

Research Article

African Locust Bean Pod Extract: A Green Solution for Bamboo Preservation

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Abstract

There is high demand for sustainable building materials bringing bamboo into the spotlight due to its rapid growth, versatility, and environmental benefits. However, its susceptibility to biological degradation especially by termites limits its broader application in construction and furniture industries. Towards achieving SDG 15 (life on land), environmental concerns surrounding synthetic wood preservatives surge. There is therefore the need to identifying natural and biodegradable alternatives to curb this menace. Agricultural by-products such as the African Locust Bean Pod Husk (ALBPH) offer untapped potential for development into eco-friendly wood preservatives. This study therefore investigated the potential of African Locust Bean Pod Husk (ALBPH) extract as a natural preservative to enhance the resistance of *Bambusa vulgaris* to termite attack. ALBPH extract was prepared by soaking 250g, 500g, and 750g of pounded husk in 3000mL of either water or ethanol for 24 hours, followed by filtration. Bamboo samples were immersed in the extracts for five days to ensure adequate absorption and then oven-dried. After 12 weeks of termite exposure, percentage weight loss was measured for five replicates of each treated sample (500mm × 25mm × 10-20mm). Data were analyzed using IBM SPSS version 25 and presented using descriptive and inferential statistics. Treated samples exhibited weight loss ranging from 7.29% to 18.61%, while untreated controls showed the highest loss at 38.78%. Water-extracted ALBPH resulted in 8.29 to 18.42% weight loss, while ethanol extracts yielded 7.29 to 18.61%. No statistically significant difference was observed between the two solvent types. The findings suggest that ALBPH extract, particularly in water-based form, is a promising, eco-friendly preservative for bamboo. This study therefore recommends that further research be conducted to optimize the concentration and application method of ALBPH extracts for large-scale use. Additionally, long-term field trials under varying environmental conditions are encouraged to validate the preservative potential of ALBPH. Given its promising performance and eco-friendly nature, water-based ALBPH extract can be promoted as a sustainable alternative to synthetic preservatives for protecting bamboo in rural and urban construction applications.

Keywords

African Locust Bean Pod Husk, Bamboo, Durability, Preservative, Termites

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1. Introduction

Wood preservation involves treating wood with chemical or biochemical substances to prevent or slow its deterioration, which is often caused by environmental factors or organisms such as fungi, insects, and wood borers [1]. These chemical or biochemical substances, known as preservatives, protect wood from biological, chemical, and physical degradation [2]. Preservatives can be organic or inorganic, with inorganic preservatives often posing risks beyond their intended targets, affecting humans, other living organisms, and the environment [3, 2]. Prolonged exposure to inorganic preservatives can result in harmful effects, including carcinogenicity, liver damage, and teratogenicity, due to their persistent nature in the environment [4]. Consequently, many of these substances have been banned in countries such as the United States, Canada, Japan, the United Kingdom, and Germany [3, 2].

Given the environmental and health concerns surrounding inorganic preservatives, there has been growing interest in the development of alternative organic preservatives that are eco-friendly and less harmful to humans and the environment [5, 6]. Organic preservatives, which are derived from natural sources, have the potential to offer effective protection against wood deterioration while posing minimal risks to the ecosystem. Many countries are now focused on finding biodegradable preservatives that are as effective as conventional ones like CCA, pentachlorophenol, and pyrinex, but with less environmental impact [6].

Recent research has emphasized the use of agricultural waste products and plant extracts as potential sources of eco-friendly preservatives. These natural substances, rich in bioactive compounds such as polyphenols, flavonoids, tannins, and terpenes, have shown promise in enhancing the durability of wood species [7, 8]. Some natural compounds, like catechin and morin, have been found to deter termite feeding and reduce termite survival rates [8, 9]. Neem (*Azadirachta indica*) leaf extracts, for instance, have been demonstrated to be effective in preserving bamboo products [10], highlighting the potential of plant-based extracts in wood preservation.

The African locust bean tree (*Parkia biglobosa*) is another valuable source of natural preservatives. Widely distributed across 19 African countries, it is known for its economic significance in providing food, medicine, fuel, and lumber [11]. Extracts from its pods, known as locust bean husk extract (LBHE), contain bioactive compounds such as tannins, saponins, flavonoids, and terpenoids, which have demonstrated antibacterial and pesticidal properties [7, 12]. These phytochemicals, which are active plant-based molecules, have been used as natural pesticides and are known to repel and kill termites [13]. The husk of *Parkia biglobosa* has been traditionally used in parts of Ghana to preserve walls and floors, preventing termite infestations and enhancing durability [14].

