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Effectiveness of Breadfruit Leaf Powder (*Artocarpus altilis*) in Controlling Rice Weevil (*Sitophilus oryzae* L.) Using the Tea Bag Method

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Abstract

The rice weevil (*Sitophilus oryzae* L.) is commonly found in stored rice and causes reductions in both weight and quality. Efforts to control this pest using plant-based materials have gained increasing attention due to their environmental safety, one of which involves the use of breadfruit leaves (*Artocarpus altilis*) that contain compounds with potential insecticidal properties. This study aimed to evaluate the effectiveness of breadfruit leaf powder in suppressing the population of *S. oryzae* through application using tea bags. The experiment employed a Completely Randomized Design (CRD) with four treatments, namely 0 g, 5 g, 10 g, and 15 g of powder per 100 g of rice, with four replications. Observed parameters included mortality, daily mortality rate, and LD₅₀ value, which were analyzed using one-way ANOVA, Duncan's multiple range test, and probit analysis. The highest dose (15 g) resulted in 50% mortality and the highest mortality rate with an average of 3.125 individuals per day, while the control treatment caused no mortality during the observation period. The LD₅₀ value obtained from probit analysis was 15.717 g per 100 g of rice. These results indicate that increasing the dose of breadfruit leaf powder is directly proportional to its toxic effect, which is presumably associated with the activity of secondary metabolites that disrupt the physiological functions of insects. Overall, breadfruit leaf powder shows potential as a simpler and safer pest control material for rice storage.

Keywords: *Artocarpus altilis*, botanical insecticide, *Sitophilus oryzae*, mortality

INTRODUCTION

Rice is the main staple food commodity in Indonesia, with a very high level of consumption. In 2023, rice consumption per capita in Indonesia reached 93.79 kg per year, indicating a strong dependence on this commodity as a primary food source (Rozi et al., 2023; Akbar et al., 2023). This high consumption necessitates proper rice storage systems to maintain both quality and quantity during storage. However, rice storage still faces serious challenges, one of which is postharvest pest infestation that can reduce both the quality and economic value of rice (Atungulu et al., 2019).

One of the major pests of stored rice is the rice weevil (*Sitophilus oryzae* L.) (Jalaeian et al., 2021; Majd-Marani et al., 2023). This pest attacks rice grains in both larval and adult stages by feeding on the internal parts of the grains, particularly carbohydrates. Infestation by *S. oryzae* results in weight loss, reduced nutritional content, product contamination, unpleasant odors, and the formation of holes in the grains (Rahman et al., 2021). Under severe conditions,

heavy infestation can cause the rice to turn into powder. The high reproductive capacity of *S. oryzae*, especially under conditions of grain moisture content above 12%, relative humidity exceeding 70%, and storage temperatures above 27°C, further exacerbates the level of damage during storage (Khanal et al., 2021).

Control of *S. oryzae* is generally carried out using chemical pesticides through fumigation. Although effective, the continuous use of chemical pesticides can lead to various negative impacts, such as environmental pollution, harmful residues in food products, and potential health risks to humans. In addition, chemical pesticides may also kill non-target organisms that play important roles in maintaining ecosystem balance. Therefore, alternative pest control methods that are safer, environmentally friendly, and sustainable are needed.

Botanical pesticides represent one promising alternative, as they are derived from natural plant materials and are relatively safer for both the environment and human health. Indonesia possesses high biodiversity, including various plant species with potential use as botanical pesticides, one of which is breadfruit (*Artocarpus altilis*) (Yuliawati et al., 2023). Breadfruit leaves are known to contain bioactive compounds such as saponins and flavonoids that function as natural insecticides (Kaihena et al., 2023). Saponins can damage the digestive tract of insects, while flavonoids can disrupt the nervous and respiratory systems, ultimately leading to insect mortality (Moniharapon et al., 2019; Moniharapon et al., 2020; Kaihena & Ukratalo, 2021; Moniharapon & Ukratalo, 2021; Aniq & Ayu, 2024).

