in Indonesia. Natural preservatives derived from plants, including citrus extracts, herbs, and spices, have been widely reported as effective in maintaining quality and extending the shelf life of fish and seafood products **(Pebriani *et al.*, 2025)**. Lime juice (*Citrus aurantifolia*), known for its high citric acid content and antimicrobial properties, has long been used in traditional fish and seafood preparations to improve flavor and reduce unpleasant odors.

The application of lime juice in fish and shrimp processing is supported by a growing body of research. **(Poernomo *et al.*, 2004)** demonstrated that lime juice effectively reduced the fishy odor in fish-based products such as *petis ikan layang* (fish paste), without negatively affecting nutritional value. Similarly, **(Tarigan *et al.*, 2016)** found that different types of acid, including lime juice, significantly influenced the aroma and flavor profiles of *naniura* (a traditional Batak dish made from raw freshwater fish marinated in acid), highlighting the acid's role in sensory enhancement. Moreover, citric acid has been shown to denature muscle proteins, increase tenderness, and reduce surface microbial load, thereby improving shelf life and sensory acceptability **(Logr *et al.*, 2022)**.

Although many previous studies have combined organoleptic, microbiological, and chemical analyses **(Vanderzant *et al.*, 1973; Beltran *et al.*, 2013; Ullah, 2023)**, this study focuses solely on sensory characteristics as the primary indicators of quality. Organoleptic evaluation—including color, odor, texture, and taste—offers a direct assessment of how consumers perceive product freshness and quality. Sensory properties are highly sensitive to biochemical changes in shrimp tissue during storage or treatment. For example, the denaturation of surface proteins caused by acidic pH can lead to a firmer texture and reduced fishy odor due to the suppression of volatile amines such as trimethylamine (TMA) and ammonia **(Wang & Zheng, 2025)**, which are responsible for off-smells. Although no chemical or microbial parameters are directly measured in this study, changes in organoleptic scores may indirectly indicate alterations in microbial activity and chemical composition, particularly when supported by established literature.

The use of lime juice offers several advantages: it aligns with traditional culinary practices, poses minimal health risks, and supports the sustainable use of regional agro-fishery resources. Furthermore, the integration of natural acid treatments into small-scale processing may empower local producers to extend shelf life, maintain product quality,

and improve market value, particularly in areas with limited access to refrigeration or synthetic preservatives.

This study aimed to evaluate the influence of lime juice addition on the organoleptic quality of fresh shrimp. Specifically, it examines sensory changes in terms of appearance (color and clarity), aroma (freshness and off-odor), taste (sourness and balance), and texture (firmness and cohesiveness) of shrimp treated with lime juice. The results are expected to provide insights into how a simple, natural acid treatment can be applied to maintain or enhance shrimp quality, thereby offering a practical and locally adaptable preservation method within the field of fishery processing technology.

MATERIALS AND METHODS

Materials and equipment

This study utilized several tools, including a digital scale, basin, knife, and airtight food-grade containers. The digital scale was employed to measure the precise weight of shrimp and supporting ingredients. A basin was used for washing and handling shrimp during cleaning, while a sharp knife was used for deveining and trimming. All marination steps were carried out in sealed containers to ensure uniform exposure to lime juice and to prevent contamination during storage.

Materials

The primary raw material was fresh medium-sized shrimp (approximately 125 g per portion), selected for its high perishability and responsiveness to acid-based treatment. The key treatment ingredient was lime (*Citrus aurantifolia*), with juice from three whole fruits (75 ± 5 g) freshly squeezed and applied to the shrimp. Lime juice was chosen for its high citric acid content, which reduces pH, enhances sensory characteristics, and suppresses microbial growth through protein denaturation and neutralization of amine compounds responsible for fishy odors.

Supporting ingredients included seven red chili peppers (≈20 g), four sliced shallots (≈30 g), 2 g of fresh lemon basil leaves (*Ocimum* × *citriodorum*), and one teaspoon of salt (≈5 g; equal to 1.5% w/w based on shrimp weight). These were incorporated post-marination to enrich flavor, contribute aroma, and enhance the overall sensory profile. Chili and shallots—common aromatics in traditional Indonesian cuisine—provided heat and sweetness, while lemon basil added a fresh herbal note. Salt was used to season the shrimp and assist in texture development through osmotic interaction with tissue proteins.