Bamboo, a fast-growing renewable resource, has emerged as a sustainable alternative to wood due to its rapid maturity

and diverse applications, ranging from construction materials to furniture [15, 10]. However, bamboo's vulnerability to natural degradation, especially termite attacks, limits its widespread use [16]. In Ghana, where deforestation rates are high, bamboo offers a promising solution to the diminishing wood resources. Despite its potential, limited research has been conducted on using natural preservatives like *Parkia biglobosa* extracts to protect bamboo from termites.

This study aims to investigate the potential of African locust bean pod husk extract as a natural, eco-friendly preservative for bamboo. By exploring its efficacy in protecting bamboo from termite damage, this research seeks to provide a sustainable solution to bamboo degradation, contributing to the broader efforts of promoting eco-friendly wood preservation techniques in Ghana and beyond.

2. Materials and Methods

2.1. Materials

2.1.1. Source of Africa Locust Bean Pod Husk (ALBPH)

The African Locust Bean Pod Husk (ALBPH) was sourced from Kinkangu, a suburb of Bunkpurugu in the Bunkpurugu Nakpanduri district, North East Region of Ghana (Latitude 10.4934 °; Longitude 0.1479 °). The husks were sun-dried, threshed, and pounded in a mortar before being sieved using a 2 mm sieve. The powdered husk was stored in polythene bags and transported to the wood laboratory at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) in Kumasi for extraction.



Figure 1. Preparation of African locust bean pods (a) Fresh Fruits (b) Husk (c) Pounding of husk in a mortar (d) sieving of pounded husk (e) powder.

2.1.2. Bamboo Samples

Mature *Bambusa vulgaris* bamboo culms were harvested from a streamside on the AAMUSTED campus (Latitude 6.6995 °, Longitude -1.6822 °). Three, four, and five-year-old bamboo culms were selected from two clusters, with six culms from each cluster. Five bottom internodes from each culm were used for the study. *Bambusa vulgaris* was chosen due to its availability in Ghana. The harvested bamboo samples were transported to the woodworking laboratory at the

Forestry Research Institute of Ghana (CSIR-FORIG) for processing.

The bamboo samples were processed according to [17] standards into dimensions of 5 cm (length) × 2.5 cm (width) × 1.0-2.0 cm (thickness). After processing, the samples were oven-dried at 103 ± 2 °C for 48 hours or until they reached a constant weight. They were then randomly selected, weighed, and stored in polythene bags before treatment with ALBPH extract.

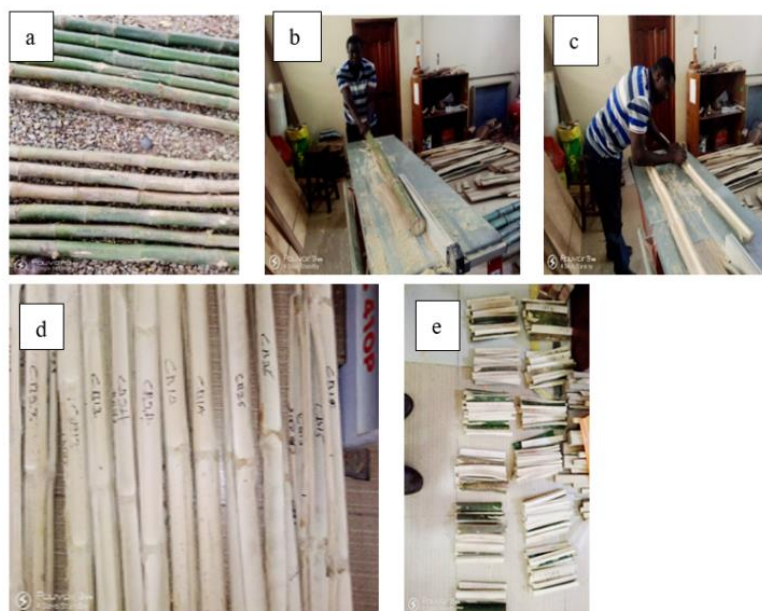


Figure 2. Preparation of bamboo culms into required dimensions (a) Bamboo culms (b) splitting of culms (c) Labeling of splitted culms (d) labelled Strips of culms (e) prepared samples of culms to required dimensions.

