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Rhyzopertha dominica (Fab.) (Bostrichidae: Coleoptera) susceptibility to fumigant and contact toxicity of *Secamone afzelii* extracts as food grains preservatives

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ABSTRACT

The study aims to investigate the ability of *Secamone afzelii* extracts to protect wheat grains against *Rhyzopertha dominica* infestation. Fumigant and contact bioassay were carried out, as 20 g of disinfected wheat was treated with 50, 100, 150 and 200 µL in triplicate of different extracts of *S. afzelii*, at different times of exposure. Contact toxicity on adult mortality increased as concentration and exposure time increased. Mortalities were 22.06% - 28.45%, 26.78% - 30.59%, 28.45% - 43.68% and 29.87% - 49.43% at 48 h' exposure, as concentration increased. At 48 and 72 h, the highest mortality was achieved by acetone extracts at 150 µL (30.46% and 36.63% respectively) and 200 µL (34.20% and 37.05% respectively) concentration for fumigant toxicity. Extracts of *S. afzelii* significantly ($p < 0.05$) reduce loss in grains weight and emergence of *R. dominica*. In the contact bio-assay, lowest LC50 (Lethal Concentration 50) toxicity on *R. dominica* was achieved with *S. afzelii* ethyl acetate extract at 24 and 48 h exposure (171.0 µL and 233.6 µL) respectively. Meanwhile, the acetone extract had the least LC50 (276.4 µL and 327.7 µL, respectively) in the fumigant bioassay. The present study indicates that these extracts can safeguard stored grains from insect pest infestations and damage.

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1. Introduction

Insect infestation remains one of the main sources of postharvest deterioration of stored agricultural Produce, leading to significant losses in both quality and quantity after harvesting.

This negatively affects the market value, nutritional composition, and germinative potential of stored grains

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(1). Globally, insect infestation accounts for approximately 5–10% loss of stored grains in temperate regions and up to 20–30% in tropical regions, resulting in annual economic losses estimated at about $4 billion (2). Sch losses pose a grave challenge to food sufficiency and security, particularly in developing nations where dependence on stored grains is high.

Rhyzopertha dominica (F.) (Bostrichidae: Coleoptera), is one of the most destructive stored produced insect pests, including wheat, maize, rice, and dried cassava chips (3,4). It is regarded as an important internal feeder and a primary stored grains insect pest, because both adult and larval stages cause extensive damage (5). Infestation by *R. dominica* results in severe quantitative and qualitative grain losses (6), as the insect feeds primarily on the germinal region of grains, thereby reducing seed viability, germination potential, and seed vigor, leading to considerable economic loss (7). In addition, infestation causes deterioration in nutritional quality (8) and adversely affects the organoleptic and aesthetic properties of stored cereal grains (9).

Synthetic insecticides and fumigants have traditionally been the primary means of controlling insect infestations in stored food grains because of their effectiveness against storage pests. However, despite their widespread use and effectiveness, repeated and prolonged application of synthetic insecticides has created several serious challenges, including ozone depletion (10), pest resurgence (11), development of genetic resistance in insect populations (12), deadly effects on non-target organisms (13), contamination risk to users during application (14), chemical residues in food products (15), environmental pollution, and associated health hazards (16). These concerns have raised increasing questions about the long-term sustainability of relying solely on synthetic chemical control methods.

In response to these challenges, recent research has increasingly focused on plant-derived insecticides as safer and environmentally sustainable alternatives for stored-product protection. Various plant materials have demonstrated insecticidal, ovicidal, larvicidal, antifeedant, and repellent activities against several storage insect pests, while also being ecological and usually less harmful to the environment and humans (17,18). However, although numerous studies have investigated the insecticidal potential of different botanical extracts, many previous studies have focused mainly on commonly studied pesticidal plants, while limited attention has been given to underutilized indigenous plant species with potentially strong bioactive compounds. In particular, there is inadequate scientific evidences on *Secamone afzelii* insecticidal efficacy against major insect pests of stored-product such as *R. dominica*. Furthermore, few studies have simultaneously evaluated both fumigant and contact toxicities of this plant species against this economically important pest.

