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Soaking Water of Pineapple Peel (*Ananas Comocus L. Merr*) Solution on Reducing Formaldehyde Levels in Salted Fish

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ABSTRACT Formaldehyde is frequently misused as a preservative in salted fish to prolong shelf life, despite its toxic and carcinogenic effects when ingested. Continuous exposure to formaldehyde poses serious health risks, including gastrointestinal irritation, organ damage, and neurological complications. Therefore, identifying effective methods to reduce formaldehyde levels in salted fish is critical for food safety. This study aimed to evaluate the effectiveness of soaking salted tuna (Euthynnus sp.) in pineapple peel (Ananas comosus L. Merr) solution at varying concentrations to reduce formaldehyde content. A pre-experimental study using a one-group pretest-posttest design was conducted. Salted fish samples were soaked for 60 minutes in pineapple peel solutions at concentrations of 20%, 40%, 60%, and 80%, with clean water (PDAM) as a control. Formaldehyde levels were measured before and after soaking using the spectrophotometric method. Statistical analysis was performed using paired t-tests and ANOVA. The initial formaldehyde concentration in salted tuna averaged 13.30 mg/kg. Post-soaking measurements showed significant reductions: 6.58 mg/kg (20%), 4.16 mg/kg (40%), 0.15 mg/kg (60%), and 0.11 mg/kg (80%), compared to 8.14 mg/kg using tap water. The highest reduction occurred at 80% concentration, with a 99.14% decrease. The findings demonstrate a significant relationship between pineapple peel solution concentration and reduction in formaldehyde levels ($p < 0.05$). These results suggest that pineapple peel solution, a natural and eco-friendly by-product, can be a promising alternative for reducing formaldehyde in salted fish prior to consumption. Future studies should investigate the use of other fruit peels, varying soaking durations, and real-time application in household or industrial contexts.

INDEX TERMS Formaldehyde (CH_2O), salted fish, pineapple peel, food safety, natural preservative

I. INTRODUCTION

Salted fish is a traditional food product widely consumed in many countries due to its affordability and long shelf life. However, improper preservation techniques, including the illegal use of formaldehyde, have raised serious public health concerns. Formaldehyde, a known toxic and carcinogenic compound, is often misused in salted fish processing to inhibit microbial growth and extend storage time [1], [2]. Prolonged exposure to formalin through dietary intake has been linked to a range of adverse health effects such as gastrointestinal irritation, liver and kidney dysfunction, neurological damage, and even carcinogenesis [3]–[6]. Although several regulatory bodies, including the World Health Organization (WHO) and Indonesia’s BPOM, have set stringent limits on formaldehyde exposure, its misuse in traditional markets persists [7], [8].

To mitigate formaldehyde contamination, several physical and chemical treatment methods have been explored. Thermal processing methods such as frying and boiling can reduce formaldehyde levels but are often insufficient and may degrade food quality [9], [10]. Chemical treatments using natural materials have gained attention as a safer, eco-friendly alternative. Prior studies have demonstrated the efficacy of natural extracts such as garlic peel, green chili, and turi leaves in reducing formaldehyde in food items [11]–[14]. Among these, pineapple peel (Ananas comosus L. Merr), rich in bioactive compounds like saponins and antioxidants, is a promising candidate due to its saponification properties that can bind and neutralize formaldehyde molecules [15]–[18].

Despite the potential, the application of pineapple peel extract as a natural decontaminant for salted fish remains underexplored. Few empirical studies have systematically evaluated its effectiveness at various concentrations and under controlled soaking conditions. Moreover, prior research has focused primarily on tofu or anchovy products, with limited analysis on tuna-based salted fish [19], [20]. This highlights a critical research gap in identifying sustainable, affordable, and practical pre-processing techniques for reducing formalin in commonly consumed fish types.