2.1.3. African Locust Bean Pod Husk Extract Preparation

The extraction process used both water and ethanol (95.5%) as solvents. For each extraction, 250g, 500g, and 750g of the powdered ALBPH were mixed with 3 liters of either water or ethanol in plastic containers, stirred, and left to stand for 48 hours to ensure adequate extraction (solvent-to-solute ratios of 1:12, 1:6, and 1:4). The quantities of solvent and solute were measured using beakers and a digital scale, respectively. After the extraction period, the mixtures were filtered through muslin cloth to obtain the ALBPH extract.

2.1.4. Treatment of Bamboo Samples with ALBPH Extracts

The bamboo samples were treated by immersing them in the ALBPH extract for five days to ensure maximum absorption. Seven treatment groups including control were established based on different extract concentrations and solvents:

T1: 250g ALBPH in water

T2: 500g ALBPH in water

T3: 750g ALBPH in water

T4: 250g ALBPH in ethanol

T5: 500g ALBPH in ethanol

T6: 750g ALBPH in ethanol

T7: Untreated (Control)

Each treatment group consisted of five replicates, resulting in a total of 35 samples. After treatment, the samples were oven-dried and stored for further testing.

2.2. Durability / Graveyard Test

A field test was conducted at AAMUSTED (Latitude 6.7012 °, Longitude -6.6777 °) using a natural termite infestation site maintained by the Wood Science and Technology Education Department. Both the untreated (control) and the treated bamboo samples were mounted vertically in the ground with 50 cm spacing between samples, leaving a portion exposed to facilitate termite detection. The test lasted for three months, with observations recorded at two-week intervals, following the guidelines of [18].

After the exposure period, the bamboo stakes were removed, cleaned to remove soil particles, and oven-dried for 48 hours or until they achieved a constant weight. The weight loss of each sample was then measured to assess termite damage.



Figure 3. Field activities (a) Pre-exposure condition (b) In-ground field exposure (c) Subterranean termites (d) Post exposure condition of specimens.

2.2.1. Research Design

This experimental study was designed to evaluate the durability of *Bambusa vulgaris* treated with ALBPH extracts. The research investigated the effectiveness of water and ethanol extracts of ALBPH in preserving bamboo against termite attacks. The bamboo and ALBPH were sourced from AAMUSTED and Bunkpurugu, respectively. Treatment was conducted using immersion techniques according to the [17] standard.

2.2.2. Sampling and Sampling Techniques

Purposive sampling was employed to select the bamboo culms based on age, availability, and maturity. Only the butt sections of the culms were used to ensure uniformity. The ALBPH was collected under controlled conditions to prevent contamination from rain and other environmental factors.

2.3. Data Analysis Techniques

Microsoft Excel was used to calculate the percentage weight loss of the bamboo samples, providing a measure of termite resistance. Analysis of Variance (ANOVA) was per-

formed using IBM SPSS Statistics 25 to compare the mean weight losses and determine any significant differences between the treatment groups. Descriptive statistics, p-values, and pairwise comparisons were used to interpret the results.

Percentage Weight Loss Calculation

The percentage weight loss of the bamboo samples were calculated using the following formula:

$$\text{Percentage Weight Loss} = \frac{W_i - W_f}{W_i} \times 100 \quad (1)$$

Where:

W_i = Initial oven-dried weight of bamboo before termite exposure

W_f = Final oven-dried weight of bamboo after termite exposure

This calculation was used to quantify the extent of termite damage and assess the durability of the specimens.

3. Results

3.1. Durability of Bamboo Treated with ALBPH Extract

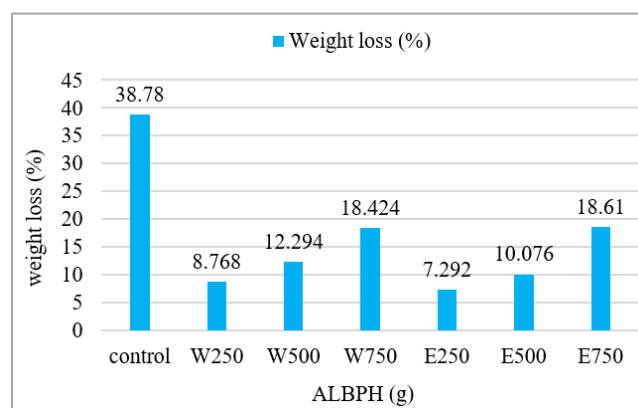


Figure 4. Comparison of durability of bamboo using weight loss.