Therefore, there is a need to investigate alternative botanical resources that are locally available, environmentally friendly, cost-effective, and capable of reducing dependence on synthetic insecticides in grain storage. The current study was designed to evaluate the fumigant and contact insecticidal capability of *S. afzelii* extracts against *R. dominica* as a potential control alternative. The discoveries from this research may contribute to the advance of safer botanical insecticides

for stored grain protection, reduce postharvest losses, improve food security, and provide farmers with sustainable pest management options.

The innovation of this study lies in being among the few investigations to evaluate *S. afzelii*, a relatively underexplored indigenous plant species, for *R. dominica* management. In addition, the study provides a comparative assessment of both fumigant and contact toxicological effects of the plant extract, thereby generating new scientific knowledge that may support the development of eco-friendly, plant-based bioinsecticides for sustainable stored-product pest management.

2. Materials and Methods

2.1. Materials

Analytical grade Hexane, Ethyl acetate, Acetone and Methanol manufactured by Avondale Laboratories Limited, England, electric blender (Binatone model, Japan), rotary evaporator (Rotavapor R-IIA (Buchi) Switzerland), vial bottles, refrigerator (Royal, China), Whatman's No. 1 filter paper, sieve, plastic containers, muslin cloth, electric oven, Petri dish and desiccator, micro pipette, glass rod, micropipette (Eppendorf, England)

2.2. Rearing of *R. dominica*

Rhizopertha dominica collected from infested grains was maintained on wheat grains (*Titricum aestivum* (L.) at 32± 2°C and RH 80 ± 5% in the Entomology Laboratory, Department of Crop, Soil and Pest Management Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria. About 250 g of wheat was infested with thirty adult insects in plastic containers protected with a muslin cloth to permit oviposition and adult emergence under laboratory temperature and humidity environment at 12 h dark/light photoperiods to get adult insects of same aged (2- 4 days old) used in the bioassays.

2.3. Collection and preparation of *S. afzelii*

Vines of *S. afzelii* that were collected from Ipe Akoko and Ondo farmstead in Ondo State, Nigeria, were placed in aseptic black polythene packs and transported to the Forestry and Environment Management Department, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria were the plant identity was confirmed. The plant leaves were detached, rinsed with clean water and air-dried on a laboratory bench at prevailing temperature and relative humidity. The brittle dried leaves were then milled into powder with electric blender (Binatone model, Japan). Thereafter, the powder was sifted with a 0.25 mm mesh sieve to get a fine homogeneous powder. For 48 h, 500 mL of hexane, ethyl acetate, acetone, and methanol (analytical grade, England) were used to soak about 300 g of *S. afzelii* powder in cold extraction. Whatman's No. 1 filter paper was used to filter the final extracts (19). To render it solvent-free, the solvent from the crude extracts was concentrated and evaporated in a rotary evaporator (Rotavapor R-IIA (Buchi) Switzerland) at low pressure and below 60°C (20). For later insecticidal actions by contact and fumigant toxicity, the crude extracts were kept in vial bottles and refrigerated.

2.4. Contact and fumigant toxicity of *S. afzelii* extracts against *R. dominica*

Clean wheat grainss used for the experiment were bought from traditional food grains vendors at Oja-Oba, Owo. To ensure that only intact, uninfested seeds were selected, the seeds were thoroughly sieved and

handpicked. Nevertheless, the seeds were spread out on the laboratory bench to cool down and prevent mouldiness after being sterilised in an electric oven to eliminate any immature stage or concealed infestations. For the contact and fumigant bioassay, 20 g of the disinfected wheat were then weighed into each Petri dish and desiccator respectively.

