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Assessment on the Potential of Tabon-tabon *(Atuna racemosa)* as a Natural Food Preservative Through Drying and Direct Application for Improved Shelf Life of Pork

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Abstract: *This study assessed Tabon-tabon (Atuna racemosa) as a natural preservative for raw pork using a Completely Randomized Design. Twenty-seven samples were assigned to three treatments: untreated control (T0), 5% Tabon-tabon powder (T1), and 20% Tabon-tabon solution (T2). Stored at 4°C, samples were analyzed every three days over 14 days for color (ΔE), pH, firmness, and weight change. Phytochemical screening showed low levels of alkaloids, flavonoids, tannins, and saponins. By day 14, T0 had the highest weight loss (24.59%) and lowest pH (4.78), while T1 and T2 maintained higher pH (6.60, 6.59) and firmness (0.98 N vs. 0.51 N in T0). T2 had the highest ΔE (12.36), indicating better visual quality. Sensory tests showed T0 led in appearance (4.23) and aroma (4.03), while T1 was preferred for flavor (3.10) and overall acceptability (3.20). All treatments had similar microbial counts, indicating Tabon-tabon, especially in powder form, helps preserve pork quality.*

Keywords: antimicrobial activity; *Atuna racemosa*; natural food preservative; pork shelf life; sensory analysis.

1. INTRODUCTION

Tabon-tabon (*Atuna racemosa*), a tree from the Chrysobalanaceae family, was native to Southeast Asia and the Pacific Islands [1]. In Northern Mindanao, Philippines, it was recognized as an exotic tropical fruit [2]. Also called "atung fruit," it grew in countries such as Papua New Guinea, Indonesia, Malaysia, and Thailand. Communities traditionally used its fruit for anti-inflammatory oil, as a raw fish condiment in the Philippines, and as caulking material in Samoa [3]. Previous studies reported its antibiotic and chemotherapeutic properties [4]. Despite its applications, the fruit's tough texture and strong astringency made it inedible when ripe.

Food spoilage, caused by microbial, chemical, and physical factors, significantly contributes to global food waste. Oxygen exposure accelerated the degradation of proteins, pigments, and lipids [5]. Microbial decomposition accounted for approximately 25% of global food loss, primarily affecting perishable goods [6, 7]. According to the [8], consumers and retailers wasted about 14% of the global food supply, valued at 400 billion dollars.

Manufacturers used synthetic preservatives to limit spoilage, although health concerns led to increased interest in natural alternatives [9]. Researchers identified bioactive compounds in tabon-tabon with antimicrobial properties. Ethyl acetate seed extracts inhibited various spoilage organisms. [10] found that raw seed powder extended shrimp shelf life by 17 hours. However, no studies had tested its application on pork. This study applied oven-dried tabon-tabon powder to pork and evaluated its antimicrobial activity and shelf-life extension.

2. MATERIALS AND METHODS

2.1 Sample Preparation

Researchers prepared Tabon-tabon powder following standardized methods to ensure its efficacy as a natural food preservative. Fruits were rinsed and disinfected using a 200-ppm chlorinated solution [11], then dried, sliced, and the flesh extracted. Fresh pork meat was sourced from Langihan Public Market, washed, and dried with sterilized cloth. A total of 5 kg of pork was divided into 27 samples: nine controls, nine treated with 5% powder, and nine with 20% solution. Additionally, 162 smaller 10-gram samples were prepared for destructive testing [12]. These were analyzed every three days over two weeks to assess weight change, pH, firmness, and color, supporting the study's reliability and evaluating treatment effects on meat quality.

2.2 Preparation of Tabon-Tabon Powder

Researchers followed a standardized process to prepare Tabon-tabon powder as a natural food preservative. Selected fruits were rinsed with distilled water and disinfected using a 200-ppm chlorinated solution (5 ml bleach per 3.8 L water) [11]. After air-drying for one hour, the fruits were sliced, and the flesh extracted. The flesh was oven-dried at 45 ± 3°C for 24 hours, with regular monitoring to avoid over-drying [13]. Once dried, the flesh was ground into fine powder using a Hanahishi bullet blender (model HJB-118) and sieved with a mesh size of 40 for uniform consistency [11]. The powder was stored in airtight containers to preserve its quality and natural properties.

