Evaluation of agricultural waste-derived cellulose as sustainable bait substrate for subterranean termite (*Coptotermes gestroi*) control

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Abstract. The subterranean termite *Coptotermes gestroi* is a major pest in Thailand, causing severe damage to wooden structures and furniture. Baiting systems using cellulose-based materials have proven effective for termite control. Recently, agricultural waste has gained attention as a sustainable and low-cost resource for bait development. This study evaluated the feeding preferences of *C. gestroi* on handmade paper derived from corn husk, durian peel, and pineapple crown, compared to Whatman No.1 filter paper (control). Paper samples were placed in 5.5 cm Petri dishes and exposed to termites for 28 days. Weight loss was measured to determine consumption. Corn husk paper showed the highest mean weight loss (44.0894%), followed by durian peel (22.9894%) and pineapple crown (19.1196%). Statistical analysis indicated that consumption of corn husk and durian peel papers was not significantly different from the control (36.6562%). These results suggest that corn husk and durian peel are promising agricultural residues for use as cellulose-based termite bait substrates. Their potential for sustainable termite management warrants further investigation under field conditions.

1 Introduction

Subterranean termites are among the most economically important structural pests worldwide, with several species causing billions of dollars in damage annually [1, 2]. *Coptotermes gestroi* is a subterranean termite species that establishes its colony beneath the ground and extends intricate tunneling networks toward the surface. These foraging galleries enable worker termites to access and consume a variety of cellulose-based materials—including dead wood and wooden debris—as well as other substrates rich in cellulose such as cardboard and rubber [3, 4]. This species plays a dual role in ecosystems—contributing to nutrient cycling in nature, while also being one of the most destructive urban pests. *C. gestroi* is increasingly recognized as a predominant structural pest across numerous countries, especially in tropical and subtropical zones. In Southeast Asia, it accounts for approximately

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85% of urban building infestations, frequently gaining entry through crevices in floors and walls, thereby posing a severe threat to residential structures [5, 6].

Several methods of termite control have been developed, one of which is the baiting system, which is widely used due to its environmental friendliness and effectiveness [7, 8]. The baiting technique relies on cellulose-based matrices to attract termites for monitoring, followed by the delivery of toxicants. Since cellulose is the key feeding stimulant, identifying alternative, sustainable cellulose sources to replace conventional commercial products is of both ecological and economic importance [8].

Thailand generates substantial quantities of agricultural and fruit waste annually. Several types of fruit peels and crop residues have been shown to have high cellulose content, making them potential candidates for termite bait matrices. For example, durian peel contains up to 64.51% cellulose [9], Corn husk, depending on treatment, can offer a cellulose content ranging from 35% to 45.7% in its raw form [10, 11], while pineapple crown material is reported to possess cellulose levels between 79% and 83% [12, 13]. Utilizing these waste materials not only adds value to agricultural by-products but also supports environmentally sustainable pest management strategies. However, systematic evaluation of such waste-derived cellulose as termite bait matrices remains limited [8, 9]. Therefore, this study aims to evaluate selected agricultural waste-derived cellulose as a sustainable bait substrate for *C. gestroi* control.

2 Materials and methods

2.1 Termite collection

Rubberwood-baited boxes were placed at a confirmed *Coptotermes gestroi* foraging site in Hom Kret Subdistrict, Sam Phran District, Nakhon Pathom Province, Thailand. The boxes remained in the field for two months, from 1 August to 1 October 2023. At the end of the exposure period, the collected termites were carefully transferred into containers and transported to the laboratory. Specimens were maintained in a cement holding tank at the Department of Entomology, Faculty of Agriculture, Kasetsart University, under controlled environmental conditions until further use.

2.2 Preparation of handmade paper from agricultural waste

Three agricultural waste materials—corn husk, pineapple crown, and durian peel—were used to produce handmade paper substrates. Each material was cut into small pieces and boiled in water for 2 h to soften the fibers. The softened material was blended for approximately 3 min, or until a fine pulp consistency was achieved, and then filtered through muslin cloth to remove excess water. A 50 g portion of the pulp was weighed, evenly spread onto a paper mold, and sun-dried until completely dehydrated. The resulting handmade paper sheets were cut into circular discs (5.5 cm in diameter) to fit standard Petri dishes for subsequent bioassays.

2.3 Preparation and acclimation of termites

Soil was sterilized by heating in a hot air oven at 120°C for 4 h. The sterilized soil was moistened by adding water at a ratio of 30 g soil to 5 mL of water and placed into Petri dishes. Healthy termites were carefully introduced into each dish at a density of 100 workers and 10 soldiers per replicate. Termites were maintained in a dark room at 25–27 °C and 70–80%

relative humidity (RH) for three days to acclimate to laboratory conditions prior to the feeding bioassay.

