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Research Article

Utilization of Nipa Palm (*Nypa fruticans*) Leaf Extract as a Natural Preservative for Salted Three-Spot Gourami (*Trichopodus trichopterus*)

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Abstract:

Background: Salted three-spot gourami (*Trichopodus trichopterus*) is a traditional fish product that is susceptible to microbial spoilage and quality deterioration during storage. The use of plant-based bio-preservatives has been explored as an alternative to synthetic additives to improve product safety and shelf life.
Aims: This study aimed to assess the effectiveness of nipa palm (*Nypa fruticans*) leaf extract at different concentrations as a natural preservative for salted three-spot gourami.
Methods: The experiment was arranged in a Completely Randomized Design (CRD) with four treatments (0%, 10%, 15%, and 20%) and three replications. Parameters observed included moisture content, Total Plate Count (TPC), and organoleptic attributes (appearance, aroma, and texture).
Results: The application of nipa palm leaf extract significantly ($P < 0.05$) affected moisture content, microbial growth, and sensory quality during storage. The 15% treatment (P2) produced the lowest moisture content throughout storage, reaching 19.83% on day 30. Microbial counts in all extract-treated samples remained within the maximum permissible limit of the Indonesian National Standard ($\leq 1 \times 10^5$ CFU/g), with the 20% treatment (P3) showing the lowest microbial load (1.0×10^5 CFU/g) on day 30. Sensory evaluation indicated that extract-treated samples maintained acceptable appearance, aroma, and texture throughout storage, with better sensory stability than the untreated control.
Conclusion: Nipa palm leaf extract effectively improved the storage quality of salted three-spot gourami. Although the 15% concentration (P2) achieved the greatest moisture reduction, the 20% concentration (P3) is recommended for practical application because it provided the strongest microbial inhibition while maintaining acceptable sensory quality during 30 days of storage.

Keywords: Microbial stability; Nipa palm leaf extract; Salted three-spot gourami; Sensory quality; Shelf life

1. INTRODUCTION

Fish and fishery-based products are essential sources of animal protein globally, especially in developing countries such as Indonesia, where fish plays a major role in meeting nutritional needs (FAO, 2022). Among various processed fish commodities, salted fish remains widely consumed due to its affordability, unique taste, and cultural acceptance. However, salted fish is highly perishable, particularly when produced and stored under traditional conditions, making it prone to microbial spoilage, oxidative damage, and sensory deterioration (Tahiluddin et al., 2022). In South Sumatra Province, one of Indonesia's major fishery-producing regions, the three-spot gourami (*Trichopodus trichopterus*), locally known as *ikan sepat*, represents a readily available freshwater species throughout both dry and rainy seasons (Jusmaldi et al., 2021). The continual availability of this species has supported the emergence of small-scale enterprises specializing in the production of salted gourami, a traditional fish product with cultural and economic importance in local communities (Indrastuti et al., 2019). These artisanal industries contribute to household income and support local livelihoods; however, they frequently employ rudimentary preservation techniques that may compromise product quality and safety.

Salted fish products, including salted gourami, are expected to remain safe, nutritious, and acceptable to consumers throughout their intended storage period. In practice, however, traditional salting methods often lack sufficient control over factors that influence microbial proliferation and chemical degradation, leading to spoilage, textural weakening, and sensory deterioration (Puspitasari et al., 2021). This situation reveals a substantial gap between ideal quality expectations and actual product outcomes in traditional processing systems. Similar challenges have been documented across various forms of fermented and preserved fish products in South and Southeast Asia, where conventional techniques struggle to ensure consistent

shelf stability and consumer acceptability (Narzary et al., 2021).

Salting is one of the oldest and most widely applied fish preservation techniques because it reduces water activity and inhibits microbial growth. Nevertheless, salting alone cannot completely prevent biochemical deterioration during prolonged storage (Nosić, 2026). In artisanal fish processing, species with slender body shapes, such as the three-spot gourami (*Trichopodus trichopterus*), tend to dry more rapidly due to increased surface-to-volume ratios, making them suitable for traditional salting and drying operations (Jusmaldi et al., 2021). Nonetheless, salting alone is often insufficient to ensure long-term product stability.

To extend shelf life and enhance sensory attributes, processors frequently use additional food additives, including preservatives, colourants, and flavour enhancers. While these compounds can improve product appeal and storage performance, their indiscriminate or unregulated use raises significant safety concerns (Haetami et al., 2024).