Sample preparation

Fresh whiteleg shrimp (*Litopenaeus vannamei*) were obtained from a traditional seafood market in Samarinda, East Kalimantan, Indonesia. Sampling was conducted in the early morning (≈07:00 WITA) to ensure freshness and minimize post-harvest deterioration. The ambient market temperature at the time of sampling was 28–30 °C. The shrimp were medium-sized, measuring 10–12 cm in length and weighing 12–15 g per individual, with a total of 3 kg collected.

Upon arrival at the laboratory, the shrimp were rinsed under clean running water. Heads, shells, and tails were manually removed, and the shrimp were deveined via dorsal incisions. Cleaned samples were placed into sanitized, airtight containers and subjected immediately to lime juice marination at room temperature (27 ± 1 °C). Prior to treatment, baseline sensory observations (appearance, texture, aroma) were recorded.

Lime juice marination and seasoning

Fresh lime juice (*C. aurantifolia*) was manually extracted and added to the containers until the shrimp were fully submerged. The containers were sealed and left at room temperature (≈27 °C) for 30 minutes. During marination, visual and olfactory changes (e.g., color shift, tissue firmness, odor intensity) were recorded to monitor the effects of acid exposure.

After marination, seasoning ingredients—sliced shallots (*Allium cepa*), red chili peppers (*Capsicum annuum*), lemon basil leaves (*O.* × *africanum*), and salt (1.5% w/w)—were added directly to the shrimp mixture. The contents were gently stirred to ensure uniform distribution, then rested for an additional 10 minutes at room temperature in covered containers to allow flavor integration. Final observations were made on shrimp color, aroma, and texture to assess the organoleptic impact of lime-based marination.

Data analysis

A descriptive qualitative approach was used to assess sensory changes in shrimp during the marination process. The evaluation focused on four key attributes—color, texture, aroma, and taste—at three defined stages:

1. Prior to treatment,
2. After 30 minutes of lime juice marination, and
3. Following the addition of seasoning and a 10-minute resting period.

Observations were carried out through direct visual, olfactory, tactile, and gustatory assessments by trained evaluators. No instrumental or quantitative methods were employed; instead, results were described narratively to capture subtle sensory transformations not easily quantified. Descriptive terminology familiar in culinary and food processing contexts was used to characterize changes.

Findings were systematically organized and presented in a comparative table to illustrate the progression of organoleptic characteristics. This qualitative approach was selected to simulate real-world practices in local seafood processing, where rapid, practical, and experience-based sensory assessments are often more feasible than advanced instrumental analyses.

By employing this method, the study sought to highlight the practical effectiveness of lime-based marination as a traditional yet functional preservation and flavor-enhancement technique for small-scale or household-level seafood preparation.

RESULTS

The sensory changes in shrimp before, during, and after treatment with lime juice were observed and summarized in Table (1). The parameters evaluated included appearance (color and clarity), aroma (freshness and off-odor), taste (sourness and balance), texture (firmness and cohesiveness), and observed shelf life under room temperature and chilled storage conditions.

Table 1. Sensory observation of shrimp before, during, and after lime marination treatment

Paramater	Before Treatment	After 30 Minute of Lime Marination	After Final Mixing (50 Minutes)
Appearance (Color and Clarity)	Translucent white	Reddish-orange, more opaque	Slightlt pale orange-white with visible seasoning particles
Texture (Firmness and Cohesiveness)	Firm and chewy	Firm and elastic	Slightly tender, easy to cut or chew
Aroma (Freshness and Off-odor)	Fresh shrimp odor	Dominated by citrus (lime), shrimp odor reduced	Herbal-spicy aroma (basil, chili, shallot), shrimp odor almost absent
Taste (Firmness and	-	Mildly sweet, umami, citrusy, no	Balanced flavor of lime, shallot, chili

Cohesiveness)		fishy aftertaste	and basil), no lingering fishy taste
Observed Shelf Life	2-6 hours at room temperature, 1-2 daysunder refrigeration	±12 hours at room temperature, 1-2 days under refrigeration	±12 hours at room temperature, 2-3 days under refrigeration

Fig. (1) presents the visual appearance of the shrimp product after 50 minutes of marination with lime juice and the addition of shallots, chili, lemon basil, and salt. The shrimp exhibit a slightly pale orange-white color, with visible seasoning ingredients,

indicating fullabsorption of the marinade and integration of local aromatic herbs .

