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Promoting the Use of Carved Bamboo Utensils as Sustainable Alternative at School: An Analysis of Mechanical Strength and Thermal Resistance

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ABSTRACT

This study addresses the critical environmental challenge of single-use plastic-based utensils by evaluating carved bamboo utensils made from Bambusa blumeana as a substitute. Utilizing a quantitative mixed-method framework, the research subjected both bamboo utensils (experimental group) and conventional plastic-based utensils (control group) to stress profiling, thermal thresholds up to 99.1 ℃, and a 14-day environmental exposure, as well as the use of descriptive survey of twenty-five purposively selected consumers in Maigo, Lanao del Norte. The outcomes reveal that the fibrous structure of Bambusa blumeana contains a high tensile strength of approximately 23,500 psi, compared to the structure of the plastic-based utensils. The study utilized a comparative experimental design to evaluate mechanical strength, thermal resistance, and environmental durability, complemented by a descriptive survey involving twenty-five purposively selected consumers. While the survey results indicated a high level of consumer acceptance (GWM = 4.34), the findings should be interpreted within the context of the study's limited sample size. Overall, the results suggest that integrating regional bamboo resources into institutional supply chains may be a mechanically viable and environmentally sustainable strategy for reducing dependence on single-use plastic utensils.

Keywords, Carved Bamboo Utensils, Mechanical Strength, Thermal Resistance, Sustainability, Plastic Pollution, Eco-Friendly Materials, Consumer Acceptance, Bambusa blumeana

INTRODUCTION

This study examines the use of carved bamboo utensils as an eco-friendly alternative to plastic-based utensils. It highlights environmental issues caused by the widespread accumulation of non-biodegradable plastic utensils in food service establishments, which contribute to severe environmental degradation (BioLeader Pack, 2025). As a rapidly renewable organic resource with a brief three-to-five-year growth cycle, bamboo offers a practical low-carbon choice for institutions striving to minimize environmental footprints (Global Growth Insights, 2025). Empirical material characterizations confirm that natural bamboo fibers and advanced bioplastics display impressive tensile strength and structural stiffness (SciELO Brazil, 2025; Nature Communications, 2025). Furthermore, the low thermal conductivity of bamboo preserves its structural integrity during heat exposure (Scientific Reports, 2025; Zhou et al., 2019). Local structural characterization of regional Philippine species confirms that specific engineering treatments enhance raw material properties for functional tableware design. A testing by Panti et al. (2024) documented the exact compressive capacities of native bamboo variants, proving that their inherent biological density meets structural safety requirements. While Jimenez Jr. et al., (2025) verified that controlled thermal modification significantly stabilizes the physical dimensions of Bambusa blumeana and Dendrocalamus asper without diminishing their capacity to handle heavy crushing loads. Furthermore, wood preservation research conducted by Marasigan and Daguinod (2025) highlighted how the dense cell structure and robust mechanical traits of Gigantochloa apus support precise, defect free manual carving during tool fabrication. Concluding these processing insights, trials by Ramos and Jimenez Jr. (2025)

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demonstrated that utilizing specialized steam cycles combined with recycled cooking oil barriers successfully improves the moisture resistance and operational durability of both Dendrocalamus asper and Bambusa spinosa.

The objectives of this study are as follows:

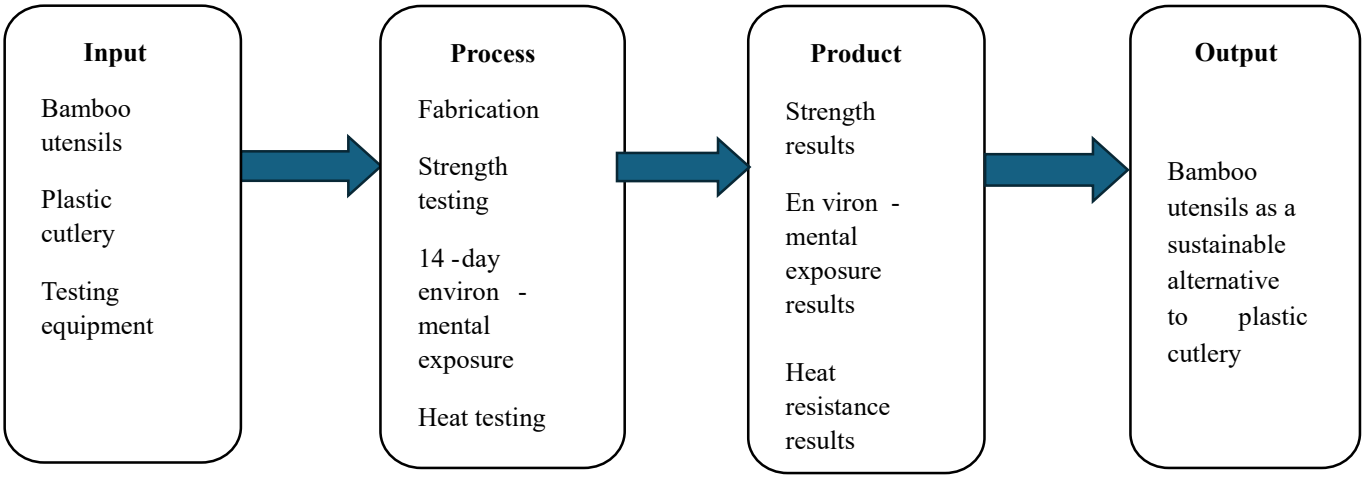
1. To determine the tensile strength of carved bamboo utensils and compare them to that of commercially available plastic cutlery.