2.3 Preparation of Tabon-Tabon Powder and Solution

Researchers followed the mass-over-volume method described by [14] in preparing Tabon-tabon (*Atuna racemosa*) powder and solution. Treatment 0 served as the control using 100% raw pork meat. Treatment 1 involved 5% Tabon-tabon powder, prepared by mixing 5 grams with 100 grams of pork. Treatment 2 used a 20% solution, made by dissolving 4 grams of powder in 16 grams of water to form 20 grams of solution. The solution

was evenly applied to the pork. Each treatment group contained three samples, replicated three times, totaling nine samples per treatment. Twenty-seven pork samples were prepared and used across all treatments for analysis.

2.4 Direct Application of Tabon-Tabon Powder and Solution to Raw Pork Meat

Researchers prepared pork samples by cleaning, drying, and cutting them into uniform 100-gram portions. Nine samples were treated with 5% Tabon-tabon powder (5 g/100 g meat), while another nine received a 20% solution (4 g powder in 16 g water). Each treatment group included 54 additional 10-gram samples for destructive analysis every three days over two weeks, assessing weight change, pH, firmness, and color. In the 5% group, 0.5 g of powder was applied per 10 g sample; in the 20% group, 2 g of solution containing 0.4 g powder was used. Tools and surfaces were sterilized to reduce contamination. Samples were wrapped in cling wrap and stored in individual containers under chilled conditions [15].

2.5 Quality Parameters

2.5.1 Phytochemical Analysis

Researchers analyzed 300 grams of ground tabon-tabon powder at MSU-IIT to quantify its bioactive compounds. Using standard laboratory procedures and Fourier Transform Infrared Spectroscopy (FTIR), they determined the presence of alkaloids, flavonoids, tannins, and saponins, providing a chemical profile for evaluating the powder's potential properties.

2.5.2 Color

Pork meat color was assessed using a colorimeter (LS172) and the CIELAB system. Values for L* (lightness), a* (redness), b* (yellowness), and chroma (C) were recorded. Color differences were calculated to provide an objective, quantitative evaluation of meat color characteristics.

2.5.3 pH

A digital pH meter (PH800, Apera Instruments) measured the pork samples' pH to assess freshness and spoilage. Accurate pH readings indicated quality, safety, and shelf life. Elevated pH levels signaled spoilage, making pH monitoring essential for maintaining meat quality during storage.

2.5.4 Firmness

Firmness was measured using a penetrometer (Lutron FR-5105) by applying controlled pressure to chilled, standardized pork samples. The force required for penetration, recorded in grams or Newtons, was averaged across multiple trials to provide reliable, quantitative data for evaluating pork meat quality.

2.5.5 Percentage Weight Change

Percent weight change was measured to assess water loss in pork. Initial weights were recorded using a calibrated digital balance (Sartorius BSA2202S-CW), and samples were reweighed every three days. Weight loss reflected moisture retention, helping evaluate preservation effectiveness and overall meat quality during chilled storage.

2.5.6 Sensory Analysis

Sensory evaluation of cooked pork used a 5-point hedonic scale to assess texture, aroma, flavor, appearance, and overall acceptability. Panelists rated attributes such as tenderness, aroma intensity, flavor balance, and visual appeal. Scores were totaled to determine the overall sensory quality of Tabon-tabon-treated pork.

2.5.7 Total Plate Count

The Total Plate Count (TPC) estimated aerobic mesophilic bacteria in pork samples analyzed at DOST Caraga. It indicated sanitary quality, processing conditions, and shelf life. While it did not identify specific microbes, TPC reflected microbial load and potential spoilage when counts approached 10^6–10^7 CFU/g or mL.

2.5.8 Statistical Analysis

Statistical analysis using a completely randomized design (CRD). ANOVA determined significant differences among treatments, followed by Fisher's LSD for pairwise comparisons. Microsoft Excel 2021 and STAR software processed the data, ensuring accurate interpretation and validating the effectiveness of Tabon-tabon in pork preservation.

3. RESULTS AND DISCUSSIONS

3.1 Phytochemical Analysis

The FTIR analysis of Tabon-tabon (*Atuna racemosa*) confirms the presence of several phytochemicals, although in relatively low concentrations. As shown in Table 1, the extract contains alkaloids, flavonoids, saponins, tannins, coumarins, terpenoids, and steroids, all marked at low levels (+). This result indicates that Tabon-tabon has the potential to be a source of bioactive compounds. On the other hand, anthraquinones and cardiac glycosides were not detected (−), suggesting their absence in the sample. These findings reflect the selective phytochemical makeup of Tabon-tabon, which may play a role in its antioxidant activity and possible medicinal benefits in targeted uses.