One of the most problematic chemical additives found in some traditional markets is formaldehyde (formalin), which is sometimes applied illegally due to its low cost and its ability to impart a firmer texture and apparent cleanliness to fish products (Haetami et al., 2024). Formaldehyde is classified as a human carcinogen, and chronic exposure through contaminated food may lead to respiratory irritation, gastrointestinal disorders, and increased cancer risk (Li et al., 2023; Sun et al., 2025). Investigations in Indonesia have documented the presence of formalin in salted fish sold in traditional marketplaces, indicating a persistent public health issue despite regulatory prohibitions (Haetami et al., 2024). Such findings underscore the urgent need for safer, natural preservative alternatives that can maintain product quality without compromising consumer safety. Preliminary laboratory analyses conducted by the authors on samples collected from several traditional markets in Palembang revealed indications of formaldehyde presence, supporting the urgency of this problem in the local supply chain (unpublished data).

Plant-derived preservatives have gained increased scientific attention as potential alternatives to synthetic additives because they contain a range of bioactive compounds with demonstrated antimicrobial and antioxidant properties, which can help maintain food quality and safety (Pereira et al., 2026). Among underutilized mangrove plants in Southeast Asia, the nipa palm (*Nypa fruticans* Wurmb.) has shown considerable promise due to its rich phytochemical profile, including polyphenols, flavonoids, tannins, and terpenoids, which are associated with inhibitory activity against foodborne pathogens and oxidative processes (Quoc et al., 2025). Recent literature has reported that various parts of *N. fruticans* exhibit biological activities relevant to food preservation, such as antioxidant capacity and antibacterial effects, underscoring its potential application beyond traditional uses (Quoc et al., 2025). Despite its wide distribution in tropical coastal regions and its economic abundance, the utilization of nipa palm in food systems remains limited compared to other plant resources with established preservative applications, highlighting both a research gap and an opportunity to explore its functionality in extending the shelf life of perishable products.

Figure 1. Nipa palm (*Nypa fruticans*)

Research Gap and Novelty

While earlier studies have primarily focused on the use of nipa palm extract in fresh aquatic products, limited research has been conducted on its application in traditional salted fish preservation. This study seeks to address this gap by evaluating the effect of nipa palm leaf extract on salted three-spot gourami, a culturally and economically important product in Indonesia.

Objective and Hypothesis

Therefore, this study was undertaken to investigate the influence of nipa palm (*Nypa fruticans*) leaf extract at different concentrations on the chemical, microbial, and sensory properties of salted three-spot gourami (*Trichopodus trichopterus*). It is hypothesized that the addition of nipa palm leaf extract at an optimal concentration will significantly enhance microbial stability, reduce moisture content, and preserve sensory quality, thereby extending the shelf life of salted three-spot gourami.

2. MATERIAL AND METHOD

2.1 Type of Research

This study employed an experimental approach to evaluate the effectiveness of nipa palm (*Nypa fruticans*) leaf extract as a natural preservative in salted three-spot gourami (*Trichopodus trichopterus*). A Completely Randomized Design (CRD) was applied, consisting of one treatment factor, namely the concentration of nipa leaf extract, with four levels: 0% (control/P0), 10% (P1), 15% (P2), and 20% (P3). Each treatment was conducted in triplicate.

2.2 Research Time and Location

The research was conducted from February to April 2025. Fresh nipa leaves were collected from Sungsang Village, Banyuasin Regency, South Sumatra, Indonesia. Fresh three-spot gourami were obtained from 16 Ilir Market, Palembang City, South Sumatra, Indonesia.
The experimental procedures were carried out at three different laboratories:

1) Workshop of Fishery Product Processing Technology (WSTPHP), Faculty of Fisheries and Marine Science, Universitas PGRI Palembang: for drying nipa leaves, producing nipa leaf powder, preparing salted fish samples, oven drying, yield determination, and sensory evaluation (appearance, aroma, and texture).
2) Laboratory of Agricultural Product Chemistry, Universitas Sriwijaya, Palembang: for nipa leaf extraction, phytochemical screening, and moisture content analysis.
3) Microbiology Laboratory, Universitas PGRI Palembang: for Total Plate Count (TPC) analysis.