The weight loss of *Bambusa vulgaris* samples during the three-month durability field test is presented in Figure 4. The bamboo samples were exposed to natural weather conditions and termite attacks. The percentage weight loss varied across different treatments, with the untreated control group showing the highest weight loss of 38.78%. In contrast, the samples treated with ethanol and water extracts of African Locust Bean Pod Husk (ALBPH) exhibited significantly lower weight loss, ranging from 7.29% to 18.61% for ethanol-treated samples and 8.77% to 18.42% for water-treated samples.

Specifically, the percentage weight loss for ethanol-treated bamboo samples was as follows:

E250 (7.29%)

E500 (10.07%)

E750 (18.61%)

For water-treated samples, the percentage weight loss was:

W250 (8.77%)

W500 (12.29%)

W750 (18.42%)

These results indicate that the control samples were more severely degraded by termites than those treated with either ethanol or water extracts of ALBPH, with ethanol-treated samples showing slightly better protection.

3.2. Comparison of Durability of Bamboo Using Descriptive Statistic

Table 1 summarizes the descriptive statistics for the durability test results, providing the mean, standard deviation (SD), and standard error of the mean (SEM) for each group. The control group, with a mean weight loss of 38.78%, exhibited more than double the mass loss compared to both the water-treated (8.77%-18.42%) and ethanol-treated (7.29%-18.61%) samples. This suggests that treatment with ALBPH extracts significantly reduced termite-induced degradation.

The standard deviations and standard errors further support the consistency of the results, with treated samples showing lower variability compared to the control. The observed differences in mean values among the treatment groups indicate that these differences are unlikely to be due to random chance, suggesting statistically significant effects.

Table 1. ANOVA test result for weight loss (%).

Descriptive statistic					
Treatment Name	N	Missing	Mean	Std Dev	SEM
control	5	0	38.78	13.59	6.078
W250	5	0	8.768	4.325	1.934
W500	5	0	12.294	2.098	0.938
W750	5	0	18.424	8.604	3.848
E250	5	0	7.292	1.598	0.715
E500	5	0	10.076	2.132	0.954
E750	5	0	18.61	16.42	7.343

3.3. Statistical Analysis of Differences Between Treatments

Table 2 presents the results of a statistical analysis of the differences in mass loss between the various treatment groups. The differences in mean weight loss were statistically significant, with a p-value of <0.001. This confirms that the treatments had a significant impact on the bamboo's durability, reducing termite damage compared to the control.

Table 2. ANOVA test result for weight loss (%).

One Way RM ANOVA					
Source of Variation	DF	SS	MS	F	P
Between Subjects	4	476.419	119.105		
Between Treatments	6	3539.281	589.88	8.055	<0.001
Residual	24	1757.665	73.236		
Total	34	5773.365	169.805		

Pairwise Comparison of Treatments

A post-hoc pairwise comparison (Table 3) was conducted to identify where the significant differences between treatment groups lay. The analysis revealed that there were significant differences in mass loss between the control and all treatment groups ($P < 0.05$). This indicates that all treatments had a positive, significant effect on the durability of the bamboo samples, reducing termite damage compared to the untreated control.

Interestingly, no significant differences in mass loss were

found between samples treated with ethanol extracts and those treated with water extracts of ALBPH. This suggests that both ethanol and water were equally effective as solvents for extracting the preservative compounds from the ALBPH.

Additionally, there were no significant differences in mass loss among bamboo samples treated with varying quantities of ALBPH (250 g, 500 g, and 750 g), regardless of the solvent used. This suggests that the lowest tested quantity of 250 g was just as effective as the higher quantities in preserving bamboo. Therefore, even smaller quantities of ALBPH may poten-

tially be used without compromising the preservative effect.

Table 3. Pairwise comparison between P-values.