Table 1. Phytochemical Profile of Tabon-tabon (*Atuna racemosa*) Based on FTIR Analysis [absence (−), low levels (+), moderate levels (++), high levels (+++)]

Phytochemicals	DESCRIPTION
Alkaloids	+
Flavonoids	+
Saponins	+
Anthraquinones	-
Tannins	+
Coumarin	+
Terpenoids	+
Steroids	+
Cardiacglycoside	-

3.2 Color

In Figure 1, it illustrated the changes in ΔE values of pork meat stored under chilled conditions for 14 days. Color served as a key indicator of freshness, quality, and consumer acceptability. All treatments (T0, T1, T2) showed significant differences across five characterizations. ANOVA confirmed statistical significance ($p < 0.05$), and LSD tests identified specific group differences. ΔE values increased from T0 to T2, with T2 consistently exhibiting the highest brightness. By the fifth characterization, T1 and T2 remained

significantly different from T0 but not from each other. A low coefficient of variance (CV = 4.63%) supported trend reliability. The results suggested that phenolic compounds in *tabon-tabon* enhanced color through pigment binding or oxidative interactions, aligning with [16].

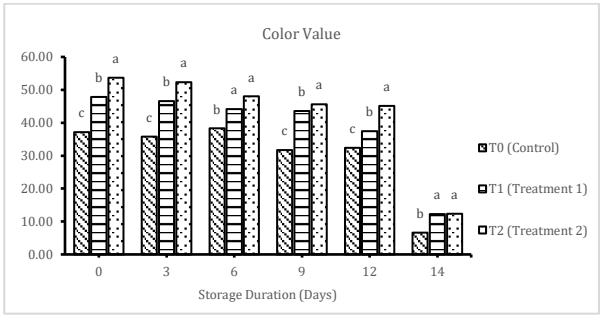

Figure 1. Characteristic Analysis using Color

3.3 pH

In Figure 2, it illustrated the pH changes of T0, T1, and T2 over a 14-day chilled storage period. On Day 0, T0 had the highest pH, followed by T1 and T2. All treatments showed a gradual pH decline over time, indicating increased acidity. By Day 6, T0 exhibited a significant drop in pH compared to T1 and T2. From Day 9 onward, T1 and T2 maintained significantly higher pH levels than T0. This trend continued through Day 14, with T0 recording the lowest pH. These results suggested that T1 and T2 effectively delayed acidification and better preserved the sample. The treatments helped maintain pH stability, indicating improved preservation and potential inhibition of spoilage during chilled storage.

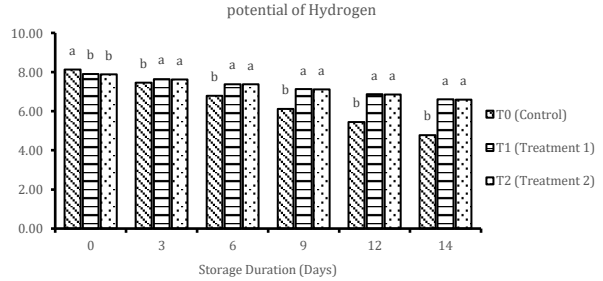

Figure 2. Characteristic Analysis using the Potential of Hydrogen

3.4 Firmness

As shown in Figure 3, the results illustrate significant differences in firmness across five characterizations during 14-day storage. Firmness declined over time, with mean values decreasing from 5.16 (first) to 0.98 (fifth characterization). T1 and T2 consistently retained higher firmness than T0. On Day 0, T0 already showed lower firmness, as T1 and T2 were coated with tabon-tabon, which enhanced structural integrity and delayed early degradation. This aligned with [17], who reported that protective coatings improved meat firmness by limiting moisture loss. ANOVA results showed significant differences ($p < 0.05$), and LSD confirmed that T0 significantly differed from T1 and T2. Despite decreasing means, variance remained uniform. Overall, T1 and T2 effectively preserved texture compared to the untreated control.