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This study aims to investigate the effect of different concentrations of pineapple peel solution on the reduction of formaldehyde levels in salted tuna. Soaking treatments were carried out at concentrations of 20%, 40%, 60%, and 80%, with tap water serving as a control. The formaldehyde content was measured before and after treatment using a spectrophotometric method. The main contributions of this research are as follows:

1. It provides empirical evidence of pineapple peel extract as a natural agent for reducing formalin in salted fish.
2. It offers a quantitative comparison of different concentrations and their efficacy, guiding practical applications.
3. It proposes a sustainable method utilizing fruit waste, contributing to food safety and environmental health.

II. METHODS

This study employed a pre-experimental design using the one-group pretest-posttest approach to evaluate the effectiveness of pineapple peel (Ananas comosus L. Merr) solution in reducing formaldehyde levels in salted tuna (Euthynnus sp.). This design was chosen to assess the difference in formaldehyde concentration before and after treatment within the same group, allowing for a controlled comparison of outcomes following the soaking intervention [31].

A. STUDY SAMPLES AND MATERIALS

The research sample consisted of 24 salted tuna pieces that had been intentionally exposed to formalin for standardization. Fresh tuna fish (±25 cm in length and ±300 grams in weight) were obtained from local markets and subjected to a simulated salting process using a solution of 10 ml of 37% formalin diluted in 10 liters of clean water. The fish were immersed in this solution for 2 hours to replicate market practices, followed by the traditional salting and sun-drying process. Each fish was cut into 3 cm segments weighing approximately 65 grams per sample [32]. The soaking treatments were conducted using pineapple peel filtrate at concentrations of 20%, 40%, 60%, and 80%, with PDAM tap water as the control. Four replicates were conducted for each treatment group, resulting in a total of 24 salted tuna samples. Pineapple peels were sourced from mature Cayenne (honey) pineapples obtained from fruit vendors in Surabaya. A total of 7 kg of pineapple peels were washed, blended without additional water, and filtered to obtain a 100% filtrate [33]. Each sample was immersed in 500 ml of the corresponding solution for 60 minutes at room temperature. The control group was immersed in 500 ml of tap water under the same conditions [34]. The pineapple peel filtrate was then diluted with PDAM water to create four solution concentrations:

1. 20% solution: 400 ml filtrate + 1600 ml water
2. 40% solution: 800 ml filtrate + 1200 ml water
3. 60% solution: 1200 ml filtrate + 800 ml water
4. 80% solution: 1600 ml filtrate + 400 ml water

B. INSTRUMENTATION AND MEASUREMENT

The primary parameter measured in this study was the formaldehyde concentration (mg/kg) in the salted tuna samples before and after soaking. The measurement was conducted using a UV-Visible spectrophotometer with Schiff reagent following standard analytical procedures. This method allows precise quantification of formaldehyde concentration in food matrices with high sensitivity and reproducibility [35]. Each sample's formaldehyde content was tested in duplicate to ensure reliability. The data were then averaged for final analysis. Calibration of the spectrophotometer was performed before each session using formaldehyde standards to ensure accuracy and linearity across the measurement range [36].

C. DATA ANALYSIS

The collected data were processed through coding, tabulation, and entry using Microsoft Excel. Statistical analysis was performed using SPSS software. To determine the significance of changes in formaldehyde levels pre- and post-treatment, the paired t-test was applied, assuming normal data distribution. Additionally, one-way ANOVA followed by a post-hoc test (Tukey HSD) was used to compare the effectiveness between the different concentration groups and the control [37]. Significance was determined at a confidence level of 95% ($\alpha = 0.05$). The interpretation of results focused on the average reduction in formaldehyde levels and the percentage decrease observed in each treatment group.

D. ETHICAL CONSIDERATIONS

This study did not involve human or animal subjects and therefore did not require ethical clearance from a health research ethics committee. However, all research procedures were conducted in alignment with principles of scientific integrity and biosafety, especially in handling formalin and food materials.

E. REPLICATION AND QUALITY CONTROL

To ensure reproducibility, each treatment was performed in quadruplicate. Laboratory instruments were calibrated daily, and all reagents used were analytical grade. The soaking time of 60 minutes was selected based on previous literature, which suggests this duration is sufficient for chemical diffusion and interaction between bioactive compounds and formaldehyde [38]. All salted fish samples were processed and analyzed under consistent environmental conditions (room temperature 26–28°C), and cross-contamination between treatments was prevented through individual containers and sterilized tools.