Using a micro pipette, 20 g of disinfected wheat seeds were treated in triplicate with 50, 100, 150 and 200 µL of different extracts of *S. afzelii* in 250 mL plastic dishes to test for contact toxicity. The After thoroughly mixing the treated seeds with a glass rod to ensure that the extracts were evenly mixed with the seeds, the seeds were left to air dried for approximately half an hour (21). Ten unsexed adult *R. dominica* that were 2-4 days old were added to each Petri dish containing treated wheat seeds following the solvent vaporisation. Additionally, a control treatment with untreated seeds was used.

In a different experiment, the fumigant activity of *S. afzelii* extracts was tested on ten unsexed adult *R. dominica* that were 2-4 days old and exposed to varying concentrations (50 - 200 µL) in 0.85-l L desiccators that contained 20 g of wheat seeds that served as the fumigation chambers under ambient laboratory conditions. A Whatman No. 1 filter circle, measuring 9 centimetres, was used as an evaporating surface for injecting extracts using Eppendorf micropipette. For each extract concentration, there were Three replicates of each extract concentration were used for each dose, along with an equal number of control treatments that contains untreated seeds.

Adult mortality data were detected and recorded at 24, 48, 72, 96 and 120 h afterward infestation when insects failed to respond to sharp object probing (22). Insects were deemed dead when leg or antenna did not move. Abbott's formula (23) was used to calculate and correct mortality. After the observation of adult mortality, both dead and surviving insects (if any) were removed seven days after infestation, and the experiment was left unobstructed on the work benches of the laboratory till the appearance of the next generation. was counted daily After 40 days of initial infestation, the number of emerging adult insects was counted daily till 45 days in both treated and control group. The percentage reduction in adult emergence was calculated using this formula: to determine the.

% Reduction in the emergence of adults =

$$\frac{No.\,of\ emerged\ adult\ from\ control\ dish - No.\,of\ emerged\ adult\ from\ treated\ dish}{No.\,of\ emerged\ adult\ from\ control\ dish} \ x\ 100$$

After 45 days of infestation, the weight loss of wheat in the treated and control groups was determined using Parkin's (24) formula on a fresh weight:

$$\frac{WI - W}{WI}\ X\ 100$$

Where *W* is the weight of the grains at the completion of the experiment, and *W1* is the weight of the grains prior to the experiment.

2.4. Statistical analysis

Data in percentage were arcsine transformed before analysis. The data analysis was executed using analysis of variance, and where treatment means was significant, these were compared at 0.05 level of significance by Tukey's honest significance difference test using the SPSS statistical software package (SPSS, ver. 21.0; Chicago, IL, USA).

3. Results

The contact toxicity of *S. afzelii* extracts on *R. dominica* adult mortality is shown in Table 1.

Table 1. Contact toxicity of *Secamone afzelii* extracts on *R. dominica* adult mortality