Previous studies have shown that breadfruit leaves have potential as pest control agents. The application of breadfruit leaf powder at various concentrations has been reported to reduce activity and increase mortality of *S. oryzae* during rice storage (Putri, 2018). However, the utilization of breadfruit leaf powder using a simple and practical application method, such as tea bags, still requires further investigation. The tea bag method is expected to facilitate application, minimize direct contact between the powder and rice, and reduce the risk of residue on food products.

Based on this background, this study aims to evaluate the effectiveness of breadfruit leaf powder (*Artocarpus altilis*) in controlling *Sitophilus oryzae* in stored rice, particularly in terms of mortality, mortality rate, and LD₅₀ value using the tea bag application method.

RESEARCH METHODS

The study was conducted in June 2025 at the Taxonomy Laboratory, Department of Biology, Faculty of Science and Technology, Pattimura University. This research was a laboratory experimental study employing a Completely Randomized Design (CRD) with four treatments and four replications. The treatments consisted of different doses of breadfruit leaf powder (*Artocarpus altilis*), namely 0 g (control), 5 g, 10 g, and 15 g applied to 100 g of rice. Each experimental unit was infested with 20 adult individuals of the rice weevil (*Sitophilus oryzae* L.) to evaluate the effectiveness of the treatments.

The equipment used in this study included tea bags (Daiso tea bag), plastic containers measuring 17.3 × 5.5 cm, a digital scale, knife, scissors, containers, blender, 40-mesh sieve, cutting board, gauze cloth, label paper, magnifying glass, camera, and stationery. The materials

used consisted of mature dark green breadfruit leaves, Bulog rice, and rice weevils (*Sitophilus oryzae* L.).

The study began with the preparation of test insects, rice media, and tea bags containing breadfruit leaf powder. Rice weevils (*Sitophilus oryzae* L.) were obtained from infested rice storage and subsequently reared to obtain adults of uniform age. Rearing was conducted by introducing 50 pairs of adults into plastic jars containing 1.5 kg of rice and storing them for 30 days. Adults that emerged on the same day were used as test insects.

Mature dark green breadfruit leaves (*Artocarpus altilis*) were cleaned and air-dried at room temperature for six days without direct exposure to sunlight. After drying, the leaves were cut into small pieces and ground into powder using a blender, then sieved through a 40-mesh sieve to obtain a uniform particle size. The breadfruit leaf powder was weighed according to the treatment doses, namely 0 g, 5 g, 10 g, and 15 g.

The rice medium used was Bulog rice freshly purchased from a local grocery store. A total of 100 g of rice was weighed for each experimental unit and placed into plastic containers measuring 17.3 × 5.5 cm. The weighed breadfruit leaf powder was placed into tea bags, and one tea bag was added to each container according to the respective treatment.

Subsequently, 20 adult individuals of *S. oryzae* were introduced into each plastic container. The containers were then covered and kept under room conditions throughout the observation period. Observations were carried out daily for 14 days to record the number of dead rice weevils in each treatment.

Observed Parameters

a. Mortality

Mortality was observed daily for 14 days and used as an indicator of the effectiveness of breadfruit leaf powder in controlling rice weevils (Indriyani et al., 2019).

$$\text{Mortality (\%)} = \frac{\text{Number of dead insects}}{\text{Total number of tested insects}} \times 100\%$$

b. Mortality Rate of Rice Weevils (*Sitophilus oryzae* L.)

Mortality rate was recorded daily for 14 days and expressed as the number of dead individuals per day. This parameter was used to determine the speed of the toxic effect of breadfruit leaf powder (Indriyani et al., 2019).

$$V = \frac{T_1N_1 + T_2N_2 + T_3N_3 + \dots + T_zN_z}{n}$$

Where:

V= Mortality rate (individuals/day)

T= Observation day

N = Number of dead insects (individuals)

n = Total number of tested rice weevils (individuals)

c. LD₅₀ (Lethal Dose 50%)

Mortality data at each dose were used to determine the LD₅₀ value, defined as the dose causing 50% mortality of the test population. LD₅₀ was analyzed using probit analysis with SPSS version 31.0.