2.3 Materials and Instruments

2.3.1 Materials

The primary materials included fresh three-spot gourami (average weight 22 ± 0.5 g; average length 9 ± 0.5 cm), fresh mature nipa leaves (approximately 30 kg), salt (sodium chloride/NaCl), 96% ethanol (maceration solvent), 70% ethanol (for sterilization), distilled water and analytical reagents.

Figure 2. Three-Spot Gourami (*Trichopodus trichopterus*)

2.3.2 Instruments

The equipment used included an oven (105°C and 70°C capacity), analytical balance (0.0001 g precision), blender, porcelain crucibles, Erlenmeyer flasks, glass stirring rods, filter paper (Whatman No. 42), rotary vacuum evaporator, sterile Petri dishes, incubator (37°C), desiccator, and standard microbiological glassware.

2.4 Research Procedures

The study was conducted in four main stages:

1) Preparation of raw materials (nipa leaves and fish).
2) Processing of nipa leaf powder and extract, and production of salted fish.
3) Application of nipa leaf extract to salted fish.
4) Laboratory analyses.

2.4.1 Preparation of Nipa Leaf Simplicia (Dewi et al., 2023)

Fresh nipa leaves were washed, cut into small pieces, and sun-dried at approximately 35°C for three days. The dried material was ground into powder and sieved. The powder was stored in airtight containers.

The yield of simplicia was calculated using Equation (1):

$$Nipa\ Leaf\ Flour\ Yield\ (\%) = \frac{A}{B} \times 100 \quad (1)$$

where **A** is the weight of nipa palm leaf flour obtained after drying, grinding, and sieving (g), and **B** is the initial weight of fresh nipa palm leaves (g).

2.4.2 Extraction of Nipa Leaves (Dewi et al., 2023)

Extraction was performed using the maceration method with 96% ethanol. Fifty grams of nipa leaf powder were soaked in 150 mL ethanol for 72 hours at room-temperature storage, with solvent replacement every 24 hours and occasional stirring. The filtrate was separated and concentrated using a rotary vacuum evaporator at 55°C and 200 rpm to obtain a viscous extract.

Extract yield was calculated using Equation (2):

$$Nipa\ Leaf\ Extract\ Yield\ (\%) = \frac{A}{B} \times 100 \quad (2)$$

where **A** is the weight of the concentrated nipa palm leaf extract obtained after solvent removal using a rotary evaporator (g), and **B** is the weight of nipa palm leaf flour subjected to extraction (g).

The concentrated extract was stored in sealed vials at room-temperature storage.

2.4.3 Production of Salted Three-Spot gourami (Damopolii et al., 2024)

Fresh three-spot gourami (*Trichopodus trichopterus*) with an average body weight of 22 ± 0.01 g and an average total length of approximately 9 cm were purchased from the 16 Ilir Traditional Market, Palembang, South Sumatra, Indonesia. The fish were descaled, eviscerated, thoroughly washed under running water to remove blood and impurities, and drained.

Salted three-spot gourami were prepared according to Damopolii et al.(2024) with minor modifications. Briefly, the cleaned fish were first immersed in distilled water (control) or nipa leaf extract solutions at different concentrations, as described in Section 2.4.5. After immersion, the fish were drained and dry-salted using

20% (w/w) salt for 24 h. The salted fish were subsequently dried in a hot-air oven at 70°C for 8 h, cooled to room temperature, packaged, and stored at room temperature for 30 days. Analyses were conducted immediately after drying (Day 0) and after 30 days of storage (Day 30).

2.4.4 Preparation of Extract Solutions (Modified from Sumartini & Purnama, 2021)

The concentrated nipa palm leaf extract obtained after solvent evaporation exhibited a viscous consistency. Therefore, treatment solutions were prepared on a weight/volume (w/v) basis instead of a volume/volume (v/v) basis. Extract concentrations of 10%, 15%, and 20% (w/v) were prepared by dissolving the appropriate mass of extract in distilled water to a final volume of 200 mL. The concentration was calculated using Equation (3):

$$Extract\ concentration\ (\%, w/v) = \frac{W}{V} \times 100 \qquad (3)$$

where **W** is the weight of concentrated nipa palm leaf extract (g) and **V** is the final volume of the solution (mL).

Treatment solutions were prepared by dissolving 20 g extract per 200 mL solution (10%), 30 g extract per 200 mL solution (15%), and 40 g extract per 200 mL solution (20%).

