GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(Research Article)

Chemical composition and insecticidal activity of essential oil from fresh *Callistemon viminalis* leaves on *Sitophilus zeamais*, a pest of corn stocks

Adama FAYE [1], EL Hadji Gorgui DIOUF [1,*], Alioune DIOUF [2], Toffène DIOME [3], Mamadou Latyr Ndour [1], Marie SARR [4], Adama NDIAYE [4], Mamadou KEBE [1], Ndeye Bineta Camara [1], Talibouya NDIOR [1] and Alioune NDIAYE [1]

[1] *Laboratory of Natural Products, Department of Chemistry, Faculty of Science and Technology, Cheikh Anta Diop University of Dakar, Senegal.*
[2] *Department of Chemistry, Organic chemistry and bioorganics laboratory, Faculty of Science and Technology, Cheikh Anta Diop University of Dakar, Senegal.*
[3] *Department of Animal Biology, Faculty of Sciences and Technology, Cheikh Anta Diop University, Dakar, Senegal.*
[4] *Responsible for sample extraction and metrology: CERES LOCUSTOX Laboratory.*

GSC Biological and Pharmaceutical Sciences, 2026, 35(02), 292-304

Publication history: Received on 06 February 2026; revised on 20 May 2026; accepted on 22 May 2026

Article DOI: https://doi.org/10.30574/gscbps.2026.35.2.0093

Abstract

In a context where post-harvest losses of corn remain particularly high in West Africa, mainly due to the weevil *Sitophilus zeamais*, this study aims to explore plant-based alternatives to chemical insecticides. It evaluates the chemical composition and insecticidal efficacy of essential oils extracted from fresh leaves of *Callistemon viminalis*. Two extraction techniques were compared: hydrodistillation and steam distillation. The yields obtained, ranging from 1.39 to 1.59%, remain low due to the high-water content of the leaves.

GC-MS analysis reveals that hydrodistillation produces an oil composed mainly of oxygenated sesquiterpenes, notably nerolidol (50.64%) and viridiflorol (10.12%). Steam distillation, on the other hand, produces an oil richer in aromatic phenols such as eugenol (12.18%) and methyl eugenol (2.72%), as well as hydrocarbon sesquiterpenes. Biological tests show complete mortality of *Sitophilus zeamais* adults in less than 24 hours, regardless of the dose used or the extraction method. Statistical analyses indicate that only the time factor significantly influences insect mortality.

These results confirm the high insecticidal potential of *Callistemon viminalis* for post-harvest protection of cereals and suggest its value as a sustainable and environmentally friendly solution in Sahelian areas.

Keywords: *Callistemon viminalis*; *Sitophilus zeamais*; Insecticidal activity; Essential oil; Fresh leaves; Hydrodistillation and steam distillation

1. Introduction

Food insecurity remains a major problem in tropical regions, where populations are most exposed to economic and climate vulnerability. In these areas, particularly south of the Sahara, very short rainy seasons force farmers to store their produce for several months to ensure consumption and seed availability for the next growing season [1], [2].

In these regions, crops are often stored in difficult conditions: high temperatures, high humidity, and inadequate infrastructure. These constraints promote rapid food spoilage and increase post-harvest losses. According to several studies, more than a third of production can be lost between harvest and consumption [3]. These losses affect not only quantity but also quality: grains can ferment, lose their germination capacity, or become contaminated by pathogens.

* Corresponding author: EL Hadji Gorgui DIOUF

Insect pests also play a key role in this damage. Among them, weevils and other beetles belonging to the *Curculionidae*, *Bostrichidae*, and *Bruchidae* families are particularly feared [4], [5]. The corn weevil (*Sitophilus zeamais*) is one example: widely distributed, it can cause losses of up to 30% after a few months of storage if no protective measures are taken [6]. Its attacks reduce the weight and nutritional value of the grains, while promoting the development of mold and the production of toxins when the husks are perforated.

Among these plants, *Callistemon viminalis* is particularly noteworthy. Its essential oils contain compounds such as 1,8-cineole and α-pinene, which are known for their repellent and insecticidal properties [12], [13], [14]. While their effects have already been studied on various legume pests, their specific action against the corn weevil (*Sitophilus zeamais*) under tropical storage conditions remains to be evaluated. This type of study would enable Sahelian producers to be offered a protection method that is adapted to their practices and environmentally friendly.

This research is part of this approach. Its objective is to evaluate the effectiveness of *Callistemon viminalis* essential oil on *Sitophilus zeamais* under simulated storage conditions, analyze its effects on mortality, reproduction, and population dynamics, and define an application protocol compatible with farming practices. The expected results could help reduce post-harvest losses, strengthen food security in the Sahel, and offer a sustainable alternative to conventional insecticides.