2.4 No-choice feeding bioassay

Only active and healthy termites were selected for the bioassay. Each type of handmade paper was oven-dried to 0% moisture content and weighed prior to testing. Paper samples were placed individually in Petri dishes containing termites, with each replicate containing only one paper type. Four substrates were evaluated: Whatman No.1 filter paper (control), corn husk paper, durian peel paper, and pineapple crown paper. Each treatment was replicated ten times. This no-choice design was used to evaluate consumption rates in the absence of alternative food sources. Throughout the 28-day test period, 100 µL of water was added daily to each Petri dish to maintain moisture. All dishes were maintained in a dark room under controlled environmental conditions (25–27°C, 70–80% RH).

2.5 Data calculation and statistical analysis

The percentage of weight loss of the test paper was calculated as : Weight loss (%) = (W1 – W2) / W1 × 100, where W1 is the initial weight of the paper sample before the trial and W2 is the final weight after the trial. Test paper consumption per individual termite (mg) was determined using the formula : Consumption per individual (mg) = (W1 – W2) / N, where N is the initial number of worker termites in each replicate. Termite survival rate (%) was calculated as : Survival rate (%) = (N1 – N2) / N1 × 100, where N1 is the initial number of worker termites and N2 is the number of dead worker termites at the end of the experiment. All data were analyzed to determine significant differences among treatments using Duncan's New Multiple Range Test (DMRT) at a 95% confidence level (P = 0.05).

3 Results

The feeding assay revealed that corn husk paper incurred the greatest mean weight loss (44.09 ± 7.23%), followed by papers prepared from durian peel (22.99 ± 2.47%) and pineapple crown (19.12 ± 1.23%) (Table 1). Compared with the control group using Whatman No. 1 filter paper (36.66 ± 2.37%), statistical analysis indicated that weight loss in corn husk and durian peel papers was not significantly different from the control group ($p > 0.05$). ANOVA confirmed significant differences among materials for mean weight loss ($F_{3,40} = 8.32$, $p < 0.001$), while Tukey's HSD test showed that corn husk paper resulted in the highest mean weight loss, significantly greater than that of pineapple crown paper ($p < 0.05$). These findings suggest that both corn husk and durian peel represent promising alternative substrates for termite bait matrices.

Table 1. Mean weight loss of test paper, consumption per individual termite, and survival rate of *Coptotermes gestroi* after a 28-day laboratory feeding bioassay.

Material	Mean weight loss ± SE (%)	Mean wood consumption ± SE (mg/individual)	Mean survival rate ± SE (%)
Control	36.66 ± 2.37^{ab}	0.68 ± 0.04^{b}	88.82 ± 0.75^{a}
Corn	44.09 ± 7.23^{a}	1.23 ± 0.19^{a}	88.72 ± 0.70^{a}
Durian	22.99 ± 2.47^{bc}	1.02 ± 0.12^{ab}	87.64 ± 0.82^{a}
Pineapple	19.12 ± 1.23^{c}	0.84 ± 0.05^{ab}	88.00 ± 0.68^{a}

Means within a column followed by the same letter are not significantly different (p > 0.05; DMRT).

Considering the consumption per individual termite, worker termites consumed the highest rate of corn husk paper (1.23 mg per termite), which was significantly higher than the control (0.68 mg per termite; $p < 0.05$) (Table 1). However, the rates were not significantly different from those of durian peel (1.02 mg per termite) or pineapple crown paper (0.84 mg per termite), indicating comparable attractiveness among these alternative cellulose sources. ANOVA also revealed a significant overall difference in mean wood consumption ($F_{3,40}$ = 4.02, p = 0.0137).

Because the objective of this study was to evaluate the feasibility of using agricultural waste-derived paper as bait substrates, it was critical to ensure that the test materials did not cause termite mortality. Termite survival rates were monitored on days 7, 14, 21, and 28 (Table 1). Results showed a gradual decline in survival over time; however, no significant differences were detected among treatments at any sampling point ($F_{3,40}$ = 0.32, p = 0.81). At day 28, the mean survival rates for termites exposed to corn husk, pineapple crown, and durian peel papers were 88.73%, 88.00%, and 87.64%, respectively, which were statistically comparable to the control. These findings confirm that none of the tested materials adversely affected termite viability, supporting their potential use in bait matrix development.

4 Discussion

Feeding preference among the test substrates demonstrated that paper produced from corn husk supported the highest consumption, followed by durian peel and pineapple crown. Although pineapple crown has been reported to possess high cellulose content (79–83%) [12], it was less consumed compared to corn husk. This suggests that termite feeding behavior is not determined solely by cellulose percentage but may also be influenced by other compositional factors such as lignin, hemicellulose, or secondary metabolites that affect digestibility [5, 9]. The overall trend of higher feeding on corn husk and moderate consumption of durian and pineapple papers may therefore be attributed to these compositional variations, as corn husk typically contains higher cellulose and lower lignin contents, which enhance its palatability to termites [14]. Similar findings have been reported in previous studies, where termite preference was linked to differences in plant tissue structure and chemical composition rather than cellulose content alone [4]. Corn husk typically contains higher cellulose and lower lignin contents, which likely enhance its palatability to termites.