2.4.5 Application of Extract to Fish (Damopolii et al., 2024)

Four immersion solutions were prepared consisting of distilled water (0%, control), and nipa palm leaf extract at concentrations of 10%, 15%, and 20% (w/v). Fish were immersed individually in 200 mL of the respective solution for 2 h at room temperature before being subjected to salting and drying.

After immersion, the fish were drained and subjected to dry salting using 20% (w/w) salt for 24 h, followed by drying in a hot-air oven at 70°C for 8 h. The dried fish were cooled, packaged, and stored at room temperature for 30 days.

Physicochemical analyses, microbiological analyses, and sensory evaluation were performed on the dried fish immediately after processing (Day 0) and after 30 days of storage (Day 30).

2.5 Parameters Observed

2.5.1 Phytochemical Screening

Qualitative phytochemical screening was performed to identify the presence of flavonoids, terpenoids, phenolics, and tannins using established colorimetric procedures (Dewi et al., 2023). Positive results were indicated by characteristic color changes following the addition of specific reagents.

2.5.2 Moisture Content Analysis (BSN, 2006a)

Moisture content was determined according to SNI 8273:2023 using the oven-drying method at 105°C for 24 h. Moisture content was calculated using Equation (4):

$$Moisture\ Content\ (\%) = \frac{B-C}{B-A} \times 100 \qquad (4)$$

where **A** is the weight of the empty crucible (g), **B** is the weight of crucible + fresh sample (g), and **C** is the weight of crucible + dried sample (g).

2.5.3 Microbiological Analysis (Total Plate Count, TPC) (BSN, 2006b)

TPC analysis followed SNI 8273:2023. Five grams of sample were homogenized in 45 mL Buffer Peptone Water (BPW). Serial dilutions were prepared up to 10^{-6}. One millilitre of each dilution was plated on Nutrient Agar (NA) and incubated at 37°C for 24 h. Colonies were counted and expressed as CFU/g.

2.5.4 Sensory Evaluation (BSN, 2025)

Sensory assessment was conducted using a modified SNI 2346:2025 scoring method. Fifteen semi-trained panellists evaluated appearance, aroma, and texture. Samples were scored using a structured scoring scale under controlled conditions.

2.6 Data Analysis

Data were analyzed using one-way analysis of variance (ANOVA). When significant treatment effects ($P < 0.05$) were detected, the coefficient of variation (CV) was calculated to determine the appropriate post-hoc test according to the criteria described by Hanafiah (2010). Based on the obtained CV values, Fisher's Least Significant Difference (LSD) test was selected for mean separation at the 5% significance level. Statistical analyses were performed using IBM SPSS Statistics version 26.

2.7 Scope and Limitations

This study focused on evaluating the preservative potential of nipa leaf extract in salted three-spot gourami during 30 days of room-temperature storage. The investigation was limited to phytochemical, moisture, microbiological (TPC), and sensory parameters and did not include detailed compound isolation or shelf-life modelling beyond the specified storage period.

3. RESULT AND DISCUSSION

3.1 Results

3.1.1. Processing of Salted Sepat Fish

Fresh three-spot gourami (*Trichopodus trichopterus*), averaging 22 g in weight and 9 cm in length, were processed into salted fish following the procedures described in the Research Procedures section. The products were then immersed in nipa palm (*Nypa*

fruticans) leaf extract as a natural antibacterial treatment at four concentrations: P0 (0%, control), P1 (10%), P2 (15%), and P3 (20%).

3.1.2. Yield Analysis

Yield of Dried Nipa Leaves

The initial mass of fresh nipa leaves was decreased from 30 kg to 12 kg after drying, corresponding to a recovery yield of 40%, indicating substantial moisture loss during the drying process.

Yield of Nipa Leaf Extract

From 5kg of dried nipa leaf powder, 380mL of concentrated extract was obtained after maceration and solvent evaporation. Assuming a density of 1 g/mL, this equals 380g, resulting in an extraction yield of 7.6%, reflecting the efficiency of the extraction process.

3.1.3. Phytochemical Screening of Nipa Leaf Extract

Phytochemical screening revealed the presence of several bioactive secondary metabolites. Positive reactions were observed for flavonoids, triterpenoids, phenolic compounds, and tannins, indicated by characteristic color changes during testing:

1) Flavonoids : yellow to reddish-orange
2) Triterpenoids : reddish-orange to purple
3) Phenolics : green to bluish-black
4) Tannins : green to bluish-black

These results confirm that the extract contains compounds with potential antimicrobial activity. The presence of these secondary metabolites suggests that the extract possesses potential antimicrobial and antioxidant activities suitable for food preservation.