2. Materials and methods

2.1. Biological material

2.1.1. Plant material

The plant material, consisting of *Callistemon viminalis* leaves, was collected from the botanical garden (14°41'03''N; 17°27'43''W) of the Faculty of Science and Technology at Cheikh Anta Diop University (UCAD). The fresh leaves were carefully washed with tap water and then subjected directly to the extraction processes.

2.1.2. Insects and breeding

Corn kernels were infested with *Sitophilus zeamais* insects from a mass breeding facility in the Department of Animal Biology at FST/UCAD. The necessary humidity was maintained using cotton wool soaked in water, and the ambient conditions of the laboratory were respected. The procedure was as follows: 250 g of previously infested corn kernels were weighed and placed in glass jars, then covered with a porous cloth to ensure good ventilation. The jars were kept at room temperature for ten (10) days, protected from any external infestation. After this period, the adult *Sitophilus zeamais* insects were removed by sieving, and breeding was continued only with the grains containing eggs for 23 days in order to obtain a new generation of insects.

2.2. Extraction methods

For this study, fresh *Callistemon viminalis* leaves were subjected to two extraction methods: hydrodistillation and steam distillation using a Clevenger apparatus. For each experiment, 150 g samples of the aerial part of the plant were used for a three-hour extraction. The condensed steam obtained resulted in two distinct phases. The organic phase, recovered after decantation, was treated with sodium sulfate (Na_2SO_4) to remove traces of water and was designated as essential oil. Yields were calculated using the following equation:

$$\textbf{Yield} = \frac{\textbf{mass of essential oil}}{\textbf{mass of sample}} \times \mathbf{100}$$

These two methods enabled us to compare the yields and chemical composition of essential oils extracted from fresh and dry leaves.

2.3. Gas chromatography

GC/MS analyses of the essential oils were performed using an Agilent GC7890A gas chromatograph connected to a 5975C mass spectrometer, equipped with an HP-5MS capillary column (5% phenyl polysiloxane, 30 m × 0.25 mm, 0.25 µm film) and an automatic injector. The oven temperature was programmed from 150°C to 290°C at a rate of 10°C/min. The ion source temperature was set at 300°C, and electron ionization was performed at 70 eV. Helium (99.999%) was used as the carrier gas, with a constant flow rate of 1.5 mL/min, and 1.0 µL of sample was injected in split mode (split 30:1).

The identification of the essential oil components was performed by comparing the mass spectra obtained with those in the NIST libraries, as well as with data from the relevant literature. The relative quantities of each compound were calculated from the GC peak areas, without applying correction factors.

2.4. Biological test

The insecticidal activity of *Callistemon viminalis* essential oils was evaluated using a contact test on adults of *Sitophilus zeamais*, the main pest affecting corn stocks. The insects used came from a mass breeding program maintained under controlled temperature and humidity conditions in the laboratory.

For each test, 20 g of corn kernels were placed in 90 mm diameter Petri dishes and treated with different volumes of essential oil (100, 75, 50, and 25 μL). Each dish was then infested with 25 adult *Sitophilus zeamais*. Observations focused on mortality over a period of 29 days, as well as the emergence of the new generation.

Each concentration was tested in four replicates, and an untreated control was included in each experimental series. Mortality and emergence rates were corrected using Abbott's formula (1925) [15], and the data obtained were subjected to analysis of variance (ANOVA) using Minitab Statistical Software 22. This analysis made it possible to evaluate the effect of different parameters (dose, duration, and type of extract) on toxicity. This protocol thus made it possible to determine the insecticidal efficacy of essential oils and to compare the activity of extracts obtained from fresh leaves.

3. Results

3.1. Yield

The extraction yield of essential oils from *Callistemon viminalis* varies depending on the method used. Analyses show that, regardless of the method used, freshly harvested leaves provide relatively modest amounts of essential oil. Steam distillation yielded 1.39%, while hydrodistillation slightly improved extraction, reaching 1.59%. This low content is mainly due to the natural moisture content of fresh leaves, which limits the release of volatile compounds during the extraction process.

3.2. Chemical composition of essential oils

Gas chromatography coupled with mass spectrometry (GC-MS) analysis identified the main constituents of the essential oil extracted from fresh *Callistemon viminalis* leaves. Identification was based on comparison of the spectra obtained with the NIST08.L database and CAS reference numbers. Two extraction methods were used: hydrodistillation and steam distillation, in order to evaluate the influence of the process on the chemical composition.