III. RESULT

The examination of formalin content was carried out on salted tuna with formalin that had not been soaked. Salted tuna given 37% formalin is dissolved in 10 liters and then immersed into the solution for 2 hours. The following are the results of the examination of formalin levels in salted tuna without soaking: TABLE 1 shows that the results of the examination of formalin levels in salted tuna with the highest value of 14.06 mg/kg and the lowest level with a value of 12.65 mg/kg with an average of 13.30 mg/kg. Examination of formalin levels is carried out on salted formalinized tuna after soaking using PDAM water with a soaking time of 60 minutes. Clean water used as soaking is

TABLE 1
Formalin Content of Salted Tuna Before Soaking

Replication	Formalin content of salted tuna mg/kg (ppm)
1	12,65
2	13,60
3	14,06
4	12,90
Total	53,21
Average	13,30

TABLE 2
Formalin Content of Salted Tuna After Soaking

Replication	Formalin content of salted tuna mg/kg (ppm)
1	9,11
2	7,88
3	7,01
4	8,58
Total	32,58
Average	8,14

PDAM water which is then prepared according to the amount of volume needed for 4 replications of 2000 ml. The following are the results of the examination of formalin levels in salted formalized tuna after soaking in PDAM water. TABLE 2 shows that the results of the examination of formalin levels in salted tuna with the highest value of 9.11 mg/kg and the lowest level with a value of 7.01 mg/kg with an average of 8.14 mg/kg. Examination of formalin levels was carried out on salted tuna with formalin after soaking using pineapple peel solution concentrations of 20%, 40%, 60%, and 80% with a soaking time of 60 minutes. The pineapple peel solution is made by smoothing the pineapple peel using a blender and then squeezing and taking the filtrate to obtain a concentration of 100% pineapple peel solution (without dilution). The soaking water of pineapple peel solution concentrations of 20%, 40%, 60%, and 80% used for soaking was made by homogenizing the pineapple peel filtrate with the solvent, namely PDAM water. The following are the results of the examination of formalin levels in salted fish after soaking.

TABLE 3 shows the results of the examination of formalin levels in salted tuna with the highest mean value of 6.58 mg/kg and the lowest level with a mean value of 0.11 mg/kg. The following are the results of the decrease in formalin levels in salted formalized tuna before and after soaking in pineapple peel solution.

TABLE 3
Formalin Content of Salted Tuna After Soaking in Pineapple Peel Solution

Replication	Formalin Level mg/kg (ppm)			
	Pineapple Peel Solution			
	20%	40%	60%	80%
1	7,05	4,31	0,16	0,12
2	6,18	3,90	0,18	0,11
3	7,01	4,60	0,13	0,10
4	6,08	3,85	0,15	0,12
Total	26,32	16,66	0,62	0,45
Average	6,58	4,16	0,15	0,11

TABLE 4 shows that the results of the examination of formalin levels in salted tuna before and after soaking in pineapple peel solution of 20% concentration have an average decrease of 6.72 mg/kg with a percentage decrease of 50.45%. TABLE 5 shows that the results of the examination of formalin levels in salted tuna before and after soaking in 40% concentration pineapple peel solution have an average decrease of 9.13 mg/kg with a percentage decrease of 68.66%. TABLE 6 shows that the results of the examination of formalin levels in salted tuna before and after soaking in pineapple peel solution with a concentration of 60% have an average decrease of 13.14 mg/kg with a percentage decrease of 98.82%.