3.1.4. Moisture Content Analysis

Moisture content was measured on day 0 and day 30 of storage.

Table 1. Moisture Content of Salted Three-Spot Gourami During Storage

Treatment	Day 0 (%)	Day 30 (%)
P0	22.64 ± 0.10^{b}	26.86 ± 1.07^{b}
P1	22.65 ± 0.16^{b}	22.36 ± 0.58^{a}
P2	17.06 ± 0.46^{a}	19.83 ± 0.89^{a}
P3	20.80 ± 0.70^{ab}	25.83 ± 1.61^{ab}

Values are presented as mean ± standard deviation (n = 3). Means within the same column followed by different superscript letters differ significantly according to Tukey's Honestly Significant Difference (HSD) test ($P < 0.05$).

3.1.5. Total Plate Count (TPC)

Microbiological quality was evaluated on day 0 and day 30.

Day 0

1) P0: 2.8×10^{4} CFU/g
2) P1: 2.9×10^{4} CFU/g
3) P2: 2.8×10^{4} CFU/g
4) P3: 2.7×10^{4} CFU/g

Day 30

1) P0: 3.5×10^{6} CFU/g
2) P1: 1.2×10^{5} CFU/g
3) P2: 1.1×10^{5} CFU/g
4) P3: 1.0×10^{5} CFU/g

Only the control (P0) exceeded the maximum permissible microbial limit (1×10^{6} CFU/g) (BSN, 2023) after storage. Treatments containing nipa leaf extract effectively suppressed microbial growth, demonstrating its antibacterial potential during storage.

3.1.6. Sensory Evaluation

Sensory evaluation was conducted on day 0 and day 30 using 15 panellists assessing appearance, aroma, and texture. Significant treatment effects identified by ANOVA were further analyzed using Fisher's Least Significant Difference (LSD) test, as selected based on the coefficient of variation criteria proposed by Hanafiah, (2010).

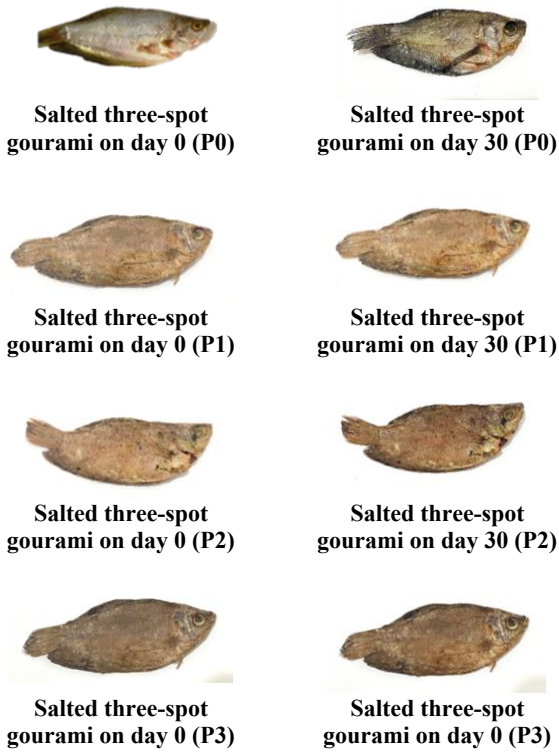

Figure 3. Appearance of Salted Three-Spot Gourami During Storage After Nipa Leaf Extract Treatment

Table 2. Sensory Attributes of Salted Three-Spot Gourami Containing Different Concentrations of Nipa Leaf Extract on Day 0

Treatment	Appearance	Aroma	Texture
P0 (0%)	4.60 ± 0.51^{b}	3.73 ± 0.80	4.53 ± 0.52
P1 (10%)	3.40 ± 0.63^{a}	3.73 ± 0.70	4.27 ± 0.70
P2 (15%)	3.27 ± 0.80^{a}	3.73 ± 0.59	4.20 ± 0.68
P3 (20%)	3.20 ± 0.86^{a}	3.73 ± 0.59	4.27 ± 0.80

Values are expressed as mean ± standard deviation (n = 15). Means within the same column followed by different superscript letters differ significantly according to Fisher's Least Significant Difference (LSD) test ($P < 0.05$). No superscript letters are presented for

aroma and texture because ANOVA indicated no significant differences among treatments ($P > 0.05$).