The data obtained were analyzed using one-way Analysis of Variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$). If significant differences were found, Duncan's New Multiple Range Test (DNMRT) at a 5% significance level was applied.

RESULTS AND DISCUSSION

Mortality of *Sitophilus oryzae*

Based on observations over 14 days, the mortality percentage of *S. oryzae* increased with increasing doses of breadfruit leaf powder. Treatment K1 (0 g) caused no mortality in the test insects (0%), while K2 (5 g) resulted in an average mortality of 15%. Increasing the dose to K3 (10 g) produced an average mortality of 22.5%, and the highest mortality was observed in K4 (15 g) with an average of 50%.

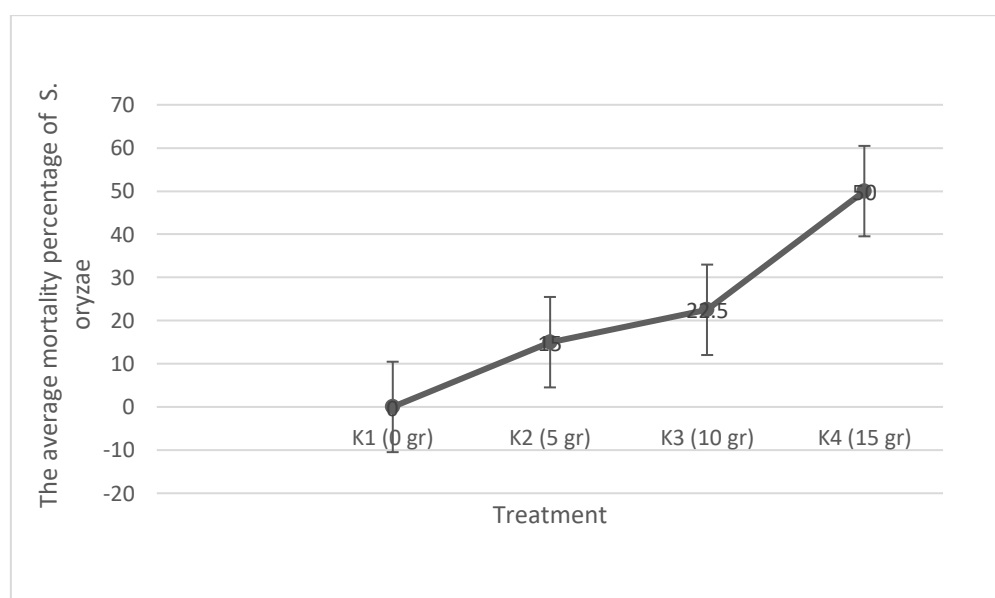


Figure 1. Graph of the average mortality percentage of *S. oryzae* over 14 days of observation

Figure 1 shows that the higher the dose of breadfruit leaf powder applied, the higher the mortality of *S. oryzae*. This indicates that breadfruit leaf powder has potential as a botanical insecticide for controlling rice weevils.

To determine the statistical effect of the treatments, a one-way ANOVA was conducted. The results showed that breadfruit leaf powder treatments had a highly significant effect on *S. oryzae* mortality at the 99% confidence level ($\alpha = 0.01$). To identify differences among treatments, Duncan's Multiple Range Test was performed, as presented in Table 1.