3.2.1. Essential oil obtained by hydrodistillation

Hydrodistillation reveals a high presence of sesquiterpenes, with a notable predominance of oxygenated compounds. Nerolidol is the main compound, accounting for 50.64% of the total composition. It is followed by viridiflorol (10.12%), while β-eudesmol and farnesol appear only in modest proportions.

Hydrocarbon sesquiterpenes represent the second largest family, dominated by β-humulene (8.75%), α-gurjunene (1.90%), and δ-cadinene (6.67%). The fraction also contains a few compounds with a higher molecular weight, such as phytol (1.39%) and squalene (0.57%), associated with minor oxygenated compounds such as hexahydrofarnesylacetone (0.50%) and hexadecanoic acid (3.17%).

Overall, the oil obtained from hydrodistillation is characterized by a composition dominated by oxygenated sesquiterpenes (61.22%), followed by hydrocarbon sesquiterpenes (25.37%). Other oxygenated compounds account for 3.67%, while diterpenes and triterpenes total 1.96%.

Table 1 Chemical composition of oils obtained by hydrodistillation of fresh leaves of *Callistemon viminalis*

Peak	TR (min)	Identified compounds	CAS NIST	%	Qual.	Families
4	7.151	α-Gurjunene	489-40-7	1.90	96-98	Hydrocarbon sesquiterpenes
		(+)-Cyclosativene	22469-52-9		92	
5	7.277	10S,11S-Himachala-3(12),4-diene	60909-28-6	8.05	93	
		Caryophyllene	87-44-5		93	
		(+)-Cycloisosativene	1000109-88-1		90	
6 7	9.512	Nerolidol	142-50-7 7212-44-4	50.64	80-94 86-93	Oxygenated sesquiterpenes
8	10.212	β-Humulene	116-04-1	8.75	92	Hydrocarbon sesquiterpenes
		γ-Gurjunene	22567-17-5		89	
		Viridiflorol	552-02-3		89	Oxygenated sesquiterpenes
9	10.571	2-isopropyl-5-methyl-9-methylene-bicyclo-1-decene(4.4.0)	150320-52-8	6.67	95	Hydrocarbon sesquiterpenes
		δ-cadinene	483-76-1		90	
		(+)epi-bicyclosesquiphellandrene	54324-03-7		87	
10	10.661	Viridiflorol	552-02-3	10.12	86	Oxygenated sesquiterpenes
		β-Eudesmol	473-15-4		86	
		Aromandendrene	489-39-4		84	Hydrocarbon sesquiterpenes
11	10.733	Farnesol	106-28-5	0.46	93-95	Oxygenated sesquiterpenes
14	11.272	Hexahydrofarnesyl acetone	502-69-2	0.50	91	Other oxygenated compounds
15	12.043		57-10-3	3.17	89-97	
16	13.175	Hexadecanoic acid	150-86-7	1.39	86-93	Diterpenes and triterpenes
20	18.417	Phytol	7683-64-9	0.57	91	

3.3. Essential oil obtained by steam distillation

The oil extracted by steam distillation has a contrasting chemical profile, marked by a high proportion of hydrocarbon sesquiterpenes (37.68%). These mainly include caryophyllene (14.88%), caryophyllene-(I1) (2.73%), α-calacorene (1.61% and 10.63% depending on the peaks), as well as several cadinene compounds, including β-cadinene (3.74% and 2.02%), δ-cadinene (2.02%), and cadine-1,4-diene (2.07%).

Unlike hydrodistillation, this method allows the detection of aromatic phenols, notably eugenol (12.18%) and methyl eugenol (2.72%), as well as aromatic hydrocarbons such as cadalene (2.18%) and azulene, present in small proportions. Oxygenated sesquiterpenes are less abundant (5.48%), including epiglobulol (1.64%) and viridiflorol (3.84%).

Table 2 Chemical composition of oils obtained by steam distillation of fresh leaves of *Callistemon viminalis*

Peak	TR (min)	Identified compounds	CAS NIST	%	Qual.	Families
3	6.936	Eugenol	97-53-0	12.18	96-98	Aromatic phenols
4	7.214	Methyleugenol	93-15-2	2.72	96-98	
5	7.465	Caryophyllene-(I1)	1000158-18-5	2.73	93	Hydrocarbon sesquiterpenes
		10S,11S-Himachala-3(12),4-diene	60909-28-6		92	
		Alloaromadendrene	25246-27-9		92	
6	7.690	Caryophyllene	87-44-5	14.88	99	
		Isocaryophyllene	118-65-0		97	
7	8.040	Cadine-1,4-diene	16728-99-7	2.07	83-91	
		β-Cadinene	523-47-7		87	
8	8.202	β-Cadinene	523-47-7	3.74	99	
		σ-Cadinene	5951-61-1		98	
		δ-Selinene	28624-23-9		98	
9	8.417	δ-Cadinene	483-76-1	2.02	95	
		β-Cadinene	523-47-7		95	
10	8.695	α-Calacorene	1000293-02-3	1.61	80	
11	8.839	α-Calacorene	1000293-02-3	10.63	91	
12	8.947	Epiglobulol	1000150-05-1	1.64	93	Oxygenated sesquiterpenes
13	9.431	Viridiflorol	552-02-3	3.84	97	
17	9.988	Cadalene	483-78-3	2.18	93-94	Aromatic hydrocarbons
		Azulene	489-84-9		91	