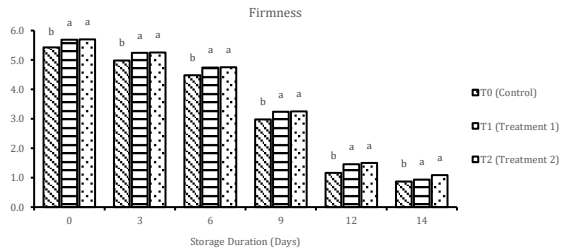

Figure 3. Mean Firmness of Meat Samples Across Five Characterization Periods

3.5 Percentage Weight Change

Figure 4 illustrated moisture accumulation trends during 14-day storage. On Day 0, all treatments showed minimal water gain, indicating meat freshness. By Day 3, T0, T1, and T2 had similar water content, suggesting limited spoilage activity. As storage progressed, T0 exhibited a greater increase in moisture, caused by tissue degradation and fluid release due to microbial and enzymatic activity. In contrast, T1 and T2 showed lower water weight changes, attributed to tabon-tabon forming a semi-permeable barrier that restricted moisture movement. This coating likely reduced microbial access and enzymatic breakdown. These findings supported [18, 19], who reported that protective coatings and powdered preservatives enhanced moisture control, delayed spoilage, and extended shelf life by maintaining structural integrity and reducing water migration.

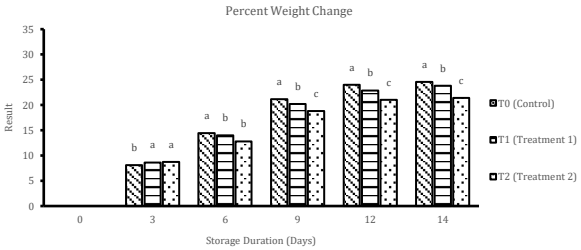

Figure 4. Percent Weight Change of Meat Samples Across Five Characterization Periods

3.6 Total Plate Count

Meat, a primary protein source, was prone to microbial contamination, especially during slaughter, processing, and transport [20]. High moisture content, ranging from 60% to 75% in meat and up to 80% in fish, increased spoilage risk [21, 22]. As shown in Table 2, pork samples from all groups recorded 5.9×10^6 CFU/g after 14 days of chilled storage at 4°C, near international safety limits [23]. According to the Philippine Food and Drug Administration (FDA) [24] This count remained acceptable but suggested potential spoilage. Microbial levels were uniform across groups, suggesting chilling inhibited bacterial growth. Minor differences implied that tabon-tabon may offer mild antimicrobial benefits during storage.

Table 2. Total Plate Count (TPC) Results of Pork Samples from Control and Treatment Groups After Chilling at 4°C

Sample	Results
T0	5 900 000 estimated cu/g
T1	5 900 000 estimated cu/g
T2	5 900 000 estimated cu/g

3.7 Sensory Analysis

3.7.1 Appearance

Figure 5 shows appearance ratings from the sensory analysis for three treatments: T0 (control), T1, and T2. T0 received the highest mean score of 4.2, indicating superior visual quality. T1 and T2 both received lower mean scores of 2.7. Statistical analysis using the Least Significant Difference (LSD) test at a 5% significance level revealed no significant difference between T1 and T2 but a significant difference between T0 and both treatments. These findings indicated that T0 had a significantly better appearance than T1 and T2. The consistently lower scores for T1 and T2 suggested that the modifications applied in these treatments negatively impacted the product's visual quality, reducing their acceptance compared to the control.

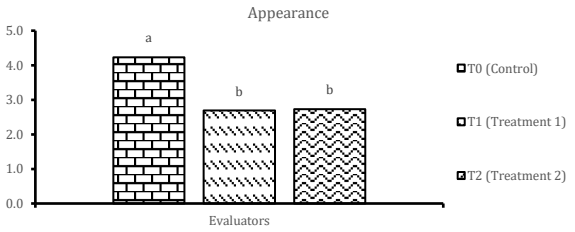

Figure 5. Sensory Analysis Appearance

3.7.2 Aroma

Figure 6 presents the sensory evaluation results for aroma across three treatments: T0 (control), T1 (treatment 1), and T2 (treatment 2). T0 received the highest mean score of 4.0, indicating a more favorable aroma. In contrast, T1 and T2 received lower, statistically similar scores, both below 3.5. The Least Significant Difference (LSD) test at a 5% significance level revealed significant differences between T0 and both T1 and T2, but no significant difference between T1 and T2. These findings indicated that the control treatment had a more favorable aroma, while the modifications in T1 and T2 negatively impacted aroma perception. The lower scores for T1 and T2 suggested that the changes adversely affected the aroma quality.