Table 1. Duncan's test results on mortality of *S. oryzae*

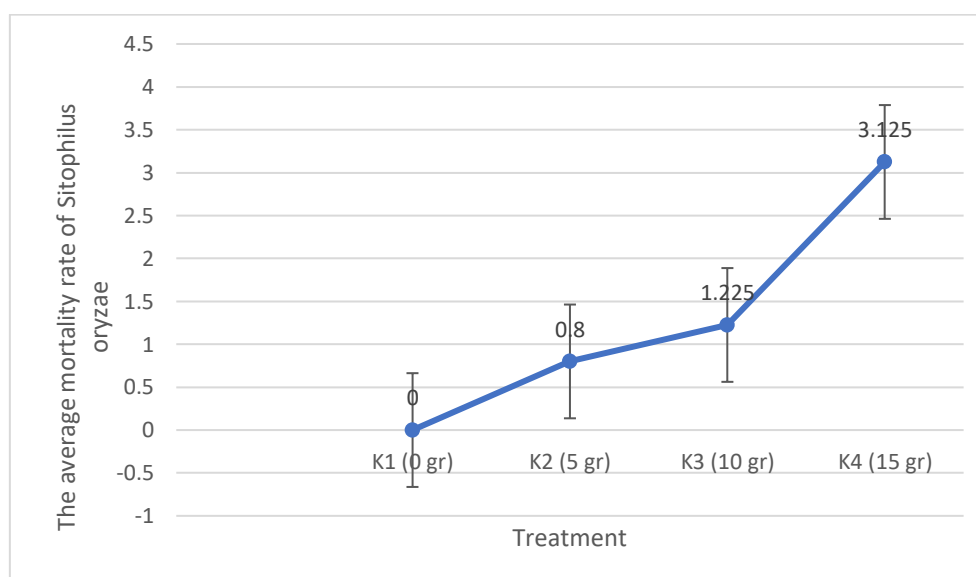
Treatment	Mortality (%)
K1 (0 g)	0,00 ± 0,00 ^c
K2 (5 g)	15,00 ± 10,80 ^{bc}
K3 (10 g)	22,50 ± 12,58 ^b
K4 (15 g)	50,00 ± 12,24 ^a

Note: Values followed by the same letter are not significantly different based on Duncan's Multiple Range Test (DMRT) at a 5% significance level

The Duncan test results showed that mortality in treatment K1 (0 g) was significantly different from K2 (5 g), K3 (10 g), and K4 (15 g). Treatments K2 and K3 were not significantly different from each other, but both differed significantly from K4, which exhibited the highest mortality.

The results of Duncan's multiple range test showed that mortality in treatment K1 (0 g) was significantly different from K2 (5 g), K3 (10 g), and K4 (15 g). Treatments K2 and K3 were not significantly different from each other; however, both were significantly different from K4, which exhibited the highest mortality.

The mortality rate of *S. oryzae* also increased with increasing doses of breadfruit leaf powder. Treatment K1 (0 g) resulted in no mortality (0 individuals/day), while K2 (5 g) produced an average mortality rate of 0.8 individuals/day. Treatment K3 (10 g) resulted in an average mortality rate of 1.225 individuals/day, and the highest was observed in K4 (15 g), with an average of 3.125 individuals/day.

Figure 2. Graph of the average mortality rate of *S. oryzae*

Based on the results of one-way ANOVA, breadfruit leaf powder treatments had a highly significant effect on the mortality rate of *S. oryzae* ($F_{\text{calculated}} = 8.51 > F_{\text{table } 0.01} = 5.95$). Following the ANOVA, Duncan's test was conducted to determine significant differences among treatments, as presented in Table 2.

Table 2. Duncan's test results on the mortality rate of *S. oryzae*

Treatment	Average Mortality Rate
K1 (0 g)	0,00 ± 0,00 ^b
K2 (5 g)	0,80 ± 0,78 ^b
K3 (10 g)	1,23 ± 1,22 ^b
K4 (15 g)	3,13 ± 3,12 ^a

Note: Values followed by the same letter are not significantly different based on Duncan's Multiple Range Test (DMRT) at a 5% significance level

The Duncan test results indicated that treatment K4 (15 g) was significantly different from treatments K1 (0 g), K2 (5 g), and K3 (10 g). Meanwhile, treatments K1, K2, and K3 were not significantly different from each other. Treatment K4 (15 g) exhibited the highest mortality rate compared to the other treatments.