A **B** **C**

Fig. 1. Visual appearance of shrimp at different stages of lime marination and seasoning. The image illustrates the organoleptic transformation over time.
(A) Fresh raw shrimp before treatment,
(B) Shrimp after 40 minutes of marination with lime juice and salt,
(C) Final product after the addition of shallots, chili, lemon basil, and further resting

The marination of shrimp with freshly squeezed lime juice produced distinct and progressive changes in their organoleptic characteristics.

In the untreated state, the shrimp exhibited a translucent white coloration, a firm and elastic texture, and a characteristic fresh marine aroma typical of raw shrimp.

After 30 minutes of lime juice marination, the shrimp underwent notable transformations. The color shifted to a reddish-orange, indicating acid-induced protein denaturation. The texture remained firm and elastic, suggesting that structural integrity was maintained during this stage. The aroma was dominated by a refreshing citrus note, while the typical shrimp odor was markedly reduced. Taste evaluation revealed the development of mild sweetness, umami depth, and a distinct citrus character, with no detectable fishy

aftertaste. At this stage, shelf life was extended to approximately 12 hours at room temperature and 1–2 days under refrigeration.

Following the addition of shallots, chili peppers, basil leaves, and salt, and an additional 10 minutes of resting (50 minutes total processing), further sensory modifications were observed. The shrimp appeared slightly paler with orange-white tones, and seasoning particles were visible on the surface. The texture became moderately tender, making the shrimp easier to cut and chew. The aroma was enriched with herbal and spicy notes derived from basil, chili, and shallots, effectively masking any residual shrimp odor. Taste evaluation revealed a balanced profile combining citrus, savory, and herbal flavors, with no lingering off-taste. At this stage, shelf life was maintained at 12 hours at room temperature and extended to 2–3 days under refrigeration, indicating enhanced preservation compared to untreated shrimp.

DISCUSSION

1. Change in appearance (Color and Clarity)

One of the most prominent changes during lime juice marination was the alteration in shrimp appearance. In their raw state, the shrimp exhibited a translucent white color typical of fresh muscle tissue. After 30 minutes of marination, the shrimp turned reddish-orange, indicating acid-induced protein denaturation, particularly of myosin and actin **(Acharya, 2021; Logr *et al.*, 2022)**. The acidic environment created by citric acid lowers the pH, disrupting hydrogen bonding and electrostatic interactions within muscle proteins. These structural changes affect the refractive index and opacity of the tissue, resulting in a more vivid and opaque appearance **(Lan *et al.*, 2024)**.

This increased opacity gave the shrimp a “cooked” appearance, which may enhance consumer acceptance. After the addition of shallots, chili, basil, and salt, and a further 10-minute resting period, the shrimp showed a slightly paler orange-white tone with visible seasoning particles. This dilution effect did not reduce the perception of freshness; instead, it provided a more appetizing presentation consistent with traditional culinary practices.

2. Changes in texture (Firmness and Cohesiveness)

During the initial 30 minutes of marination, the shrimp retained a firm and elastic texture, associated with acid-induced protein tightening. The denaturation and aggregation of structural proteins under acidic conditions enhanced tissue rigidity **(Li *et al.*, 2018; Uranga *et al.*, 2020)**. Citric acid facilitates protein aggregation through electrostatic interactions and hydrogen bond disruption, which increases muscle firmness in the early stages of treatment.

After seasoning and a further 10-minute resting period, the shrimp texture became noticeably more tender and easier to cut. This softening effect likely resulted from

continued acid diffusion into the muscle fibers, leading to further protein denaturation and partial breakdown of connective structures. Additionally, the osmotic action of salt contributed to water loss from intracellular spaces, reducing protein–water interactions and weakening structural integrity **(Aksu & Kaya, 2007; Gu *et al.,* 2020)**. The acidic environment also lowered water-holding capacity, leading to increased moisture release and a more pliable texture **(He *et al.,* 2015)**.

From a microbiological perspective, the acidic and saline conditions may also have indirectly stabilized texture by inhibiting spoilage-associated enzymatic degradation. Citric acid reduces pH to levels that disrupt bacterial cell membranes and enzymatic activity, limiting proteolytic softening **(Logr *et al.,* 2022)**. Salt enhances microbial inhibition via osmotic stress, dehydrating microbial cells and prolonging textural stability. Collectively, these physicochemical and microbiological interactions highlight the dual role of acid marination in both modifying texture and extending shelf life.

