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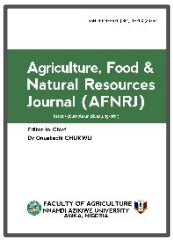

Original Article

Effects of processing methods and botanical protectants on the susceptibility of dried cassava chips to larger grain borer

OPEN ACCESS

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ABSTRACT

The larger grain borer (Prostephanus truncatus Horn) is a destructive storage pest of dried cassava chips in sub-Saharan Africa. This study evaluated the effects of cassava processing methods and a botanical insecticide on adult mortality and postharvest damage of dried cassava chips. Chips were processed using two methods, parboiling and non-parboiling (plain)—and treated with graded concentrations of Zingiber officinale extract (500, 250, 125, and 62.5 µL/mL), alongside a reference insecticide and an untreated control. One hundred grams of each processed and treated sample were infested with ten unsexed adult P. truncatus under laboratory conditions. Adult mortality was recorded at 24, 48, and 72 h, and 7 days after treatment, while weight loss, perforation, and adult emergence were assessed following a 14-day oviposition period and an additional 25-day observation period. Data were analyzed using analysis of variance (ANOVA), and treatment means were separated using least significant difference (LSD) at $P < 0.05$. Results showed that both processing method and Z. officinale concentration significantly influenced adult mortality and damage parameters ($P < 0.05$). At 500 µL/mL, adult mortality reached 100% at 7 DAT, while lower concentration (62.5 µL/mL) resulted in 68–70% mortality. Weight loss and perforation were completely prevented (0.00%) at 250–500 µL/mL, compared to the untreated control (86.33% weight loss and 100% perforation). Parboiled chips showed lower damage at moderate concentration, with reduced weight loss (4.67% vs 10.33%) and perforation (10.00% vs 15.66%) at 125 µL/mL. The findings indicate that combining parboiling with Z. officinale extract is an effective, low-cost postharvest strategy for reducing P. truncatus infestation and preserving the quality of dried cassava chips.

KEYWORDS: *Adult emergence, Parboiling, Perforation index, Postharvest infestation, Stored-product damage*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a key staple in sub-Saharan Africa, providing carbohydrates and income for millions of households. Postharvest losses are common due to rapid deterioration of fresh roots and infestations by storage pests. The larger grain borer (*Prostephanus truncatus* Horn) (Coleoptera: Bostrichidae) is a major pest of dried cassava chips, capable of causing significant quantitative and qualitative losses due to its rapid reproduction and high feeding capacity (Quellhorst *et al.*, 2021).

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While synthetic insecticides can reduce *P. truncatus* populations, their use is constrained by cost, environmental concerns, health risks, and the development of resistance. Consequently, non-chemical alternatives, including botanical extracts, are gaining attention for smallholder postharvest management (Isman, 2020). Plant-based oils and extracts such as *Zingiber officinale* (ginger), *Allium sativum* (garlic), and *Capsicum annuum* (chili pepper) have been reported to possess insecticidal properties, acting via contact toxicity, fumigant effects, or feeding deterrence (Mutungi *et al.*, 2014; Singh *et al.*, 2022).

Processing methods, such as parboiling, can alter the physical and biochemical properties of cassava chips, affecting insect susceptibility by modifying moisture content, tissue hardness, and chemical composition. Evidence suggests that combining botanical treatments with appropriate processing may enhance protection against storage pests (Eze *et al*., 2021).

This study addresses the limited understanding of the combined effects of cassava processing methods and botanical treatments on the susceptibility of dried cassava chips to *Prostephanus truncatus*. While previous studies have independently demonstrated the protective effects of botanical extracts and the influence of processing techniques, there is insufficient information on how these factors interact to influence pest infestation and damage in stored cassava chips.

Therefore, this study aimed to evaluate the interactive effects of parboiling and *Zingiber officinale* extract on the susceptibility of dried cassava chips to *P. truncatus* under laboratory conditions. Specifically, the study assessed the impact of these treatments on adult mortality, weight loss, perforation, and progeny emergence, with a view to identifying an effective and sustainable postharvest management strategy.

MATERIALS AND METHOD

Study Area

The study was conducted at the Department of Parasitology and Entomology, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria (approximately 6°14′–7°08′ N, 6°14′–7°09′ E). The area experiences an annual rainfall of 1,000–1,500 mm with distinct rainy and dry seasons. Ambient laboratory temperature ranged from 25–34 °C with relative humidity between 61–92 %.

Experimental Design

The experiment followed a 2 × 4 factorial design (processing method × extract concentration) arranged in a completely randomized design (CRD) with three replicates per treatment. Treatments consisted of two processing methods (parboiled and plain cassava chips) and four concentrations of *Zingiber officinale* extract (500, 250, 125, and 62.5 µl/ml). Deltamethrin (0.005 µl/ml) served as a reference insecticide, while acetone-treated chips served as the control.