3.4. Comparative analysis of the two methods

Analysis of the chemical compositions of essential oils extracted from fresh *Callistemon viminalis* leaves reveals significant variations depending on the extraction method used.

Hydrodistillation produces an oil characterized by a high proportion of oxygenated sesquiterpenes, representing 61.22% of the total composition. Hydrocarbon sesquiterpenes are the second largest family, accounting for 25.37%, while other oxygenated compounds account for 3.67%. Low levels of diterpenes and triterpenes (1.96%) are also detected in this oil.

The oil obtained by steam distillation has a different chemical profile. Hydrocarbon sesquiterpenes are the most abundant group, accounting for 37.68%. This method also allows the detection of aromatic phenols (14.9%) and aromatic hydrocarbons (2.18%), which are absent in the oil obtained by hydrodistillation. Oxygenated sesquiterpenes represent only 5.48% of the total in this fraction.

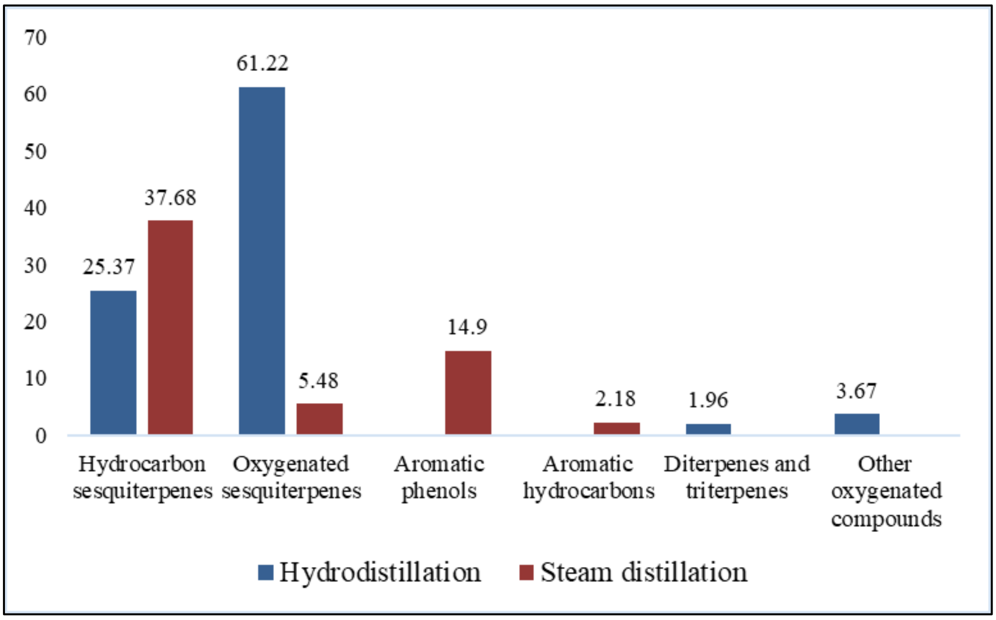

Figure 1 Percentage of chemical families in extracts: Hydrodistillation and Steam Distillation

3.5. Insecticidal activity of essential oils

3.5.1. Steam distillation of fresh leaves

ANOVA indicates a significant effect of the time factor ($p < 0.001$), while the effects of doses and the interaction between doses and time are not significant ($p > 0.05$).

Table 3 Analysis of variance in mortality

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Doses	3	0.01	0.002	0.04	0.990
Time	28	9354.49	334.089	5887.54	0.000
Doses*Time	84	4.70	0.056	0.99	0.520
Error	348	19.75	0.057		
Total	463	9378.94			

These results show that mortality is maximal regardless of the concentration applied. Total mortality (100%) is achieved within the first 24 hours of exposure. Tukey's test and the main dose effect curve classify all doses in the same statistical group, confirming that there is no significant difference between concentrations.