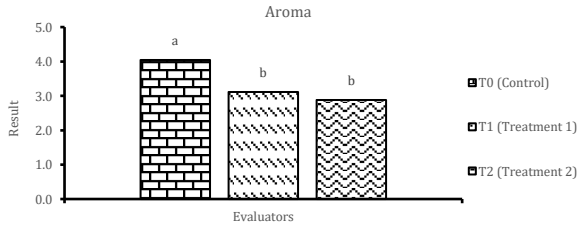

Figure 6. Sensory Analysis Aroma

3.7.3 Flavor

Figure 7 presents sensory evaluation results for flavor across three treatments: T0 (control), T1 (treatment 1), and T2 (treatment 2). T0 received the highest mean score, followed by T1, while T2 received the lowest rating. The Least Significant Difference (LSD) test at a 5% significance level showed no significant difference between T0 and T1, as both were grouped under the same letter. However, T2 differed significantly from the other treatments, indicating lower flavor acceptability. These results suggested that T0 and T1 had similar and acceptable flavor profiles, while T2's formulation changes negatively impacted flavor quality. These findings aligned with [25], who noted that trained panelists tend to categorize sensory attributes more accurately than untrained panelists.

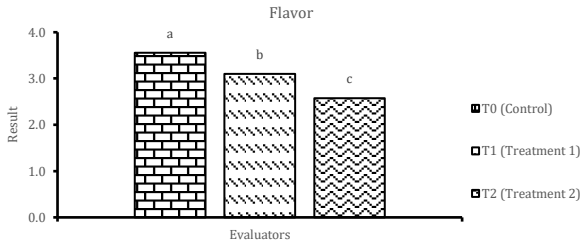

Figure 7. Sensory Analysis Flavor

3.7.4 Texture

Figure 8 displays sensory analysis results for texture across three treatments: T0 (Control), T1 (Treatment 1), and T2 (Treatment 2). The Least Significant Difference (LSD) test at a 5% significance level ($P<0.05$) indicated significant differences among treatments. T0 and T1 received higher texture ratings, both above 3.0, and were not significantly different, sharing the letter "a." In contrast, T2 received a significantly lower mean score of 2.5, marked with the letter "b," indicating a significant difference from the other treatments. These results suggested that T2 negatively affected texture quality, while T0 and T1 maintained higher and similar sensory acceptance. These findings aligned with [26], who emphasized the importance of texture in shaping consumer evaluations and overall product quality.

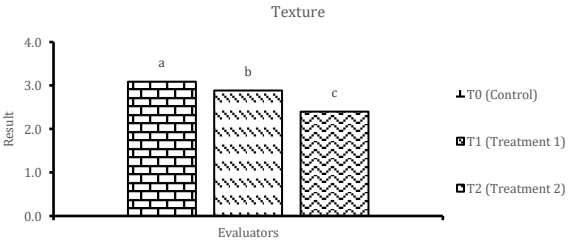

Figure 8. Sensory Analysis Texture

3.7.5 Overall Acceptability

Figure 9 illustrates the overall acceptability ratings from professional and non-professional panelists for the three treatments. T0 and T1 received higher mean scores of approximately 3.5 and 3.3, respectively, and were not significantly different, sharing the letter "a." In contrast, T2 received a significantly lower score of around 2.8, marked with the letter "b," indicating a statistically significant difference at the 5% level according to the Least Significant Difference (LSD) test. These findings suggest that T2 negatively impacted overall acceptability compared to T0 and T1. Both T0 and T1 maintained similar, more favorable evaluations from the panelists, reflecting better overall acceptability.