The application of breadfruit leaf powder (*Artocarpus altilis*) in this study was proven to have a significant effect on the mortality of *Sitophilus oryzae*. Increasing the dose of breadfruit leaf powder showed a corresponding increase in mortality, where the highest dose treatment (15 g/100 g rice) resulted in 50% mortality. This indicates that higher doses provide greater amounts of active compounds, thereby enhancing the toxic effects on the test insects. Breadfruit leaves are known to contain various chemical compounds such as saponins, tannins, flavonoids, polyphenols, hydrocyanic acid, acetylcholine, riboflavin, and phenols, which have potential as botanical insecticides (Hutami, 2013). In addition, flavonoid derivatives such as quercetin and artoindonesianin have also been reported to exhibit toxic effects against storage pests (Hutami, 2013).

The observed increase in mortality is consistent with the basic principles of insect toxicology, where higher concentrations of active compounds entering the insect body lead to increased toxicity (Djojsumarto, 2000). These findings are supported by previous studies showing that breadfruit leaf powder can increase the mortality of *S. oryzae* with increasing doses (Putri, 2018). Other studies have also reported that breadfruit leaf extract is effective in increasing insect mortality, although the level of effectiveness varies depending on the formulation used (Sadewo, 2015). This suggests that both powder and extract forms of breadfruit leaves have potential as botanical insecticides, although their effectiveness may be influenced by the application method and formulation.

The mechanism of mortality of *S. oryzae* in this study is presumed to be associated with the activity of secondary metabolites contained in breadfruit leaves. Compounds such as flavonoids, saponins, triterpenoids, tannins, and polyphenols are known to possess insecticidal activity (Novianti, 2011). Flavonoids may act as respiratory toxins by entering through spiracles and disrupting the insect respiratory system, leading to oxygen deficiency (hypoxia) and eventually death (Ismatullah et al., 2014). Meanwhile, saponins act as stomach poisons by damaging epithelial tissues in the digestive tract and inhibiting nutrient absorption (Aniq & Ayu, 2024).

Furthermore, specific compounds such as quercetin and artoindonesianin are also suspected to contribute to the toxic effects. Quercetin may induce oxidative stress that disrupts enzyme function and cellular metabolism, while artoindonesianin may inhibit energy

metabolism (Rao et al., 2010). Although the role of each compound was not directly examined in this study, their combined presence likely works synergistically to cause insect mortality. In addition, contact toxicity may also occur, particularly from saponins and tannins that can penetrate the insect cuticle and disrupt cellular metabolism. Triterpenoids are also known to inhibit cholinesterase enzyme activity, leading to nervous system disorders characterized by continuous muscle contraction, paralysis, and ultimately death (Kurniawan et al., 2013).

In addition to mortality, the mortality rate also showed an increasing pattern with higher doses of breadfruit leaf powder. The highest dose (15 g/100 g rice) resulted in a mortality rate of 3.125 individuals per day, indicating that toxic effects act more rapidly at higher doses. This is associated with the greater amount of active compounds, resulting in more intense interaction with the insect body. This finding is consistent with previous studies showing that increasing doses enhance the toxicity of botanical pesticides (Sadewo, 2015). Similar results have also been reported, indicating increased insect mortality rates at higher doses (Rahmawati, 2018).

The differences in effectiveness are likely influenced by the formulation of the material. In liquid extracts, active compounds are more readily available and quickly absorbed into the insect body, whereas in powder form, the release of active compounds is slower and more limited. However, the use of powder has practical advantages, as it does not require solvents or extraction processes, making it easier to apply at the household level. This is consistent with reports stating that botanical powders generally have moderate effectiveness but remain practical and economical for pest control (Khanal et al., 2021).