TABLE 4
Formalin Content of Salted Tuna Before And After Soaking At 20% Concentration

Replication	Formalin Level in Salted Fish Tongkol mg/kg (ppm)		The difference in Reduction of Fromalin Level mg/kg (ppm)	Decrease of Fromalin mg/kg (ppm)
	Before	After		
1	12,65	7,05	5,60	44,26
2	13,60	6,18	7,42	54,55
3	14,06	7,01	7,05	50,14
4	12,90	6,08	6,82	52,86
Average	13,30	6,58	6,72	50,45

TABLE 5
Formalin Content of Salted Tuna Before And After Soaking 40% Concentration

Replication	Formalin Level in Salted Fish Tongkol mg/kg (ppm)		The difference in Reduction of Fromalin Level mg/kg (ppm)	Decrease of Fromalin mg/kg (ppm)
	Before	After		
1	12,65	4,31	8,34	65,92
2	13,60	3,90	9,70	71,32
3	14,06	4,60	9,46	67,28
4	12,90	3,85	9,05	70,15
Average	13,30	4,16	9,13	68,66

TABLE 6
Formalin Content of Salted Tuna Before and After Soaking at 60% Concentration

Replication	Formalin Level in Salted Fish Tongkol mg/kg (ppm)		The differe nce in Reduct ion of Fromal in Level mg/kg (ppm)	Decrease of Fromalin mg/kg (ppm)
	Before	After		
1	12,65	0,16	12,49	98,73
2	13,60	0,18	13,42	98,67
3	14,06	0,13	13,93	99,07
4	12,90	0,15	12,75	98,83
Average	13,30	0,15	13,14	98,82

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Vol. 4 No.5, pp.385-391, October 2024

TABLE 7 shows that the results of the examination of formalin levels in salted tuna before and after soaking in 80% concentration pineapple peel solution have an average decrease of 13.19 mg/kg with a percentage decrease of 99.14%. The following are the results of the decrease in formalin levels in salted formalized tuna before and after soaking in PDAM water. TABLE 8 shows that the results of the examination of formalin levels in salted tuna before and after immersion in PDAM water have an average decrease of 5.15 mg/kg with a percentage decrease of 38.41%. Based on the normality test shows that the data is normally distributed, so the test can continue using the *Paired t* test. Based on the results of the *Paired t* test (appendix 4) between the salted fish group before soaking with the salted fish group after soaking with pineapple peel solution, the result of P = 0.000 < α (0.05) shows that there is a significant difference in the decrease between formalin levels in salted fish tuna group before soaking with the group after soaking using pineapple peel solution.

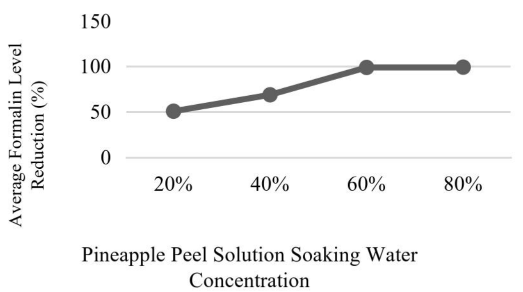
TABLE 7
Formalin Content of Salted Tuna Before and After Soaking 80% Concentration

Replication	Formalin Level in Salted Fish Tongkol mg/kg (ppm)		The difference in Reduction of Fromalin Level mg/kg (ppm)	Decrease of Fromalin mg/kg (ppm)
	Before	After		
1	12,65	0,12	12,53	99,05
2	13,60	0,11	13,49	99,19
3	14,06	0,10	13,96	99,28
4	12,90	0,12	12,78	99,06
Average	13,30	0,11	13,19	99,14

TABLE 8
Formalin Content of Salted Tuna Before and After Soaking in PDAM Water

Replication	Formalin Level in Salted Fish Tongkol mg/kg (ppm)		Difference in Reduction of Fromalin Level mg/kg (ppm)	Decrease of Fromalin mg/kg (ppm)
	Before	After		
1	12,65	9,11	3,54	27,98
2	13,60	7,88	5,72	42,05
3	14,06	7,01	7,05	50,14
4	12,90	8,58	4,32	33.48
Average	13,30	8,14	5,15	38,41

FIGURE 1 Reduction in formalin content of salted fish tuna before and after soaking in pineapple peel solution



Based on FIGURE 1 the *Anova* statistical test (appendix 4), the result of P = 0.000 < α (0.05) shows that there is a difference in the value of formalin levels between the soaking water of 20%, 40%, 60%, 80% pineapple peel solution, and PDAM water on salted tuna, then based on the *Post Hoc Test* further test (appendix 4) shows the results that soaking using 20%, 40%, 60%, and 80% pineapple peel solution can reduce formalin levels in salted tuna significantly. This shows that the higher the concentration of pineapple peel solution, the greater the decrease in formalin levels in salted tuna.