Comparison	Diff of Means	T	P	P<0.050
control vs. E250	31.488	5.818	<0.001	Yes
control vs. W250	30.012	5.545	<0.001	Yes
control vs. E500	28.704	5.303	<0.001	Yes
control vs. W500	26.486	4.894	<0.001	Yes
control vs. W750	20.356	3.761	0.016	Yes
control vs. E750	20.17	3.727	0.017	Yes
E750 vs. E250	11.318	2.091	0.516	No
W750 vs. E250	11.132	2.057	0.518	No
E750 vs. W250	9.842	1.818	0.669	No
W750 vs. W250	9.656	1.784	0.665	No
E750 vs. E500	8.534	1.577	0.778	No
W750 vs. E500	8.348	1.542	0.768	No
E750 vs. W500	6.316	1.167	0.929	No
W750 vs. W500	6.13	1.133	0.918	No
W500 vs. E250	5.002	0.924	0.958	No
W500 vs. W250	3.526	0.651	0.988	No
E500 vs. E250	2.784	0.514	0.991	No
W500 vs. E500	2.218	0.41	0.99	No
W250 vs. E250	1.476	0.273	0.99	No
E500 vs. W250	1.308	0.242	0.964	No
E750 vs. W750	0.186	0.0344	0.973	No

4. Discussion

4.1. Discussions of Findings

Durability of Bamboo Treated with ALBPH Extract

The results demonstrate that untreated bamboo samples experienced the highest percentage of weight loss at 38.78%, indicating substantial degradation caused by termite attack in the field. In contrast, the bamboo samples treated with the African Locust Bean Pod Husk (ALBPH) extract showed significantly lower weight loss, ranging from 7.29% to 18.61%. This confirms the efficacy of ALBPH as a natural preservative for bamboo against termite attack. These findings are consistent with earlier studies, such as [15, 10], who found that termites attacked untreated wood at a significantly

higher rate than treated samples submerged in neem oil extract. Similarly, [19] reported that untreated wood lost more mass than treated samples using cashew nut shell liquid extract.

The high weight loss in the untreated control group confirms previous studies by [20-22], which indicated that bamboo is highly susceptible to termite attack due to its rich content of starch, sugars, and other organic materials that attract pests and fungi. [23] Also observed similar results in untreated bamboo, which lost 67.66% of its body weight compared to only 25.99% for treated bamboo using conventional procedures.

The results of the current study align with [19], who observed a 15.7% weight loss in bamboo samples treated with cashew nut extract. Similarly, [24] reported a 7.55% weight loss for *Bambusa vulgaris* treated at high temperatures. However, these values are lower than those observed for neem

oil-treated samples, which had a weight loss of 24.22% [19]. [21] Also reported significant weight loss (35.93-58.83%) for bamboo treated with traditional preservatives like CCB, further underscoring the value of natural preservatives such as ALBPH.

This high efficacy of ALBPH extract can be attributed to its bioactive components, including anthraquinones, phenols, flavonoids, tannins, saponins, cardiac glycosides, steroids, and terpenoids [7]. These compounds likely act as natural deterrents against termite attacks.

Comparison of Durability with Water and Ethanol Extracts of ALBPH

The ANOVA results for percentage weight loss clearly show that the mean weight loss of untreated bamboo (38.78%) was more than double that of the treated samples. Both water and ethanol extracts of ALBPH significantly improved the durability of the bamboo, with weight loss ranging from 7.29% to 18.61% across treatments. This highlights the potential of ALBPH extract as a natural, eco-friendly preservative. The reduced weight loss observed in treated samples demonstrates that the bamboo's resistance to termite attacks increased, extending its service life considerably.

The effectiveness of ALBPH in both water and ethanol extracts is supported by studies such as [7], which emphasize the chemical properties of plant-based preservatives. The findings here suggest that ALBPH is a promising alternative to synthetic preservatives, offering sustainable, natural protection for bamboo.

4.2. Statistical Significance of Treatment Groups ($P < 0.05$)

The statistical analysis revealed that the percentage weight loss of all treated bamboo samples was significantly lower than that of the control group, with a p-value range of <0.001 to 0.017 . This confirms that all concentrations of ALBPH extract (250g, 500g, and 750g) in both water and ethanol solvents met the required statistical significance level ($P < 0.05$). This suggests that the treatments can significantly enhance the durability of *Bambusa vulgaris* and are effective at prolonging the service life of products made from bamboo.

This is consistent with previous research by [19], who found a significant reduction in weight loss for wood treated with cashew nut shell liquid (CNSL) and other natural preservatives. The reduced weight loss observed in the present study can be attributed to the ALBPH extract poisoning the starch in the bamboo, which is essential for termite survival, as noted by [25].