The use of tea bags as an application medium in this study also provides advantages, including ease of use and reduced direct contact between the powder and rice, thereby minimizing residue. This is important to maintain rice quality for consumption. However, the characteristics of the tea bag material may also influence the release of active compounds, potentially affecting treatment effectiveness.

From a safety perspective, botanical insecticides are generally biodegradable, relatively safe for humans, and environmentally friendly (Aidah, 2020). The abundance of breadfruit plants in Indonesia also adds value to their utilization as pest control agents (Estalansa et al., 2018). Therefore, breadfruit leaf powder has potential as a simple, safe, and practical alternative botanical insecticide for controlling *S. oryzae*, although its effectiveness is still lower compared to extract forms.

Lethal Dose 50 (LD₅₀)

Based on the probit analysis, the median lethal dose (LD₅₀) of breadfruit leaf powder (*Artocarpus altilis*) against rice weevils (*Sitophilus oryzae* L.) over a 14-day observation period was estimated at 15.717 g per 100 g of rice, with a 95% confidence interval (CI) of 10.803–21.357 g per 100 g of rice. This value indicates that approximately 15.717 g of breadfruit leaf powder per 100 g of rice is required to cause 50% mortality in the rice weevil population under the conditions of this study. The probit analysis results were consistent with the observed mortality data, which showed that the treatment with a dose of 15 g per 100 g of rice resulted in an average mortality rate of 50%. The close agreement between the probit-estimated LD₅₀

and the experimentally observed dose associated with 50% mortality suggests consistency between the statistical model and the observed mortality pattern. However, this agreement should be interpreted cautiously, taking into account variations in mortality among replicates, the number of insects tested, and the goodness of fit of the probit model.

In toxicological studies, the LD_{50} is a parameter used to estimate the dose of a substance required to cause mortality in 50% of a test population under specified experimental conditions and within a defined observation period. In general, when substances are evaluated using comparable methods and experimental conditions, a lower LD_{50} indicates greater acute toxicity, whereas a higher LD_{50} indicates that a larger dose is required to achieve the same level of mortality (Djojsumarto, 2000). Accordingly, the LD_{50} value of 15.717 g per 100 g of rice represents the estimated dose of breadfruit leaf powder required to produce 50% mortality under the conditions of the present study. Nevertheless, this value alone is insufficient to conclude that breadfruit leaf powder has low toxicity or produces a slow-acting toxic effect without appropriate comparative data and additional supporting evidence.

From a biological perspective, the insecticidal activity of breadfruit leaf powder may be associated with the secondary metabolites present in its leaves. Breadfruit leaves may contain various groups of compounds, including flavonoids, tannins, saponins, and other phenolic compounds, depending on the characteristics of the plant material and the extraction or preparation methods used. These compounds may affect insect physiology through different mechanisms, such as disrupting feeding behavior, altering digestive functions, or interfering with specific physiological processes.

CONCLUSION

The application of breadfruit leaf powder significantly affects the mortality of rice weevils. Mortality increases with increasing doses, with the highest mortality (50%) observed at 15 g/100 g of rice. The mortality rate of rice weevils is also influenced by the dose of breadfruit leaf powder. The dose of 15 g/100 g rice resulted in the fastest mortality rate, with an average of 3.125 individuals per day, significantly different from lower doses. The LD_{50} value of breadfruit leaf powder against *S. oryzae* over 14 days was 15.717 g/100 g rice, indicating that a dose close to 15.717 g is required to cause 50% mortality in the test population.

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M.M, M.C.M and D.D.M contributed to designing the study, preparing samples and test materials, conducting the study, analyzing data, writing the manuscript and reviewing the manuscript content.

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Declaration of Interest

The authors declare no conflict of interest.

Data Sharing Statement

The data used in this are available upon reasonable request and in accordance with established procedures.

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