Collection and Extraction of Plant Material

Fresh rhizomes of *Zingiber officinale* were purchased from Eke Awka Market, Anambra State, Nigeria. Approximately 2 kg of rhizomes were washed under running water, peeled, and sliced into thin pieces (~3–5 mm thickness). The slices were shade-dried at ambient temperature (~28 ± 2 °C) for 12 days until a constant weight was achieved. The dried slices were pulverized into a fine powder using an electric grinder.

For extraction, 200 g of powdered rhizome was placed in a Soxhlet apparatus and extracted with 1.5 L of n-hexane for 6 hours (~10–12 extraction cycles). The solvent was removed under reduced pressure using a rotary evaporator at 40 °C to yield the crude extract (~15–18 g). The extract was stored in airtight amber containers at room temperature (25 ± 2 °C) until use.

Cassava Processing

A total of 20 kg of fresh cassava tubers were peeled, washed, and cut into cubes of 2–5 cm. Two processing methods were applied. For parboiling, cassava cubes were boiled for 2 minutes at approximately 100 °C in a 1:3 (w/v) cassava-to-water ratio. For oven-drying (plain), cassava cubes were dried immediately after peeling in a hot-air oven at 70 °C for 24 hours. After processing, all cassava chips were equilibrated under ambient laboratory conditions for two weeks to standardize moisture content before use in experiments.

Collection and Culture of Insect

Adults of *Prostephanus truncatus* were collected from dried cassava chips purchased at Eke Awka market. To eliminate pre-existing infestations, the chips were disinfested by refrigeration at 4 °C for three days. Disinfested chips were transferred into 2 kg transparent plastic containers and artificially infested with adult *P. truncatus*. The insects were allowed to oviposit for 10 days, after which all adults were removed. Containers were maintained under ambient laboratory conditions for 30 days to allow F_1 progeny development. Newly emerged F_1 adults (approximately 15 days old) were used for susceptibility experiments.

Susceptibility of Dried Cassava Chips to *Prostephanus truncatus*

One hundred grams of each processed cassava chip type were treated with 2 ml of *Z. officinale* extract at the specified concentrations. Treated chips were air-dried for 1 h to allow complete evaporation of acetone. Ten unsexed F_1 adults of *P. truncatus* were introduced into each plate, which was covered with muslin cloth and secured with rubber bands. Adult mortality was recorded at 24, 48, and 72 h, and at 7 days post-introduction.

Progeny Development, Weight Loss, and Perforation Assessment

After the mortality assessment period, all surviving adults were removed, and the chips were maintained for an additional 25 days to allow progeny development. Damage was assessed using count-and-weigh methods. Parameters recorded included

percentage weight loss, percentage perforation, and number of emerged adults.

Percentage of cassava chips perforated was calculated thus:

$$\% \text{ of perforated chips} = \left\{\frac{Number\ of\ cassava\ chips\ perforated}{Total\ number\ of\ cassava\ chips} \times \frac{100}{1}\right\} \quad (1)$$

$$\% \text{ Weight loss} = \left\{\frac{initial\ weight\ of\ sample - final\ weight\ of\ sample}{Initial\ weight\ of\ sample} \times \frac{100}{1}\right\} \quad (2)$$

Methods were adapted from Ukonze et al. (2019).

Data Analysis

Data on mortality, perforation, and weight loss were subjected to one-way ANOVA using GenStat 9.2. Treatment means were separated using least significant difference (LSD) at $P < 0.05$. Probit analysis was used to estimate LD50 values (Finney, 1971).

RESULTS AND DISCUSSION

Table 1 shows that processing method did not significantly affect adult mortality of *Prostephanus truncatus* at the concentrations and exposure periods tested ($P > 0.05$), indicating that mortality was primarily influenced by the concentration of *Zingiber officinale* extract, which had a highly significant effect ($P < 0.05$). Higher doses of the extract (250 and 500 µL/mL) caused consistently high adult mortality in both parboiled and plain cassava chips. Similar effects of botanical concentration driving insect mortality have been reported for plant extracts with known bioactive compounds, where efficacy is largely determined by dose rather than substrate differences (Isman, 2020).

The similar mortality levels observed between processing methods suggest that parboiling did not interfere with the insecticidal action of the ginger extract. Bioactive constituents of *Z. officinale*, such as gingerols and shogaols, have demonstrated both contact and fumigant toxicity against stored-product insects, and these modes of action are less dependent on the physical properties of the treated commodity (Regnault-Roger et al., 2012; Guru et al., 2022). This explains why the effectiveness of *Z. officinale* extract against *P. truncatus* was not significantly affected by changes in cassava chip texture due to processing.