Table 4 Tukey Pairwise Comparisons Doses: Grouping Information Using the Tukey Method and 95% Confidence

Doses	N	Mean	Grouping
D1	116	0.811999	A
D2	116	0.811999	A
D3	116	0.811999	A
D4	116	0.803292	A

Means that do not share a letter are significantly different

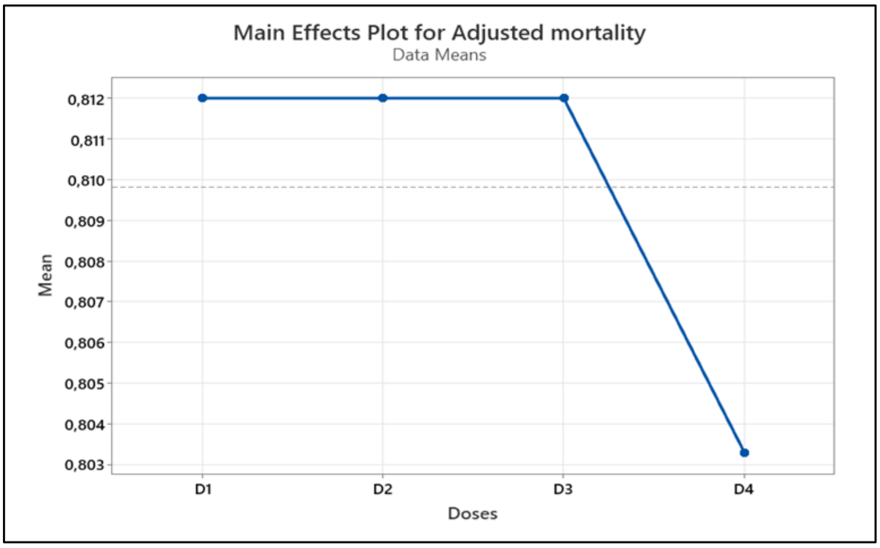

Figure 2 Main effect curves as a function of doses

The mortality curve over time shows very rapid growth in the first few hours, followed by complete stabilization after 24 hours.

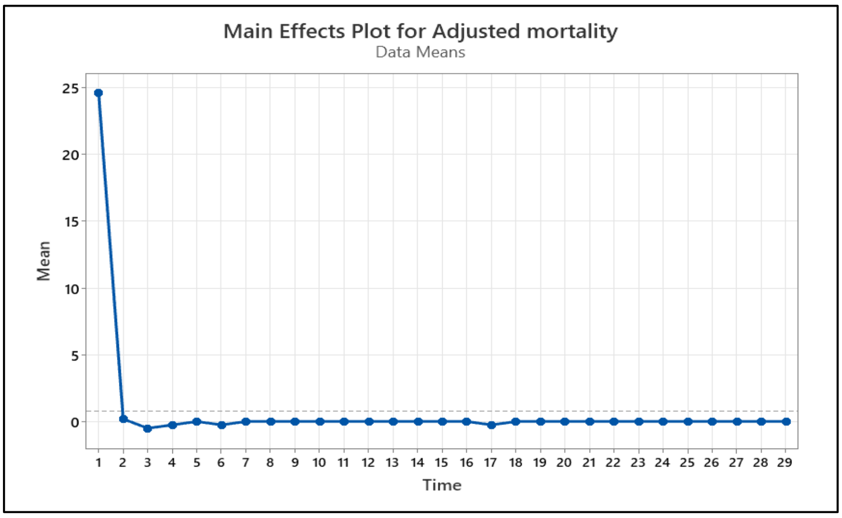

Figure 3 Main effect curves as a function of time

3.5.2. Hydrodistillation of fresh leaves

The same behavior is observed for the oil obtained by hydrodistillation. The time factor is highly significant ($p < 0.001$), while the doses and their interaction with time have no significant effect ($p \approx 1.000$).

Table 5 Analysis of variance in mortality

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Doses	3	0.01	0.002	0.05	0.986
Time	28	9502.33	339.369	7690.36	0.000
Doses*Time	84	0.18	0.002	0.05	1.000
Error	348	15.36	0.044		
Total	463	9517.87			

Mortality reaches 100% within the first 24 hours, regardless of the dose used. Tukey's results confirm statistical homogeneity between concentrations, indicating total and uniform efficacy. This observation is confirmed by the Dose × Time interaction curve.