Pairwise Comparison Using the Holm-Sidak Method

The pairwise comparison of P-values showed statistically insignificant differences ($P < 0.001$ - 0.017) between treated bamboo samples. The treated bamboo performed similarly to bamboo treated with CNSL diluted in kerosene [26], and better than conventional methods using synthetic preservatives. These results are comparable to findings by [23], who

achieved significant improvements in bamboo durability using conventional soaking and curing methods.

Between the two solvents used for extraction, ethanol performed slightly better than water in terms of termite resistance. This observation supports the assertion in the literature that alcohol-based solvents are often more efficient at extracting bioactive compounds than water. However, considering the performance of the water extract, its cost-effectiveness, and accessibility, water may still be the more practical solvent for large-scale bamboo treatment in regions like Ghana, where access to ethanol might be limited and expensive.

4.3. Observation of Bamboo Structure

Another notable observation was that termites tended to penetrate the bamboo samples through the inner layers and cut ends, while the outermost layer remained largely intact. This resistance of the outer layer is likely due to the presence of ash and silica, which naturally strengthen bamboo's exterior [27]. The interior, with higher starch content, was more vulnerable to termite attack, highlighting the importance of thorough preservation treatment to protect the entire bamboo structure.

5. Conclusions

The findings of this study demonstrate that African Locust Bean Pod Husk (ALBPH) extract is an effective natural preservative for enhancing the durability of *Bambusa vulgaris* against termite attack. Both water and ethanol extracts of ALBPH showed statistically significant results in reducing the weight loss of treated bamboo samples, highlighting their potential as eco-friendly alternatives to conventional chemical preservatives.

The study concluded that ALBPH extracted with water can be effectively used as a preservative, offering strong resistance to termite damage. This is evidenced by the treated bamboo samples, which exhibited a percentage mass loss ranging from 8.77% to 18.42%, compared to 38.78% in untreated samples. Given that water is inexpensive, readily available, and performed comparably to ethanol in most cases, it is recommended as the preferred medium for large-scale extraction.

Similarly, ALBPH extracted with ethanol also proved to be a highly effective preservative, with a slightly lower percentage mass loss (7.29% to 18.61%) compared to the water extract. The ethanol extract's higher efficiency can be attributed to its superior ability to extract bioactive compounds. However, considering the cost and availability of water, its use as an extraction medium is more practical in regions where ethanol might be less accessible.

The significant reduction in weight loss among treated bamboo samples confirms that ALBPH extract has the potential to considerably extend the lifespan of *Bambusa vulgaris*, making it more durable for construction and other applications. These results align with previous studies that em-

phasized the vulnerability of untreated bamboo to termites and other degrading agents, thus reinforcing the importance of pre-treatment before use.

As an organic preservative, ALBPH is environmentally friendly, sustainable, and poses no known risks to human health, animals, or ecosystems. This makes it a viable alternative to chemical preservatives, which are often hazardous to both humans and the environment.

5.1. Recommendations

Based on the findings, it is recommended that:

- 1) Bamboo should always be preserved before use, particularly in regions where termite activity is prevalent. This will significantly enhance the durability of bamboo products.
- 2) Water should be considered the medium of choice for extraction of ALBPH, due to its availability and cost-effectiveness, especially in resource-limited settings.
- 3) Further research should explore the use of lower concentrations of ALBPH (e.g., 150g or 200g) to test whether similar efficacy can be achieved with smaller amounts, optimizing resource use.

5.2. Future Research Directions

- 1) Testing different extraction mediums beyond water and ethanol could provide further insight into maximizing the preservative potential of ALBPH.
- 2) Comparative studies using different bamboo species or other wood species would be valuable to assess the broader applicability of ALBPH as a natural preservative.
- 3) Exploring alternative preservation methods (e.g., dipping, soaking, or pressure treatments) could improve the practical application of ALBPH in real-world scenarios.
- 4) This study paves the way for further innovation in sustainable preservation techniques, highlighting the potential of natural extracts like ALBPH to replace harmful chemical preservatives.

Abbreviations

LBHE	Locust Bean Husk Extract
ALBPH	Africa Locust Bean Pod Husk
CNSL	Cashew Nut Shell Liquid

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Author Contributions

Francis Kofi Bih, conceived and designed the research, Issah Chakurah, collect the data, processed the data and performed statistical analysis, Francis Kofi Bih supervised the research, proofread and validate the write-up, Mathew Tamirka Konlan, drafted the manuscript, improved manuscript draft. All authors read, discussed the results and contributed to the final version of the manuscript.

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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