2. To know the extent of the environmental exposure over a 14-days period and the effect it has on the mechanical strength of carved bamboo utensils compared to commercially available plastic cutlery.

3. To determine the difference in the heat resistance of carved bamboo utensils when subjected to varying liquid temperatures of up to 99.1 °C.

Figure 1.

Conceptual Framework of the Study



REVIEW OF RELATED STUDIES AND LITERATURE

Synthesis

The transition from single-use plastics to carved bamboo utensils is theoretically anchored in the Life Cycle Assessment framework (ISO 14040:2006), which validates bamboo as a superior alternative by evaluating its environmental impact from raw material extraction to end-of-life disposal. Unlike petroleum-based polymers, bamboo is a rapidly renewable resource with a harvest cycle of three to five years (Global Growth Insights, 2025), ensuring a sustainable "cradle-to-grave" trajectory. The technical feasibility of this substitution is reinforced by empirical data confirming that Philippine species, such as Bambusa blumeana and Dendrocalamus asper, possess the requisite mechanical integrity for functional tableware. Panti et al. (2024) and Jimenez Jr. et al. (2025) demonstrate that these species exhibit high compressive strength and enhanced dimensional stability through thermal modification, ensuring the utensils withstand the "usage phase" without structural failure. Complementing this material durability perspective, Moghadas et al. (2024) highlights the role of plant oils in edible films and coatings, emphasizing their antimicrobial, antioxidant, and moisture-barrier properties in food-contact applications, thereby reinforcing the potential of coconut oil as a food-safe conditioning agent for bamboo

Furthermore, the Theory of Planned Behavior (TPB) explains consumer willingness to adopt sustainable products (Ayar & Gürbüz ,2021), provides the psychological architecture necessary for consumer adoption. A shift in consumption habits is driven by the alignment of personal attitudes, subjective norms, and perceived behavioral control. Supporting studies by Condino et al. (2023) and IJPREMS (2025) suggest that as food establishments adopt eco-friendly practices, they reshape the social norms of the community, fostering a positive

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attitude toward sustainability. Crucially, the perceived behavioral control of the consumer is strengthened by the material's performance; when bamboo utensils are proven to be as thermally stable and durable as plastic counterparts (Scientific Reports, 2025), practical barriers to adoption are removed. The integration of plant-based protective coatings, supported by findings from Alam et al. (2014) and Moghadas et al. (2024), further enhances consumer confidence by ensuring that bamboo utensils are not only structurally reliable but also safe for food contact and resistant to moisture-related degradation. Ultimately, this synergy between robust material engineering, sustainable surface treatment technologies, and behavioral drivers creates a transition that is not merely an ecological necessity but a scientifically grounded and socially acceptable alternative to plastic pollution.

RESEARCH METHODOLOGY

Research Method

This study adopts a quantitative mixed-method research design, combining a comparative experimental approach and a descriptive survey method. This design was used to determine the feasibility of carved bamboo utensils as a sustainable alternative to plastic spoons and forks in school settings. The experimental component focuses on the objective measurement of mechanical strength and thermal resistance using numerical data obtained from controlled testing. A comparative experimental approach is used, wherein carved bamboo spoons and forks serve as the experimental group and plastic spoons and forks serve as the control group. The descriptive survey method is used to assess the acceptability and eco-friendliness perception of users regarding bamboo utensils in the school environment.