IV. DISCUSSION

A. INTERPRETATION OF RESULT

This study revealed a significant reduction in formaldehyde levels in salted tuna after soaking in pineapple peel (Ananas comosus L. Merr) solution. The average pre-treatment formalin concentration was 13.30 mg/kg, which declined to 6.58 mg/kg, 4.16 mg/kg, 0.15 mg/kg, and 0.11 mg/kg after immersion in pineapple peel solutions of 20%, 40%, 60%, and 80%, respectively. The most pronounced effect was observed at the 80% concentration, with a 99.14% reduction. The statistical analysis using paired t-test and ANOVA confirmed the significance of these reductions (p < 0.05). This trend suggests a dose-dependent efficacy, where increasing pineapple peel concentration corresponded with greater formalin elimination, likely due to higher concentrations of bioactive compounds. The observed detoxifying effect can be attributed primarily to saponins, which are naturally occurring glycosides capable of binding aldehydes like formaldehyde through saponification and micellization reactions [39]. These reactions convert formalin into less toxic or water-soluble compounds, facilitating their removal during soaking. Saponins, due to their amphiphilic structure hydrophilic heads and hydrophobic tails act similarly to surfactants, enhancing the emulsification and solubilization of toxins [40]. Additionally, the physical characteristics of the pineapple peel filtrate, such as acidity and enzyme content, may accelerate the breakdown of methylene compounds formed by the interaction of formaldehyde with proteins in the fish [41].

B. COMPARISON WITH PREVIOUS STUDIES

The findings of this study are consistent with other investigations exploring the use of natural materials in reducing formalin content in food. For instance, Burhan (2023) reported that garlic peel powder effectively decreased formaldehyde in salted anchovies due to its high saponin content [39]. Similarly, Yazid et al. (2023) showed that green chili extract significantly reduced formalin in tofu, measured through spectrophotometric methods [40]. In another study, Purwanti et al. (2017) demonstrated that soaking salted selar kuning fish in fermented rice water reduced formalin levels by approximately 80% [41]. However, this percentage was lower than the 99% reduction achieved with pineapple peel solution in the current study, indicating the superior effectiveness of pineapple peel as a detoxification agent. Hermawan et al. (2020) explored the

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Vol. 4 No.5, pp.385-391, October 2024

impact of different soaking doses on white shrimp, showing a moderate reduction in formalin but with considerable residue remaining post-treatment [42]. This supports the idea that water or simple dilution may not be as effective as using functional bioactive substances. Furthermore, research by Safrida et al. (2020) using Aloe vera extract on salted squid showed a maximum formalin reduction of 90% after extended soaking, reinforcing the potential of plant-based compounds for food safety interventions [43]. Compared to Aloe vera, pineapple peel not only achieved higher reduction levels but is also more accessible and typically discarded as waste. According to Hikal et al. (2021), pineapple peel contains not only saponins but also flavonoids, bromelain enzymes, and organic acids all of which may play a role in breaking down and neutralizing formaldehyde [44]. This combination of compounds likely contributes to the superior detoxifying properties observed in this study. These results collectively reinforce the potential of pineapple peel as a low-cost, sustainable alternative for reducing harmful residues in salted fish, aligning with current trends in natural food safety solutions.