Table 3. Sensory Attributes of Salted Three-Spot Gourami Containing Different Concentrations of Nipa Leaf Extract after 30 Days of Storage

Treatment	Appearance	Aroma	Texture
P0 (0%)	2.47 ± 0.99	1.87 ± 0.83[a]	1.67 ± 0.72[a]
P1 (10%)	2.80 ± 0.78	3.07 ± 0.59[b]	3.53 ± 0.74[b]
P2 (15%)	2.87 ± 0.64	3.33 ± 0.62[b]	3.47 ± 0.64[b]
P3 (20%)	2.67 ± 0.72	3.40 ± 0.74[b]	3.53 ± 0.74[b]

Values are expressed as mean ± standard deviation (n = 15). Means within the same column followed by different superscript letters differ significantly according to Fisher's Least Significant Difference (LSD) test ($P < 0.05$). No superscript letters are presented for appearance because ANOVA indicated no significant differences among treatments ($P > 0.05$).

3.2. Discussion

Yield of Dried Leaves and Extract

The drying yield of nipa leaves (40%) indicates considerable moisture removal, consistent with other plant-based materials where substantial water loss occurs prior to extraction (Plaskova & Mlcek, 2023). The extract yield (7.6%) aligns with typical yields of bioactive plant extracts and reflects moderate efficiency, influenced by solvent polarity, solvent volume, extraction duration, and drying conditions (Presenza et al., 2023). Ethanol serves as a broadly effective solvent for extracting phenolic and flavonoid compounds due to its intermediate polarity.

Phytochemical Profile

Qualitative screening confirmed the presence of flavonoids, phenolics, tannins, and triterpenoids in the extract. These compound classes are widely recognized for their antimicrobial and antioxidant properties, with phenolic compounds particularly responsible for inhibiting microbial proliferation and free-radical formation (Oulahal & Degraeve, 2022; Presenza et al., 2023). Studies on Nypa fruticans also report similar phytochemical presence and corresponding bioactivity, supporting the observed effects in this research (Utami, 2022).

Relationship Between Moisture Content and Microbial Growth

Moisture content is a critical factor affecting the quality, safety, and shelf life of dried fish products because it influences water availability for microbial growth and biochemical reactions. In general, higher moisture levels provide more favorable conditions for microbial proliferation, thereby accelerating spoilage and quality deterioration during storage (Birie, et al., 2024)

Moisture content values are presented in Table 1. One-way ANOVA showed significant differences among treatments on both Day 0 and Day 30 ($P < 0.05$). Based on the coefficient of variation criteria described by Hanafiah (2010), Fisher's LSD test was applied for mean comparison. Fish treated with 15% nipa leaf extract (P2) exhibited the lowest moisture content throughout storage, whereas the untreated control (P0) showed the highest moisture content after 30 days. Although moisture content increased during storage in all treatments, all values remained below the maximum limit of 40% established by SNI 8273:2023 (BSN, 2023) for salted dried fish.

The present findings indicate that increasing extract concentration did not proportionally reduce moisture content. Although increasing the extract concentration from 10% to 15% decreased moisture content, a further increase to 20% did not enhance this effect. Instead, treatment P3 (20%) showed higher moisture content than P2 on both day 0 and day 30. This observation suggests that the preservative effect of the extract may reach an optimum level at intermediate concentrations.

A possible explanation is that higher concentrations of nipa leaf extract promoted greater deposition of extract constituents on the fish surface, thereby reducing moisture migration during drying. Because this mechanism was not directly evaluated in the present study, further investigation is required to confirm this hypothesis.

In addition, nipa leaf extract contains phenolic compounds, flavonoids, and tannins with multiple hydroxyl groups that can interact with water molecules. At excessive concentrations, these hydrophilic constituents may contribute to water retention within the product matrix, thereby limiting further moisture reduction (Quoc et al., 2025). Consequently, the 15% extract concentration appeared to provide a more effective balance between moisture removal and extract application.

Although statistical analysis was not performed because microbiological determination was conducted without analytical replication, the results consistently showed lower microbial counts in extract-treated samples than in the untreated control throughout storage. These findings support the antimicrobial activity of phenolic compounds present in nipa leaf extract and are consistent with the improved sensory quality observed after 30 days of storage.