3. Changes in Aroma (Freshness and Off-odor)

In its raw state, shrimp emitted a characteristic marine odor derived from volatile amines and other nitrogenous metabolites. After lime juice marination, the aroma shifted toward a dominant citrus scent, while the typical "fishy" odor was significantly reduced. This reduction can be attributed to citric acid neutralizing volatile bases such as trimethylamine (TMA) and ammonia, early indicators of spoilage **(Bou *et al.,* 2017)**. The acidified environment also suppressed microbial activity responsible for producing off-odors **(Cv *et al.,* 2016)**.

After seasoning, the aroma profile became more complex and appealing. Shallots contributed sulfur-containing volatiles, chili provided capsaicinoids, and basil supplied terpenoids such as eugenol, linalool, and 1,8-cineole. These compounds not only enriched aroma but also possessed antimicrobial properties **(Tarigan *et al.,* 2016; Hutapea *et al.,* 2019)**. Their combined effect enhanced perceived freshness while masking residual shrimp odor.

Overall, aroma transformation reflected both physicochemical and microbial mechanisms. Lime marination, supported by herbs and spices, improved sensory perception and strengthened microbiological stability, making the product more acceptable for short-term storage and direct consumption.

4. Changes in taste (Sourness and Balance)

Taste evaluation revealed progressive improvements across treatments. In the untreated state, shrimp lacked distinctive flavor. After 30 minutes of lime marination, the shrimp developed a balanced profile characterized by mild sweetness, umami depth, and refreshing citrus notes, with no fishy aftertaste. The emergence of umami likely stemmed from glutamic acid and nucleotides naturally present in shrimp, which act synergistically with organic acids to enhance taste **(Chen *et al.,* 2021; Hara *et al.,* 2023)**. Acid-induced

protein denaturation released free amino acids and peptides, further contributing to flavor development.

The suppression of unpleasant ammonia-like notes was attributed to the antimicrobial action of citric acid, which reduces microbial production of volatile nitrogen compounds **(Baptista *et al.*, 2019)**. In the final preparation stage, aromatics enriched flavor complexity: shallots imparted mild sweetness and sulfur notes, chili introduced spiciness, basil contributed herbal freshness, and salt enhanced natural flavors while masking bitterness **(GroEat, 2025)**.

Thus, lime-based marination combined with seasonings not only preserved the shrimp but also transformed its flavor into a more balanced and palatable profile suitable for ready-to-eat seafood.

5. Shelf-life extension and microbiological implications

Under ambient conditions, untreated shrimp typically spoils within a few hours due to rapid microbial proliferation. In this study, lime juice marination extended shelf life to ~12 hours at room temperature (27 ± 1 °C) and up to 2 days under refrigeration (4 °C). With seasoning, shelf life was further extended to 2–3 days under refrigeration, with no observable signs of spoilage.

The enhanced stability was attributed to the antimicrobial effects of citric acid, salt, and bioactive compounds from seasonings. Citric acid disrupts microbial membranes and enzymatic function **(Zhang *et al.*, 2021)**, while salt exerts osmotic stress. Allicin from shallots and capsaicin from chili provide additional antimicrobial and antioxidant activity **(Baptista *et al.*, 2019)**. Together, these mechanisms are effective against common seafood spoilage bacteria such as *Pseudomonas* spp., *Shewanella putrefaciens*, and lactic acid bacteria **(Somboonyarithi, 1990)**.

Although microbial counts were not measured, the absence of off-odors, discoloration, and slime suggested successful inhibition of spoilage organisms. These findings indicate that lime marination, supplemented with spices and herbs, provides both sensory enhancement and a protective barrier against microbial deterioration.

CONCLUSION

Lime juice marination significantly improved the sensory qualities and storage stability of fresh shrimp. The treatment enhanced appearance (color and clarity), texture (firmness and cohesiveness), aroma (freshness and reduction of off-odor), and taste (sourness and balance), while effectively suppressing spoilage-related changes. The shelf life of untreated shrimp was limited to 2–6 hours at room temperature and 1–2 days under refrigeration. In contrast, shrimp treated with lime juice and local spices maintained acceptable quality for up to 12 hours at room temperature (±27 °C) and 2–3 days under refrigeration (4 °C).

These improvements can be attributed to the antimicrobial and protein-denaturing effects of citric acid, supported by bioactive compounds present in chili, shallots, basil, and salt. As a simple and low-cost method, lime-based marination not only aligns with traditional culinary practices but also provides a practical preservation strategy for extending shrimp freshness and acceptability in regions with limited access to cold storage.

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