		Concentration (μl)			
Hours	**Extracts**	**50**	**100**	**150**	**200**
24	Acetone	14.30 ±7.80a	22.79 ±1.45a	30.00 ±0.00b	33.00 ±2.30b
	Methanol	14.30 ±7.80a	20.36 ±6.10a	22.79 ±1.20a	24.88 ±1.30a
	Ethyl acetate	22.79 ±6.10b	25.92 ±1.45a	47.75 ±1.30c	57.73 ±0.33c
	Hexane	14.18 ±7.80a	22.55 ±0.88a	28.45 ±6.10b	32.20 ±0.67b
48	Acetone	22.22 ±0.08a	28.67 ±6.10ab	33.21 ±0.33b	35.06 ±1.20b
	Methanol	22.06 ±5.77a	26.78 ±0.67a	28.45 ±0.67a	29.87 ±6.10a
	Ethyl acetate	28.45 ±6.10b	30.59 ±1.50b	43.68 ±3.33c	49.43 ±0.33c
	Hexane	22.63 ±1.20a	28.32 ±6.10a	32.20 ±1.20b	34.57 ±6.10b
72	Acetone	28.11 ±0.33a	32.27 ±6.10b	35.18 ±1.03a	36.63 ±1.20b
	Methanol	27.97 ±0.06a	31.11 ±0.07a	32.27 ±1.20a	33.09 ±6.10a
	Ethyl acetate	32.27 ±1.06b	33.77 ±6.10c	36.75 ±7.80a	44.66 ±1.15c
	Hexane	28.38 ±0.33a	32.14 ±6.10b	34.57 ±7.80a	36.09 ±0.03b
96	Acetone	32.01 ±1.20a	34.88 ±2.31a	36.75 ±6.10a	37.23 ±1.80b
	Methanol	31.88 ±0.58a	33.89 ±1.73a	34.88 ±2.30a	35.61 ±0.01a
	Ethyl acetate	34.57 ±2.31a	35.49 ±2.89a	37.29 ±0.12a	41.90 ±0.58c
	Hexane	32.14 ±0.08a	34.51 ±0.01a	35.97 ±2.89a	37.41 ±0.33b
120	Acetone	34.45 ±2.31a	35.55 ±0.29a	37.29 ±0.12a	37.58 ±6.10ab
	Methanol	34.33 ±0.19a	35.55 ±0.06a	36.16 ±0.09a	36.63 ±1.15a
	Ethyl acetate	35.97 ±2.89a	36.81 ±0.01a	37.58 ±0.29a	40.34 ±0.11b
	Hexane	34.51 ±2.89a	35.97 ±2.89a	36.81 ±1.15a	37.70 ±1.15ab
	Control	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Using p>0.005, there is no significant difference between the means with the same alphabet down the column.

Table 2. Fumigant toxicity of *Secamone afzelii* extracts on adult mortality of *R. dominica*

		Concentration (µL)			
Hours	**Extracts**	**50**	**100**	**150**	**200**
24	Acetone	0.00 ±0.00a	14.70 ±1.15a	25.40 ±0.23c	30.26 ±0.12c
	Methanol	0.00 ±0.00a	14.30 ±0.17a	22.79 ±1.15bc	21.05 ±0.03a
	Ethyl acetate	14.30 ±0.88b	14.77 ±0.33a	17.36 ±0.17a	19.28 ±0.33a
	Hexane	0.00 ±0.00a	20.36 ±0.03b	20.44 ±0.25b	23.19 ±0.33b
48	Acetone	8.13 ±0.33a	21.89 ±0.60a	30.46 ±0.23a	34.20 ±1.34a
	Methanol	10.78 ±0.58a	21.56 ±0.29a	28.59 ±0.33a	30.52 ±0.17a
	Ethyl acetate	22.22 ±0.13b	23.50 ±0.29b	25.55 ±2.89a	27.42 ±1.15a
	Hexane	26.99 ±3.46b	27.13 ±0.08c	27.69 ±1.15a	30.59 ±2.89a
72	Acetone	18.72 ±0.33a	31.24 ±0.58a	36.63 ±1.15a	37.05 ±0.60a
	Methanol	20.96 ±2.89a	31.05 ±0.03a	33.77 ±1.73a	34.76 ±2.31a
	Ethyl acetate	30.13 ±0.08b	33.27 ±1.73a	33.58 ±0.51a	34.08 ±2.31a
	Hexane	34.29 ±0.60b	34.63 ±0.33a	35.00 ±0.00a	35.00 ±1.15a
96	Acetone	25.62 ±2.88a	34.08 ±2.31a	37.05 ±4.07a	37.76 ±0.03a
	Methanol	27.20 ±0.12ab	34.14 ±2.39a	36.69 ±3.46a	37.29 ±1.15a
	Ethyl acetate	33.27 ±1.73ab	36.09 ±0.05a	37.05 ±0.03a	39.29 ±0.72a
	Hexane	35.79 ±2.89b	36.51 ±0.29a	37.64 ±1.15a	40.05 ±0.03a
120	Acetone	31.05 ±3.17a	36.15 ±0.09a	37.76 ±1.15ab	39.93 ±0.04a
	Methanol	32.08 ±1.20a	36.51 ±0.29a	37.41 ±0.24a	41.03 ±0.59a
	Ethyl acetate	35.49 ±2.89a	37.41 ±5.78a	40.15 ±0.09bc	45.80 ±0.24b
	Hexane	38.00 ±4.62a	40.46 ±0.27a	42.25 ±0.14c	47.70 ±1.56b
	Control	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Using p>0.005, there is no significant difference between the means with the same alphabet down the column.