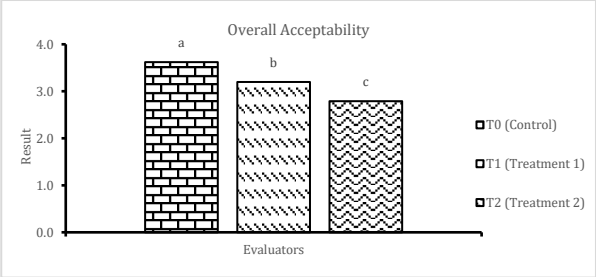

Figure 9. Sensory Analysis Overall Acceptability

3.8 Correlational Analysis

Table 3 presents the Pearson correlation matrix showing relationships between physicochemical properties and sensory attributes. The matrix revealed a strong positive correlation between percent water content (PWC) and flavor (r = 0.9), overall acceptability (OA) (r = 0.9), and texture (r = 0.9), indicating that higher PWC improved these attributes. Firmness negatively correlated with all sensory traits, especially flavor (r = -0.8) and OA (r = -0.7), suggesting higher firmness reduced sensory appeal. pH had a strong negative correlation with OA (r = -0.8), flavor (r = -0.8), and aroma (r = -0.9), implying lower pH improved sensory perception. Color value showed negative correlations with appearance (r = -0.9), aroma (r = -0.9), and flavor (r = -0.8). These findings highlight the impact of physicochemical properties on sensory quality.

Table 3. Pearson Correlation Matrix Between Physicochemical Properties and Sensory Attributes

	PWC	pH	Firmnes	Color	Appearan	Aroma	Textur	Flavor	OA
PWC	1								
pH	-0.7	1.0							
Firmness	-0.8	0.6	1.0						
Color	-0.7	1.0	0.6	1.0					
Appearan	0.6	-1.0	-0.7	-0.9	1.0				
Aroma	0.7	-0.9	-0.5	-0.9	0.8	1.0			
Texture	0.9	-0.7	-0.7	-0.7	0.6	0.8	1.0		
Flavor	0.9	-0.8	-0.8	-0.8	0.7	0.9	0.9	1.0	
OA	0.9	-0.8	-0.7	-0.8	0.7	0.9	0.9	0.9	1.0

4. CONCLUSION

This study examined the impact of powdered and solution forms of Tabon-tabon (*Atuna racemosa*) on the physicochemical, microbiological, and sensory characteristics of raw pork meat during chilled storage. FTIR confirmed the presence of phytochemicals in Tabon-tabon powder, indicating its potential as a natural preservative. Color analysis revealed significant ΔE increases, particularly in T2, suggesting pigment-phenolic interactions. Firmness analysis showed that T1 and T2 have better preserved meat texture, with slower decline in firmness compared to the control. Treated samples had a lower percentage weight change, indicating effective spoilage control. pH decreased in all samples, with T1 and T2 showing slower acidification. Sensory evaluation showed T0 favored over T1 and T2, though powdered Tabon-tabon improved texture. Tabon-tabon showed potential as a preservative, despite sensory limitations.

5. REFERENCES

[1] E. S. Fernando, B. Y. Sun, M. H. Suh, H. Y. Kong and K. S. Koh, "Anacardiaceae–Koordersiodendron pinnatum (Blanco) Merr.," *Flowering Plants and Ferns of Mt. Makiling,* p. 129, 2004.

[2] J. M. Pacaña and V. R. Galarpe, "Phytochemical screening and toxicity testing of Atuna racemosa Rafin. Chrysobalanaceae shell and seed extracts," *International Journal of Advanced and Applied Sciences,* vol. 4, no. 11, p. 110–115, 2017.

[3] G. Prance, "The Uses of Atuna racemosa Raf. (Chrysobalanaceae) in Samoa," *Economic Botany,* vol. 58, p. 470–475, 2004.

[4] E. J. Buenz, B. A. Bauer, D. J. Schnepple, D. L. Wahner-Roedler, A. G. Vandell and C. L. Howe, "A randomized Phase I study of Atuna racemosa: a potential new anti-MRSA natural product extract," *Journal of ethnopharmacology,* vol. 114, no. 3, pp. 371-376, 2007.

[5] A. I. Smirnov, "Electron Paramagnetic Resonance Spectroscopy to Study Liquid Food and Beverages," *Electron Spin Resonance in Food Science,* p. 83–109, 2017.

[6] M. Bondi, P. Messi, P. M. Halami, C. Papadopoulou and S. De Niederhausern, "Emerging Microbial Concerns in Food Safety and New Control Measures," *Biomed Research International,* p. 1–3, 2014.

[7] X. Dousset, E. Jaffrès and M. Zagorec, "Spoilage: Bacterial Spoilage," *Encyclopedia of Food and Health,* p. 106–112, 2016.

[8] FAO, "Tackling food loss and waste: A triple win opportunity - FAO, UNEP. UN Environment Programme," 2022.