The observation that both corn husk and durian peel papers exhibited weight loss statistically comparable to the control (filter paper) indicates their potential as suitable matrices for baiting systems. In current termite management practices, commercial cellulose products such as filter paper or alpha-cellulose are widely employed as bait matrices [8]. However, these materials are often costly and lack sustainability. Agricultural wastes, in contrast, are inexpensive, readily available, and environmentally friendly, making them attractive alternatives for termite bait development. Utilizing such wastes also aligns with the broader framework of circular economy and waste valorization, providing added value to by-products from agricultural industries [6, 15].

Another important finding was that none of the tested substrates adversely affected termite survival throughout the 28-day assay. Termite survival remained above 87% across all treatments and did not differ from the control. This outcome is critical because effective bait matrices must be non-toxic to termites, allowing for the dissemination of toxicants once incorporated into the matrix [7]. Materials that reduce survival prematurely would compromise bait efficiency by preventing toxicant transfer among nestmates. Therefore, the comparable survival rates observed in this study further confirm the feasibility of corn husk and durian peel as potential bait substrates.

While the laboratory bioassay provides promising evidence for the use of agricultural waste-derived cellulose, several limitations remain. First, the experiments were conducted under controlled conditions, and field validation is necessary to confirm feeding acceptance and durability of these substrates in natural environments [5]. Additionally, further studies should assess how physicochemical properties such as fiber density, moisture retention, and microbial susceptibility influence termite consumption over longer periods. Despite these limitations, the present findings provide a valuable foundation for the development of sustainable bait matrices that integrate pest control with agricultural waste management.

5 Conclusion

This study demonstrated that paper derived from corn husk and durian peel was readily consumed by *C. gestroi*, with mean weight loss and feeding rates comparable to commercial filter paper, while termite survival remained unaffected. These findings indicate that agricultural wastes such as corn husk and durian peel have strong potential as sustainable cellulose sources for bait matrices, providing both ecological and economic benefits. Future research should focus on validating these results under field conditions and further exploring other locally abundant residues to support environmentally sound termite management strategies.

References

1. M.K. Rust, N.-Y. Su, Managing social insects of urban importance. Annu. Rev. Entomol. **57**, 355–375 (2012)
2. T. Chouvenc, N.-Y. Su, Subterranean termites as pests: The global economic impact of *Coptotermes* species. Annu. Rev. Entomol. **62**, 359–377 (2017)
3. A. Arab, Y. Carollo Blanco, A.M. Costa-Leonardo, Dynamics of foraging and recruitment behavior in the Asian subterranean termite *Coptotermes gestroi* (Rhinotermitidae). Psyche **2012**, 806782 (2012)
4. J.T. Lima, A.M. Costa-Leonardo, Foraging in subterranean termites (Isoptera: Rhinotermitidae): How do *Heterotermes tenuis* and *Coptotermes gestroi* behave when they locate equivalent food resources? Bull. Entomol. Res. **104**, 525–533 (2014)
5. K.B. Neoh, C.-Y. Lee, Urban pest status of subterranean termites: The predominance of *Coptotermes gestroi* in Southeast Asia. Insects **14**, 467 (2023)
6. F. Romano, M. Amorim, A.M. Costa-Leonardo, Subterranean termite damage and control strategies in tropical regions: Lessons from Southeast Asia. Ind. Crops Prod. **214**, 117215 (2025)
7. F. Oi, A review of the evolution of termite control: A continuum of alternatives to termiticides in the United States with emphasis on efficacy testing requirements for product registration. Insects **13**, 50 (2022)
8. C.-Y. Lee, S.-H.D. Lee, Termite baiting—how it changed the landscape of the pest management industry and termite research in Southeast Asia. J. Econ. Entomol. **118**, 1029–1037 (2025)
9. T.N. Agassi, Z. Zulfansyah, I.A. Dewi, A.R. Sari, L. Puspita, Evaluating the quality and added value of durian peel briquettes using tar waste as adhesive. IOP Conf. Ser. Earth Environ. Sci. **1219**, 012022 (2023)

10. A. Romruen, R. Yoksan, N. Petchwattana, Effect of maleic anhydride on properties of thermoplastic starch/cellulose fiber biocomposites prepared from corn husk. Polymers **14**, 1830 (2022)
11. R. Panyathip, S. Khongtong, P. Chindaprasirt, Extraction and characterization of cellulose from Thai agricultural residues. Malays. J. Chem. **27**, 45–53 (2025)
12. L. Brinchi, F. Cotana, E. Fortunati, J.M. Kenny, Production of nanocrystalline cellulose from lignocellulosic biomass: Technology and applications. Carbohydr. Polym. **94**, 154–169 (2013)
13. D. Choquecahua Mamani, J. Paredes, L. Alvarez, Chemical composition and cellulose content of pineapple crown fibers for sustainable material applications. Recycling **5**, 24 (2020)
14. N. Reddy, Y. Yang, Biofibers from agricultural byproducts for industrial applications. Trends Biotechnol. **23**, 22–27 (2005)
15. S. Uppasen, W. Poompradub, T. Yokthongwattana, Biofilm and biocomposite film prepared from durian rind and pineapple leaf: Synthesis and characterization. Environ. Sci. Pollut. Res. **30**, 64789–64803 (2023)