Table 3. Effects of *S. afzlii* extracts on the adult emergence reduction of *R. dominica* and weight loss

		Concentration (µL)			
Contact toxicity	**Extracts**	**50**	**100**	**150**	**200**
% Reduction in adult emergence	Acetone	68.66 ±1.73b	73.40 ±0.23b	75.24 ±2.89b	76.26 ±0.58d
	Methanol	70.69 ±2.89b	71.95 ±0.03b	73.40 ±0.23b	81.39 ±1.65e
	Ethyl acetate	66.25 ±0.14b	66.84 ±3.46b	67.40 ±1.15b	69.24 ±0.58b
	Hexane	67.40 ±2.30b	70.11 ±2.89b	70.69 ±2.89b	71.95 ±0.03c
	Control	00.00 ±0.00a	00.00 ±0.00a	00.00 ±0.00a	00.00 ±0.00a
% weight loss	Acetone	9.12 ±0.07ab	6.10 ±1.73a	5.28 ±0.16a	2.97 ±0.12a
	Methanol	7.39 ±0.17a	6.06 ±0.61a	5.84 ±0.58a	3.19 ±0.11a
	Ethyl acetate	8.58 ±1.73ab	5.95 ±0.58a	4.86 ±1.15a	3.49 ±0.01a
	Hexane	9.56 ±1.15ab	5.42 ±1.15a	5.19 ±0.06a	3.49 ±0.86a
	Control	12.70 ±0.98b	12.70 ±0.98b	12.70 ±0.98b	12.70 ±0.98b
Fumigant toxicity	**Extracts**	**50**	**100**	**150**	**200**
% Reduction in adult emergence	Acetone	28.86 ±5.00c	36.22 ±8.00c	37.46 ±0.98b	54.40 ±3.60bc
	Methanol	25.85 ±4.10c	30.75 ±1.80bc	58.80 ±6.40c	66.87 ±2.40c
	Ethyl acetate	17.27± 2.60b	23.69 ±4.6b	32.60 ±3.60b	81.27 ±1.98d
	Hexane	10.74 ±1.30b	28.86 ±2.70b	36.05 ±1.04b	51.49 ±6.60b
	Control	0.00 ±0.00a	0.00 ±0.00a	0.00 ±0.00a	0.00 ±0.00a
% weight loss	Acetone	10.01 ±1.16b	8.68 ±2.31b	6.75 ±3.46b	5.23 ±3.48b
	Methanol	9.88 ±0.58b	7.89 ±1.73b	7.05 ±2.31b	5.61 ±2.89b
	Ethyl acetate	10.57 ±2.31b	6.49 ±0.28b	6.97 ±1.15b	5.90 ±2.89b
	Hexane	10.14 ±0.08b	6.51 ±2.31b	6.29 ±2.89b	5.41 ±0.24b
	Control	11.20 ±1.84a	11.20 ±1.84a	11.20 ±1.85a	11.20 ±1.85a

Using p>0.005, there is no significant difference between the means with the same alphabet down the column.