[9] S. Sambu, U. Hemaram, R. Murugan and A. A. Alsofi, "Toxicological and teratogenic effect of various food additives: An updated review," *Biomed Research International,* 2022.

[10] T. Moniharapon, S. T. Soekarto, S. Putro and R. Nitibaskara, "Atung fruit seeds (Parinarium glaberimum Hassk) as a preservative for fresh shrimp," *Journal Indonesian Agricultural Sciences,* vol. 3, no. 2, pp. 48-52, 1993.

[11] C. A. S. Tila, L. E. Mopera, A. S. A. Barrion and K. A. C. Israel, "Phytochemical Analysis and Antibacterial Potential of Tabon-tabon (Atuna racemosa Raf) Fruit Extract against E. Coli BIOTECH 1634," *Philippine Journal of Science,* vol. 151, no. 5, pp. 1579-1588, 2022.

[12] P. Manga, R. Rao and R. Joshi, "Assessment of Microbial Load in Raw Pork from Retail Meat Outlets of Bikaner," *International Journal of Current Microbiology and Applied Sciences,* vol. 7, no. 2, p. 268–272, 2018.

[13] O. Seely, "Proper use of a desiccator.," *Chemistry LibreTexts.,* 2022.

[14] F. Pattipeilohy, T. Moniharapon and A. V. Seulalae, "Application Multilevel Immersion Salt and Atung Seed Powder on The Quality of Dried Salted Tuna," *Indonesian Fisheries Processing Journal/Jurnal Pengolahan Hasil Perikanan Indonesia,* vol. 26, no. 3, 2023.

[15] T. Moniharapon, F. Pattipeilohy, M. N. Mailoa and L. M. Soukotta, "Production of high-quality low salt salted fish with a combination of preservative and insect repellent from atung fruit

(Parinarium glaberimum, Hassk)," *[National Strategy Research Final Report Year II]. Pattimura University,* 2019.

[16] M. Muzolf-Panek, A. Zaworska-Zakrzewska, A. Czech, D. Lisiak and M. Kasprowicz-Potocka, "Antioxidative Status and Meat Quality Traits as Affected by Dietary Supplementation of Finishing Pigs with Natural Phenolics," *Antioxidants,* vol. 13, no. 11, p. 1362, 2024.

[17] C. M. Souza, D. D. Boler, D. L. Clark, L. W. Kutzler, S. F. Holmer, J. W. Summerfield and J. Killefer, "Varying the temperature of the liquid used for high-pressure processing of prerigor pork: Effects on fresh pork quality, myofibrillar protein solubility, and frankfurter textural properties," *Journal of food science,* vol. 77, no. 1, pp. S54-S61, 2012.

[18] P. J. Fellows, " Food processing technology: principles and practice.," *Woodhead publishing.,* 2022.

[19] E. TEC, "Meat technology update," *Meatupdate. csiro. au,* pp. 0-3, 2001.

[20] D. Ercolini, F. Russo, E. Torrieri, P. Masi and F. Villani, "Changes in the spoilage-related microbiota of beef during refrigerated storage under different packaging conditions," *Appl Environ Microbiol,* vol. 72, no. 7, pp. 4663-4671, 2006.

[21] L. Towers, "Pork meat quality: Understanding industry measurements and guidelines," 2016. [Online]. Available: https://www.thepigsite.com/articles/pork-meat-quality-understanding-industry-measurements-and-guidelines. [Accessed 2025].

[22] S. Van Ruth, E. Brouwer, A. Koot and M. Wijtten, "Seafood and water management," vol. 3, no. 4, p. 622–631, 2014.

[23] J. H. Kim and D. G. Yim, "Assessment of the microbial level for livestock products in retail meat shops implementing HACCP system," *Korean journal for food science of animal resources,* vol. 36, no. 5, p. 594, 2016.

[24] FDA, "Food and Drug Administration Circular no.2022-012-Guidelines on the Microbiological requirements and assessment of certain Prepackaged processed food products repealing FDA circular No. 2013-010 entitled “Revised guidelines for the assessment of," *Microbiological quality of processed for the assessment of Microbiological quality of processed foods,* 2023.

[25] H. T. Lawless and H. Heymann, "Sensory evaluation of food: Principles and practices (2nd ed.).," *Springer,* 2010.

[26] G. V. Civille, "Food texture: pleasure and pain," *Journal of agricultural and food chemistry,,* vol. 59, no. 5, pp. 1487-1490, 2011.