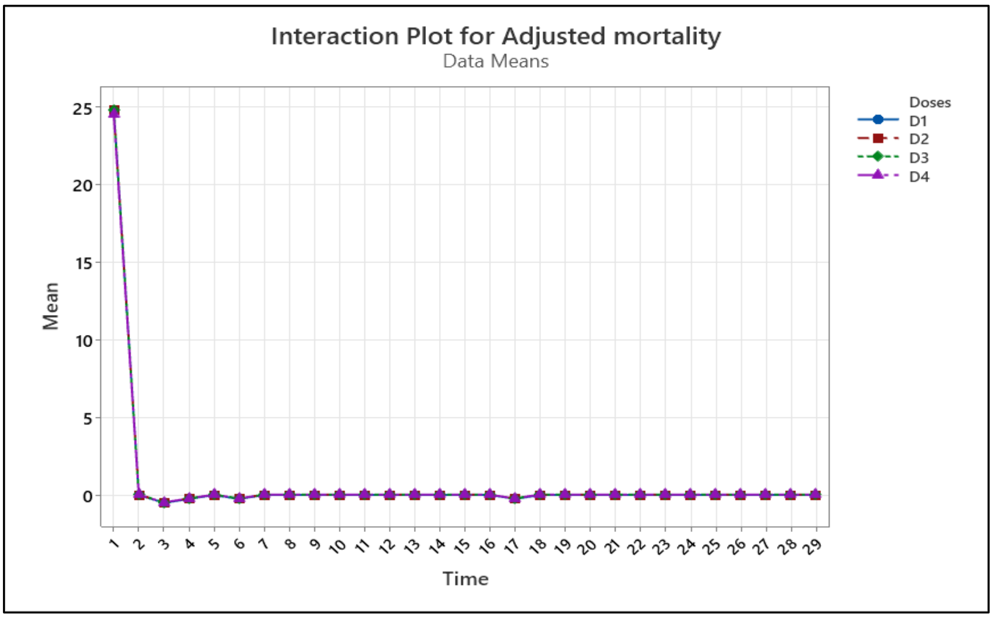

Figure 4 Dose*Time interaction curve for mortality

3.5.3. Intra-group comparison (fresh leaves)

The comparison between the two extraction methods applied to fresh leaves shows that the type of extract has no significant influence (p = 0.999). The effects of doses and multiple interactions are also insignificant (p > 0.9).

Table 6 Analysis of Variance

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Type of extract	1	0.0	0.000	0.00	0.999
Doses	3	0.0	0.004	0.09	0.968
Time	28	18856.3	673.438	13352.04	0.000
Type of extract*Doses	3	0.0	0.000	0.00	1.000
Type of extract*Time	28	0.6	0.020	0.40	0.998
Doses*Time	84	3.2	0.038	0.75	0.950
Type of extract*Doses*Time	84	1.7	0.020	0.40	1.000
Error	696	35.1	0.050		
Total	927	18896.8			

Mortality reaches 100% within 24 hours in both cases, demonstrating that the effectiveness of the essential oil is independent of the extraction process. The only difference observed is temporal: mortality is immediate in all treatments, with no significant variation between extraction methods.

Table 7 Tukey Pairwise Comparisons Doses: Grouping Information Using the Tukey Method and 95% Confidence

Doses	N	Mean	Grouping
D1	232	0,811999	A
D2	232	0,811999	A
D3	232	0,811999	A
D4	232	0,803335	A