Table 4. LC50 of *Secamone afzelii* extracts on *R. dominica* at 24 and 48 h of exposure

		Concentration (µL)	
	Solvent	**24 h**	**48 h**
Contact	Acetone	495.6	744.9
	Methanol	1101.6	1582.1
	Ethyl acetate	171.0	233.6
	Hexane	555.2	920.9
Fumigant	Acetone	276.4	327.7
	Methanol	371	472.1
	Ethyl acetate	2506.7	2734.9
	Hexane	385.2	3016.4

At 24 h of introduction, mortality recorded in 50 µL extract (22.79%) was considerably different ($p < 0.05$) compared to other extracts. Meanwhile, no noticeable difference ($p > 0.05$) among 100 µL extracts, but there was a strikingly difference ($p < 0.05$) in mortality at 150 µL and 200 µL concentrations of the extracts.

As concentration increased, mortalities were 22.06% - 28.45%, 26.78% - 30.59%, 28.45% - 43.68% and 29.87% - 49.43%, respectively, at 48 h exposure. At 72 h exposure, there was no considerable difference ($p > 0.05$) in observed mortality between 150 µL of extracts. Likewise, there was no significant difference ($p > 0.05$) in mortality achieved by the extracts for 96 and 120 h exposure in grains treated with 50, 100 and 150 µL extract concentrations (Table 1).

Table 2, shows the fumigant effects of 50 µL of *Secamone afzelii* extracts on *R. dominica* was 0.00% mortality at 24 h, except ethyl acetate (14.30%). At 48 and 72 h, the highest mortality was achieved by acetone extracts at 150 µL (30.46% and 36.63% respectively) and 200 µL (34.20% and 37.05% respectively) concentration. There was a noticable difference ($p < 0.05$) in mortality recorded amongst acetone extract (25.62%) and hexane extract (35.79%) in 50 µL concentration, at 96 h. At 120 h, the mortality in 50 µL was 31.05% - 38.00%, 100 µL (36.15% - 40.46%), 150 µL (37.41% - 42.25%) and 200 µL (39.93% - 47.70%).

Secamone afzeli extracts contact toxicity on the percentage reduction of adult emergence of *R. dominica* was considerably different ($p < 0.05$) between solvents used at 200 µL (Table 3). was Also, significant weight loss ($p < 0.05$) was recorded due to contact toxicity in extracts treated dishes compared to the control. In fumigant toxicity, the acetone extract had the highest adult emergence percentage reduction in 50 and 100 µL concentrations (28.86% and 36.22%). No significant weight loss ($p > 0.05$) was recorded among the solvent extracts, but they were noticeably different ($p < 0.05$) after the weight loss in the control.

In the contact bioassay, the lowest LC50 of *S. afzelii* on *R. dominica* was achieved with ethyl acetate for both 24 and 48 h of exposure (171.0 µL and 233.6 µL, respectively). Meanwhile, the acetone extract had the lowest LC50 (276.4 µL and 327.7 µL, respectively) in the fumigant bioassay (Table 4).

4. Discussion

The current study established that extracts of *S. afzelii* possess considerable contact and fumigant insecticidal activity against *R. dominica*, demonstrating its probable as an active botanical protectant for stored wheat. Although adult mortality at lower concentrations did not always reach high lethal levels, the extracts significantly suppressed progeny development, reduced population build-up and minimized grain weight loss, indicating substantial protective efficacy. The observed toxicity may be attributed to the volatile and lipophilic nature of phytochemical constituents, which enhance penetration through the insect cuticle and disrupt physiological processes. Similar findings were reported by Khani et al. (25), who demonstrated that essential oils of peppermint and black pepper exhibited strong insecticidal activity against *Sitophilus oryzae* through volatile compounds capable of penetrating insect tissues and interfering with metabolic activities. This observation also agrees with Rajendran and Sriranjini (2), who reported that plant-derived fumigants represent promising alternatives to synthetic fumigants because of their rapid penetration and high bioactivity against stored-product insect

pests. Similarly, Shaaya et al. (26) demonstrated that plant essential oils possess both fumigant and contact toxicity against several economically important stored-product insects, further supporting the insecticidal potential of volatile phytochemicals.