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The study evaluated the effectiveness of carved bamboo utensils made from Bambusa blumeana as a sustainable alternative to plastic-based utensils through mechanical strength testing, thermal resistance assessment, environmental exposure testing, and consumer acceptability surveys. The findings revealed that carved bamboo utensils demonstrated stronger mechanical performance compared to plastic utensils, showing lower stress levels under a standard 15 N eating force and exhibiting a tensile strength of approximately 23,500 psi, which is significantly higher than the tensile strength commonly observed in commercial plastic utensils. In terms of thermal resistance, the bamboo utensils maintained their structural integrity when exposed to temperatures of up to 99.1 °C, with no visible cracks, warping, or deformation, while plastic utensils showed signs of deformation and released visible white chemical residues under high temperatures. During the 14-day environmental exposure test, both materials remained structurally stable; however, bamboo utensils demonstrated better durability and resistance to environmental conditions. Furthermore, survey results indicated a high level of consumer acceptance, with respondents expressing positive attitudes toward sustainability, environmental protection, and the practicality of using bamboo utensils in daily activities. The study obtained a general weighted mean of 4.34, confirming that carved bamboo utensils are eco-friendly, durable, and suitable for use in schools and food establishments. Overall, the findings confirmed that carved bamboo utensils possess excellent mechanical strength, thermal resistance, and consumer acceptability, making them a practical and sustainable alternative to conventional plastic cutlery.

Mechanical strength testing was conducted by applying a standardized force of 15 N to both bamboo and plastic utensils and observing structural response and stress distribution. Thermal resistance testing involved exposing the utensils to liquids at progressively increasing temperatures up to 99.1 °C while monitoring for visible deformation, cracking, or material degradation. Environmental exposure testing was performed over a 14-day period under monitored outdoor conditions. The same testing procedures were applied to both bamboo and plastic utensils to ensure consistency of comparison. Temperature measurements were obtained using a calibrated digital thermometer, and all observations were recorded using a standardized evaluation sheet.

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Limitations of the Study

The study was limited using a small, purposively selected sample of twenty-five respondents from Maigo, Lanao del Norte. As a result, the consumer acceptability findings may not be representative of larger populations or different geographic locations.

The mechanical strength, thermal resistance, and environmental exposure assessments were conducted using the equipment and resources available to the researchers. The testing procedures were designed for comparative evaluation between bamboo and plastic utensils and did not utilize laboratory-grade calibration verification or internationally standardized material testing protocols.

Therefore, the reported performance values should be interpreted within the scope of the study. Future research may employ larger and randomly selected samples, standardized testing procedures, calibrated instruments, and comparisons with a broader range of commercially available utensils to improve the reliability and generalizability of the findings.

CONCLUSION

In conclusion, Bambusa blumeana utensils demonstrate clear structural, thermal, and social superiority over conventional plastic cutlery as a highly viable alternative for food establishments. Mechanical evaluations confirm that the bamboo spoons and forks safely distribute operational pressure under a standard 15 N eating force to yield lower internal stress levels than shorter plastics, effortlessly leveraging an exceptional tensile strength of up to 23500 psi to prevent the sudden brittle fracturing common to commercial polymers at typical loads of 10 to 25 pounds.

Furthermore, experimental testing up to a liquid heat threshold of 99.1 °C establishes excellent material endurance, with bamboo experiencing zero structural distortion while plastic exhibits visible deformation and releases toxic white chemical residues. Although both material groups maintain structural stability throughout a 14-day environmental exposure period, consumer response metrics reveal a deep behavioral shift toward ecological sustainability. Exceptional survey scores peaking at a 4.60 mean value reflect strong community readiness and open acceptance among customers to actively integrate carved bamboo tableware into daily dining operations, verifying that this natural resource successfully addresses both structural performance requirements and institutional environmental demands.

Recommendations

1. For School Administrators and Food Service Establishments

Schools and canteens are encouraged to gradually incorporate carved bamboo utensils as an alternative to plastic utensils. They should ensure that the utensils meet acceptable standards of mechanical strength and thermal resistance for daily use. Additionally, schools may promote their use through awareness campaigns, posters, or school policies that support eco-friendly practices.

2. For Manufacturers and Suppliers

Manufacturers should continue enhancing the durability and heat resistance of carved bamboo utensils to ensure they are safe and reliable for repeated use. Improving production techniques while maintaining affordability is also recommended. Partnering with schools can help increase accessibility and encourage wider adoption.

3. For Students and Consumers

Students and consumers are encouraged to actively support sustainable practices by choosing carved bamboo utensils over plastic ones. They may also help promote environmental awareness within the school by participating in campaigns and influencing peers to adopt eco-friendly alternatives.

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4. For Environmental Organizations and Local Government Units

Environmental organizations and local government units may strengthen initiatives that reduce plastic waste by promoting the use of sustainable materials such as bamboo. They may also implement school-based programs, policies, or incentives that encourage the adoption of biodegradable and reusable utensils.

5. For Future Researchers

Future researchers are encouraged to expand this study by exploring additional factors such as longterm durability, user safety, cost-efficiency, and comparative analysis with other sustainable materials. Further experimental and qualitative studies may provide deeper insights into improving bamboo utensils and increasing their acceptance in school environments.

Future studies should include more comprehensive material testing, such as moisture resistance, biodegradability rate, microbial safety, lifespan, and repeated-use durability, to provide a fuller evaluation of bamboo utensils.

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