Means that do not share a letter are significantly different

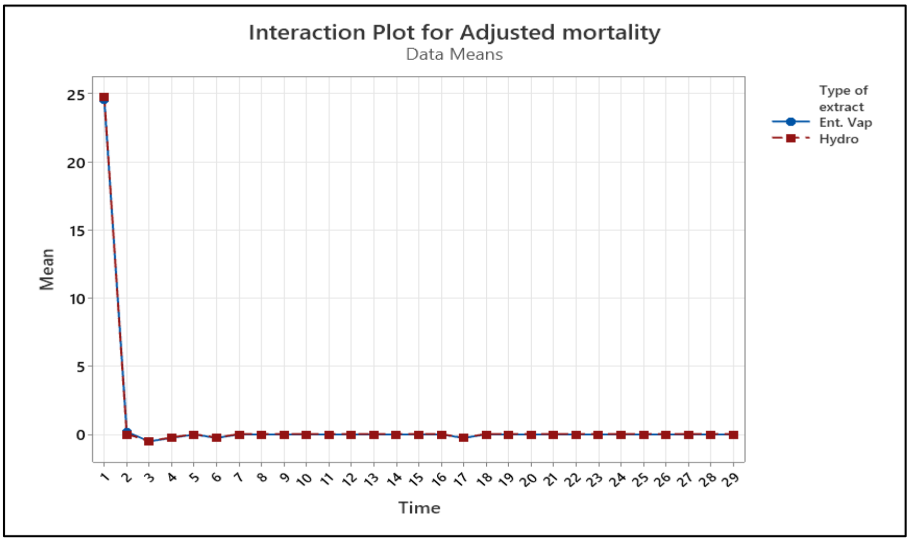

Figure 5 Extracts*Time interaction curve for mortality

4. Discussion

The extraction yield of essential oils from *Callistemon viminalis* varies significantly depending on the method used. Analyses reveal that, regardless of the technique applied, fresh leaves provide relatively modest amounts of essential oil. In this study, steam distillation yielded 1.39%, while hydrodistillation slightly improved extraction, reaching 1.59%. These results are within the range reported in recent literature, both in Africa and internationally. In Cameroon, Younoussa et al. (2020) [16] observed a yield of 1.20% by hydrodistillation of fresh leaves of *Callistemon* ssp. In Senegal, Wilane (2011) [17] obtained similar values, with 1.2% for fresh leaves and 2.02 to 2.88% for dried leaves, confirming the impact of moisture on extraction efficiency. Similarly, Indira et al. (2021) [18] demonstrated that pre-treating the leaves prior to distillation promoted the release of volatile compounds and increased the overall yield to 2.1%. In a comparative study of several Myrtaceae species, Zhang et al. (2025) [19] confirmed that combining steam distillation with prior dehydration increased oil recovery by 20 to 35%, depending on the species and the degree of grinding of the plant material. Finally, Dwivedi et al. (2025) [20] specified that, for industrial applications, the optimal yield is generally between 1.3 and 2.0%, depending mainly on the degree of drying of the leaves before extraction.

The low content recorded in this study (≈1.4-1.6%) is mainly due to the high natural moisture content of fresh leaves, which limits the vaporization and migration of volatile compounds during distillation. Several authors Bourkhiss, 2009 [21]; Indira et al., 2021 [18] have shown that the water content of plant material directly influences vapor pressure and, consequently, the release of aromatic molecules. Furthermore, Ibrahim and Moussa (2020) [22] and Zhang et al. (2025) [19] have highlighted the decisive effect of pedoclimatic factors such as temperature, relative air humidity, and soil type, which can cause extraction yields to vary by up to 40% due to changes in the biosynthesis of secondary metabolites.

GC-MS analysis of essential oils from fresh leaves obtained by hydrodistillation reveals a composition marked by a high proportion of hydrocarbon sesquiterpenes (himachalene, caryophyllene, β-humulene, gurjunene) and oxygenated sesquiterpenes (nerolidol, viridiflorol, β-eudesmol, farnesol), with minor compounds such as squalene and phytol. In contrast, the essential oil obtained by steam distillation has a profile dominated by aromatic phenols (eugenol 12.18%, methyl eugenol 2.72%) and a high proportion of hydrocarbon sesquiterpenes (caryophyllene 14.88%, α-calacorene 10.63%, β-cadinene, cadalene, etc.), as well as oxygenated sesquiterpenes (viridiflorol, epiglobulol).

This composition differs from the classic profiles dominated by 1,8-cineole, but remains consistent with the chemical variability reported in the literature depending on origin, season, and extraction method [14], [23], [24], [25], [26], [27]. The differences observed between the two oils can largely be explained by the extraction method: steam distillation, which involves passing steam more quickly through the plant material, promotes the extraction of more volatile and heat-sensitive compounds, such as aromatic phenols, while limiting their thermal degradation. Conversely, hydrodistillation, which involves prolonged exposure to heat, preferentially recovers less volatile and more stable molecules, particularly sesquiterpenes [28], [29], [30]. Thus, each method induces a distinct chemical profile, demonstrating that the choice of extraction process is a determining factor in the final composition of essential oils and can, therefore, modulate their potential biological properties.

The results show total mortality (100%) of insects within 24 hours, regardless of the extraction method (steam distillation or hydrodistillation) and the dose applied. This rapid and concentration-independent efficacy can be explained by the richness of essential oils in bioactive compounds with strong insecticidal properties. Compounds such as caryophyllene, β-humulene, nerolidol, viridiflorol, and spathulenol are well known for their toxicity to many insects, acting mainly by inhibiting acetylcholinesterase, disrupting the nervous system, or inducing cytotoxic effects, which explains their larvicidal and adulticidal efficacy reported in the literature [31], [32], [33], [34]. Added to this is the action of aromatic phenols, in particular eugenol, known for its neurotoxic, repellent, and acetylcholinesterase-inhibiting effects, as well as its ability to disrupt insect growth [35]. Even minor compounds such as squalene and phytol enhance the overall activity of the oil through synergistic effects, with phytol in particular demonstrating marked aphicidal activity [32]. Thus, oil obtained by hydrodistillation, rich in oxygenated sesquiterpenes, exhibits acute toxicity and prolonged action on several stages of insects [33], [34], while oil obtained by steam distillation, highly concentrated in eugenol and methyl eugenol, induces rapid, powerful, and often synergistic action against various pests [35]. Overall, the high insecticidal efficacy observed can be explained by the coexistence of hydrocarbon and oxygenated sesquiterpenes, combined with aromatic phenols, whose complementary and synergistic modes of action contribute to high and rapid mortality in target insects.