The insecticidal efficacy of *S. afzelii* extracts against *R. dominica* showed a clear concentration and exposure time-dependent relationship, with mortality increasing significantly as extract concentration and exposure period increased. Such dose-response relationships are characteristic of botanical insecticides and suggest cumulative physiological toxicity with prolonged exposure. Comparable discoveries were reported by Ishtiaq et al. (27), who observed progressive increases in mortality of *R. dominica* when exposed to extracts of *Nicotiana tabacum*, *Piper nigrum*, *Zingiber officinale*, and *Curcuma longa* with higher concentrations consistently producing stronger insecticidal effects. Comparable concentration-dependent toxicity was also reported by Pala and Pathipati (18), who demonstrated that botanical extracts caused significant mortality against major stored-product insect pests, with toxicity increasing progressively with dosage and exposure duration. Adesina et al. (28) similarly reported increasing larvicidal activity of *Clerodendrum capitatum* extracts against *Dermestes maculatus* with increasing concentration and prolonged exposure time. These findings collectively indicate that *S. afzelii* exhibits insecticidal characteristics consistent with other effective plant-derived insecticides.

The mortality detected in this study may be due to the extract vapours entering the insect body through spiracles and interfering with respiration, thereby causing suffocation and eventual death. Rotimi et al. (29) similarly reported that bioactive plant extracts caused significant mortality across developmental stages of *Anopheles gambiae*, suggesting disruption of essential physiological functions. Schoonhoven (30) demonstrated that vegetable oils may physically obstruct spiracles of storage insects, leading to respiratory blockage and asphyxiation. This mechanism is further buttressed by Lee et al. (10), who noted strong fumigant potential of 1,8-cineole and essential oils against major insect pests of stored grain. Similar observations were reported by Rozman et al. (31), who demonstrated significant toxicity of naturally occurring plant compounds against *R. dominica* and other stored-product insect pests, confirming the susceptibility of stored grain insects to volatile botanical compounds. Mortality may also be associated with disruption of the octopaminergic nervous system, as Enan (32) reported that essential oils interfere with octopamine receptor activity in insects, leading to nervous system failure. Similar neurotoxic activity of essential oils against *Sitophilus zeamais* was also demonstrated by Chaubey (33), confirming that botanical insecticides may exert both respiratory and neurological toxic effects.

Between the solvent extracts evaluated, ethyl acetate proved most effective as a contact insecticide across all concentrations, whereas acetone extract demonstrated comparatively higher activity at concentrations above 100 µL. Under fumigant bioassay conditions, hexane extract showed better activity at lower concentrations while acetone extract performed better at higher concentrations. These observations highlight the important effect of solvent volatility and polarity on extraction efficiency and insecticidal performance.

Similar explanations were described by Adesina et al. (22), who demonstrated that fractions of *Bridelia micrantha* extracted using different solvents differed significantly in biofumigant activity against stored grain insect pests. Wakeel et al. (34) also showed that solvent polarity significantly influences phytochemical yield up to 25–40%, affecting biological activity, while Iloki-Assanga et al. (35) reported substantial variation in phytochemical constituent profiles depending on extraction solvent used. The differential performance of solvents observed in this study therefore suggests that extraction solvent strongly determines the recovery of active phytochemicals responsible for insecticidal potency.

The extracts of *S. afzelii* significantly suppressed progeny development of *R. dominica*, indicating substantial interference with insect growth, development and reproductive processes. Reduction in adult emergence observed in both contact and fumigant bioassays suggest that phytochemical constituents present in the extracts suggests disruption of developmental stages. Similar inhibitory effects on insect development were reported by Yang et al. (36), who demonstrated that alkaloids from *Sophora alopecuroides* inhibited feeding, growth and reproductive capacity of insect pests. Adesina and Ofuya (21) reported 68–85% suppression of egg hatchability and emergence in *Callosobruchus maculatus* exposed to *S. afzelii*, supporting its growth regulatory effects, attributing the effect to the presence of glycosides, alkaloids and triterpenes. Comparable developmental suppression was reported by Denloye et al. (9), who showed that *Tephrosia vogelii* leaf powder significantly reduced survival and reproductive success of *Callosobruchus maculatus* and *Sitophilus zeamais*. Adedire and Ajayi (37), had similar observations and reported that botanical extracts significantly reduced survival, reproduction and population development of major stored grain beetles, confirming the growth-disrupting potential of plant-derived bioactive compounds.