Table 1. Effect of processing methods and concentration of *Zingiber officinale* extract on percentage mortality of *Prostephanus truncatus* adults

Concentration (ul/ml)	Processing method	24hrs	48hrs	72hrs	7DAT
500	plain	92.33	97.33	100.00	100.00
	parboiled	90.00	93.33	98.33	100.00
250	plain	85.00	88.00	93.33	100.00
	parboiled	89.00	90.67	91.67	100.00
125	plain	45.00	55.33	74.33	98.30
	parboiled	43.33	58.33	78.33	100.00
62.5	plain	7.33	13.00	38.33	68.00
	parboiled	10.00	12.00	40.33	70.00
0.00	plain	0.00	0.00	0.00	0.00
	parboiled	0.00	0.00	0.00	0.00
0.005	plain	100.00	100.00	100.00	100.00
	parboiled	98.33	100.00	100.00	100.00
LSD(0.05)		NS	NS	NS	NS

Table 2 indicates that processing method significantly affected weight loss in dried cassava chips treated with *Zingiber officinale* extract ($P < 0.05$). Parboiled chips generally showed significantly lower weight loss compared to plain chips at the same extract concentrations, which aligns with evidence that heat and moisture treatments such as parboiling change the physical structure of stored products, making them less attractive or accessible to pests (FAO, 2024).

The concentration of *Z. officinale* extract also had a highly significant effect on weight loss ($P < 0.05$), with higher concentrations (250 and 500 µL/mL) effectively preventing weight loss. Similar dose-dependent insecticidal effects have been observed for ginger essential oil and its bioactive components against stored-product insects, where higher concentration treatments significantly reduced feeding and related damage (Olufemi-Salami et al., 2024).

Lower concentrations (62.5 and 125 µL/mL) offered only partial protection, with plain chips showing slightly higher weight loss than parboiled chips. This pattern indicates that both extract concentration and chip processing significantly influence susceptibility to insect feeding and weight loss, with parboiling modifying chip characteristics in a way that may reduce pest impact.

Table 2: Effect of processing methods and concentration of *Zingiber officinale* extract on percentage weight loss of dried cassava chips

Concentration (ul/ml)	Processing method	%Weight loss
Z. officinale (500)	Plain	0.00
	Parboiled	0.00
Z. officinale (250)	Plain	0.00
	Parboiled	0.00
Z. officinale (125)	Plain	10.33
	Parboiled	4.67
Z. officinale (62.5)	Plain	16.33
	Parboiled	11.00
Z. officinale (0.00)	Plain	86.33
	Parboiled	80.83
Deltamethrin (0.005)	Plain	0.00
	Parboiled	0.00
LSD (0.05)		4.261

The effectiveness of *Zingiber officinale* extract in limiting chip perforation was highly concentration-dependent ($P < 0.05$). Higher concentrations (250–500 µL/mL) resulted in a marked reduction in perforated chips, indicating enhanced insecticidal and/or repellent activity, while lower concentrations (62.5 µL/mL) were less effective, allowing substantial feeding damage comparable to the untreated control. This aligns with previous reports demonstrating dose-dependent effects of ginger and other botanical extracts against stored-product insects (Mutungi *et al*., 2014; Singh *et al*., 2022).

The reference insecticide completely prevented chip perforation, confirming the reliability and sensitivity of the experimental setup. Overall, the combined use of parboiling and higher concentrations of *Z. officinale* extract showed a synergistic effect, significantly reducing damage caused by *P. truncatus*. These results support the concept that integrating botanical treatments with appropriate processing methods enhances protection against storage pests, as observed in other studies on cassava and cereal grains (Yang *et al*., 2020; Eze *et al.*, 2021).

Table 3. Effect of processing methods and concentration of *Zingiber officinale* extract on percentage perforation of dried cassava chips

Concentration (ul/ml)	Processing method	% Perforation
Z. officinale (500)	Plain	0.00
	Parboiled	0.00
Z. officinale (250)	Plain	0.00
	Parboiled	0.00
Z. officinale (125)	Plain	15.66
	Parboiled	10.00
Z. officinale (62.5)	Plain	26.67
	Parboiled	18.83
Z. officinale (0.00)	Plain	100.00
	Parboiled	100.00
Deltamethrin (0.005)	Plain	0.00
	Parboiled	0.00
LSD (0.05)		4.68

CONCLUSION AND RECOMMENDATIONS

This study shows that the susceptibility of dried cassava chips to *Prostephanus truncatus* is significantly influenced by both processing method and *Zingiber officinale* extract concentration. Parboiling slightly reduced weight loss and perforation, while higher extract concentrations (250–500 µL/mL) effectively minimized insect damage, demonstrating ginger's potential as a safe, environmentally friendly postharvest treatment. For smallholder farmers, combining parboiling with *Z. officinale* extract offers a practical strategy to reduce losses, particularly where synthetic insecticides are unavailable or undesirable. Future studies should evaluate its long-term efficacy and compatibility with improved storage systems to enhance cassava preservation.

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Authors' Contributions

MEO conceived the study, carried out the experiments, analyzed and interpreted the data, and wrote the first draft of the manuscript. IU assisted with data analysis and contributed to the technical review of the manuscript. JNO supervised the research. ENN, CCI, KCE, and AFE critically reviewed the manuscript for intellectual content. MNE assisted in data collection. All authors read and approved the final version of the manuscript.

Ethical Statement

This study did not involve human participants or vertebrate animals. All experimental procedures were conducted in accordance with institutional guidelines for laboratory research on insects and stored agricultural products**.**

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