The pattern of microbial growth was closely associated with changes in moisture content. On day 30, the untreated control exhibited the highest Total Plate Count (TPC) value (3.5×10^6 CFU/g), exceeding the maximum allowable limit for salted dried fish according to SNI 8273:2023 (BSN, 2023). In contrast, all treatments containing nipa palm leaf extract maintained substantially lower microbial counts, ranging from 1.0×10^5 to 1.2×10^5 CFU/g. These findings suggest that reduced moisture availability contributed to limiting microbial proliferation during storage. However, the lower microbial counts observed in the higher extract concentrations also indicate that antimicrobial phytochemicals played an important role in suppressing microbial growth.

In addition to its effect on moisture regulation, the extract likely exerted direct antimicrobial activity through its bioactive constituents. Phytochemical screening confirmed the presence of flavonoids, phenolics, tannins, and triterpenoids in the nipa palm leaf extract. Phenolic compounds are known to inhibit microorganisms through multiple mechanisms, including disruption of cell membrane integrity, leakage of intracellular materials, enzyme inhibition, and interference with essential metabolic pathways (De Rossi et al., 2025). Similarly, phenolic acids and related compounds have been reported to damage bacterial cell structures and impair cellular functions, thereby suppressing microbial growth (Lobiuc et al., 2023) The combined effects of moisture reduction and antimicrobial phytochemicals likely explain the lower microbial counts observed in the extract-treated samples.

Overall, the results demonstrate that nipa palm leaf extract improved the microbiological stability of salted three-spot gourami during storage. Although the 15% treatment (P2) was the most effective in reducing moisture content, the 20% treatment (P3) produced the lowest microbial counts while maintaining acceptable sensory quality throughout storage. These findings indicate that preservation efficiency depends not only on moisture reduction but also on the direct antimicrobial activity of the extract. Therefore, the 20% concentration (P3) represents the most effective treatment for practical preservation because it provided the greatest microbial inhibition without compromising product quality during storage.

Sensory Quality During Storage

On day 0, the control treatment (P0) received the highest appearance score because it retained the natural appearance of salted three-spot gourami, whereas the addition of nipa leaf extract caused slight discoloration that reduced initial appearance acceptance. Although initial appearance preferences slightly decreased following extract treatment, sensory traits such as aroma and texture were better maintained during storage in extract-treated samples. Antioxidant and antimicrobial compounds help retard oxidation and proteolytic breakdown, slowing quality deterioration that often produces off-odors and texture softening (Presenza et al., 2023).

Overall Findings

The addition of nipa leaf extract significantly enhanced moisture reduction, microbial inhibition, and sensory stability in salted three-spot gourami during 30 days of storage. The 15% concentration (P2) produced the lowest moisture content, whereas the 20% concentration (P3) achieved the greatest microbial inhibition while maintaining acceptable sensory quality. Overall, these findings demonstrate the potential of nipa leaf extract as a natural preservative, with the 20% concentration (P3) recommended for practical application because it provided the most effective overall preservation performance during storage, consistent with emerging research trends in sustainable food preservation.

4. CONCLUSION

The application of nipa palm (*Nypa fruticans*) leaf extract significantly improved the quality and storage stability of salted three-spot gourami by reducing moisture content, inhibiting microbial growth, and maintaining acceptable sensory characteristics during 30 days of storage. While the 15% concentration (P2) resulted in the lowest moisture content, the 20% concentration (P3) exhibited the greatest microbial inhibition, with microbial counts remaining within the Indonesian National Standard limit and sensory quality remaining acceptable throughout storage. Therefore, the 20% concentration (P3) is recommended for practical application as a natural preservative because it provides the most effective overall preservation performance by ensuring microbial safety while maintaining product quality during storage.

These findings demonstrate the potential of nipa leaf extract as a natural preservative for salted fish. Further research should quantify the bioactive compounds responsible for its preservative effects and evaluate product stability during longer storage periods.

5. ACKNOWLEDGEMENT

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AUTHOR CONTRIBUTION STATEMENT

AM conceived and conducted the experiments, collected and analyzed the data, and drafted the manuscript. RLNF supervised the research project, designed the study framework, validated the methodology, drafted and revised the manuscript and served as the corresponding author. RLU, ZHH and RDPM contributed to research design refinement, laboratory supervision, and critical revision of the manuscript. SS provided scientific input on data interpretation and contributed to manuscript improvement and academic writing structure. MS contributed to language editing, improvement of scientific English expression, and provided recommendations for international publication standards. All authors reviewed and approved the final version of the manuscript.

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REFFERENCE

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