Weight loss of wheat grains caused by *R. dominica* infestation was significantly reduced following treatment with *S. afzelii* extracts, demonstrating effective grain protection and reduction of postharvest losses. Adesina et al. (38) reported a reduction in maize grain weight loss from 18.4% in untreated grains to less than 5% in treated stored maize grains against *Sitophilus zeamais* infestation, demonstrating similar protective effects of *S. afzelii* powder. Similar grain protectant effects were reported by Tapondjou et al. (16), where powder and essential oils of *Chenopodium ambrosioides* effectively protected stored grains against multiple stored-product beetle species. Denloye et al. (9) also reported that *Tephrosia vogelii* leaf powder effectively reduced infestation levels of *Sitophilus zeamais*, *Callosobruchus maculatus* and *Tribolium castaneum*, thereby minimizing grain deterioration and quantitative losses. Obeng-Ofori and Reichmuth (39) similarly demonstrated that essential oil constituents such as eugenol exhibit strong insecticidal activity against stored-product beetles, thereby reducing infestation levels and preserving grain quality during storage.

The LC50 values obtained further demonstrated differences in extraction efficiency among solvents. Ethyl acetate extract produced the highest contact toxicity, achieving 50% mortality at 171.0 µL, indicating

greater extraction of compounds responsible for direct insecticidal action. Conversely, acetone extract exhibited superior fumigant toxicity, suggesting better extraction of volatile bioactive constituents. Iloki-Assanga et al. (35) similarly reported that extraction solvents significantly influence phytochemical profiles recovered from plant materials, while Wakeel et al. (34) demonstrated that solvent polarity facilitates phytochemical yield and antioxidant capacity, both of which affect biological activity. Collectively, these findings confirm that solvent selection is a critical determinant of botanical insecticide performance, with ethyl acetate favouring contact toxicity and acetone enhancing fumigant activity.

5. Conclusion

The findings confirm that *S. afzelii* extracts possess significant potential as an environmentally sustainable botanical insecticide for the preservation of stored wheat against *R. dominica* infestation and for minimizing postharvest losses. The extracts exhibited multifaceted insecticidal activity, with acetone extract showing stronger fumigant effects while ethyl acetate extract demonstrated higher contact toxicity. This differential activity suggests that solvent type plays a significant role in determining the efficacy of phytochemical extraction and supports the potential use of *S. afzelii* as a safer and ecologically friendly alternative to conventional synthetic insecticides in stored grain protection.

Despite these promising results, the study is limited by its laboratory-based nature, which may not fully reflect storage-structure conditions where environmental factors could influence efficacy. In addition, the study focused primarily on crude solvent extracts without isolation and characterization of bioactive chemical constituents responsible for the empirical insecticidal activity. The potential toxicity effects of the extracts on mammals were not evaluated.

Therefore, this study recommended that future research should focus on validation of *S. afzelii* extracts insecticidal potential under real storage conditions, isolation, identification and characterization of the bioactive phytochemical constituents accountable for insecticidal activity and their mode of action on insect physiology. Assess the toxicological effect of the extracts and safety using albino rats.

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Authorship contribution

AJM conceptualisation, funding sourcing, project management, and manuscript proofreading. MATE Resources, Supervision, and Data Curation and Analysis. JAR Analysis and Interpretation of the data analysis and development of the initial draft. The article was read and approved by all authors.

Declaration of competing interest

No competing interest to declare by the authors.

Data availability

Data are available on request.

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