C. LIMITATIONS AND IMPLICATIONS

Despite its promising results, the study is subject to certain limitations. Firstly, it employed a pre-experimental design without a randomized control group. This limits causal inference and the generalizability of findings to larger populations. Future research should incorporate randomized controlled trials to validate these results across different species and conditions. Secondly, the study did not evaluate sensory attributes such as taste, texture, or color of the fish after soaking. Changes in organoleptic quality could impact consumer acceptability and should be examined in future studies. Furthermore, while saponins were identified as the main compound responsible for formalin reduction, other constituents in pineapple peel such as bromelain, tannins, and acids may have contributed to the observed effect. A phytochemical profiling and fractionation approach would help determine which specific compounds are most effective [44]. Another variable that may affect formalin reduction is the thickness of the fish slices. As noted by Purwanti et al. (2017), thinner cuts facilitate faster diffusion of methylene compounds, accelerating detoxification during soaking [41]. From a public health standpoint, these findings have important implications. Formaldehyde is a classified carcinogen and exposure via food can result in serious health consequences including respiratory problems, neurotoxicity, and cancer, as recognized by agencies such as WHO and IARC [45], [46]. Therefore, strategies to reduce its presence in food are crucial, particularly in informal markets where regulation is limited. The adoption of pineapple peel soaking as a community-level intervention could enhance food safety practices and reduce health risks associated with formaldehyde consumption. Local health departments and small-scale food producers can implement this method as a simple, cost-effective, and environmentally friendly solution. Additionally, the valorization of pineapple peel aligns with global sustainability initiatives, particularly in reducing agro-industrial waste. This approach supports multiple Sustainable Development Goals (SDGs), including SDG 3 (good health and well-being), SDG 12 (responsible consumption and production), and SDG 13 (climate action). Finally, these findings encourage further exploration into other agricultural waste products for food detoxification, such as banana peels, papaya leaves, and sugarcane bagasse. Expanding the catalog of plant-based preservatives may lead to broader applications in food processing industries, particularly in developing countries.

V. CONCLUSION

This study aimed to evaluate the effectiveness of soaking salted tuna (Euthynnus sp.) in pineapple peel (Ananas comosus L. Merr) solution at varying concentrations to reduce formaldehyde levels. The findings confirmed a significant decrease in formalin content after treatment. Before soaking, the average formalin level was 13.30 mg/kg. After soaking with PDAM water (control), the level reduced to 8.14 mg/kg. In contrast, soaking in pineapple peel solutions resulted in more substantial reductions: 6.58 mg/kg (20%), 4.16 mg/kg (40%), 0.15 mg/kg (60%), and 0.11 mg/kg (80%). The highest percentage reduction of 99.14% was observed at 80% concentration, while the lowest (50.45%) occurred at 20% concentration. The statistical analysis using the paired t-test confirmed the significance of the differences ($p < 0.05$), and ANOVA tests further supported the variation in reduction based on concentration. These results demonstrate that pineapple peel solution is highly effective in reducing formalin levels in salted fish, with the effect increasing alongside concentration. The active compound responsible for this effect is believed to be saponins, which facilitate saponification and micellization, binding formalin molecules and enabling their dissolution in water. This method represents a simple, natural, and eco-friendly approach to mitigating health risks associated with formalin-contaminated fish. Future studies should examine the long-term impact on sensory properties and explore other types of fruit peels or combinations of natural ingredients with different soaking durations and concentrations. Additionally, research should aim to validate these findings under field conditions or at household and industry scales to improve generalizability and practical application. The integration of such detoxification techniques into food safety practices may support public health and reduce reliance on synthetic chemicals.

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DATA AVAILABILITY
No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION
Sugiana was responsible for the study design, sample preparation, and data collection. Narwati supervised the overall research process, conducted data analysis, and acted as the corresponding author. Marlik contributed to the preparation of pineapple peel solutions and assisted in laboratory testing. Rusmiati supported the literature review, statistical validation, and final editing of the manuscript. All authors contributed substantially to the writing and revision of the paper and approved the final version for publication.

DECLARATIONS
ETHICAL APPROVAL
Not applicable. This study did not involve human or animal participants.

CONSENT FOR PUBLICATION PARTICIPANTS.
Consent for publication was given by all participants

COMPETING INTERESTS
The authors declare no competing interests

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