5. Conclusion

Essential oils obtained from fresh *Callistemon viminalis* leaves are particularly effective against *Sitophilus zeamais*, one of the most destructive pests of stored corn in West Africa. Although yields remain modest due to the high moisture content of the leaves, the two extraction techniques used provide oils rich in bioactive compounds. Hydrodistillation is particularly effective at extracting oxygenated sesquiterpenes, notably nerolidol and viridiflorol, which are known for their strong insecticidal activity. Steam distillation, on the other hand, produces an oil that is more concentrated in aromatic phenols such as eugenol, known for its neurotoxic effects on insects.

Biological tests reveal total mortality of weevils in just 24 hours, regardless of the dosage applied or the extraction method used. This rapid action suggests a notable synergy between the various volatile compounds, whose combined effects target both the nervous system and metabolism of insects. Statistical analysis also shows that only the time factor influences mortality, highlighting the intrinsic power of the essential oil.

These results confirm that *Callistemon viminalis* is a serious, sustainable, and more environmentally friendly alternative to synthetic insecticides, particularly suited to agricultural conditions in the Sahel. Its use could help limit post-harvest losses, improve food security, and support integrated pest management strategies that are more respectful of human health and the environment. However, further research is needed on the formulation, stability, persistence, and effects on non-target organisms in order to optimize its large-scale application.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the Laboratory of Natural Products (Department of Chemistry) and the Department of Animal Biology at Cheikh Anta Diop University of Dakar, as well as CERES-Locustox for their technical support and assistance during this study.

Disclosure of conflict of interest

No conflict of interest to be disclosed. All authors declare that they have no competing interests.

Statement of ethical approval

The present study does not contain any studies with human participants or live vertebrate animals performed by any of the authors. Experimental protocols on the insect pest *Sitophilus zeamais* followed standard laboratory guidelines for entomological research.

References

[1] CILSS, « Rapport Régional sur la Sécurité Alimentaire et Nutritionnelle 2023 », 2023.

[2] FAO, The State of Food Security and Nutrition in the World 2021. FAO, IFAD, UNICEF, WFP and WHO, 2021. doi: 10.4060/cb4474en.

[3] R. J. Hodges, J. C. Buzby, et B. Bennett, « Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use », Journal of Agricultural Science, vol. 149, no S1, p. 37 45, févr. 2011, doi: 10.1017/S0021859610000936.

[4] J. Huignard, I. A. Glitho, J.-P. Monge, et C. Regnault-Roger, « Insectes ravageurs des graines de légumineuses Biologie des Bruchinae et lutte raisonnée en Afrique », 2011.

[5] F. Nanfack, Y. Dongmo, et M. Fogang, « Les insectes impliqués dans les pertes post-récolte des céréales au Cameroun : méthodes actuelles de lutte et perspectives offertes par la transgénèse », Int J Biol Chem Sci, vol. 9, no 3, p. 1630, sept. 2015, doi: 10.4314/ijbcs.v9i3.42.

[6] H. Y. D. Bawa, I. B. Baoua, M. M. Rabé, et D. Baributsa, « Hermetic Storage as a Chemical-Free Alternative for Millet Preservation in Niger », Insects, vol. 16, no 9, sept. 2025, doi: 10.3390/insects16090917.

[7] F. H. Arthur, « Grain protectants: Current status and prospects for the future », J Stored Prod Res, vol. 32, no 4, p. 293 302, oct. 1996, doi: 10.1016/S0022-474X (96)00033-1.

[8] M. Bouhalleb et M. Boumagouda, « Evaluation de la durée de persistance de l'efficacité d'une huile essentielle contre les insectes ravageurs des céréales », 2024.

[9] P. Cissokho, M. Gueye, E. Sow, et K. Diarra, « Substances inertes et plantes à effet insecticide utilisées dans la lutte contre les insectes ravageurs des céréales et légumineuses au Sénégal et en Afrique de l'Ouest », Int J Biol Chem Sci, vol. 9, no 3, p. 1644, sept. 2015, doi: 10.4314/ijbcs.v9i3.43.

[10] C. Regnault-Roger, C. Vincent, et J. T. Arnason, « Essential oils in insect control: Low-risk products in a high-stakes world », Annu Rev Entomol, vol. 57, p. 405 424, 2012, doi: 10.1146/annurev-ento-120710-100554.

[11] M. B. Isman, « Botanical Insecticides in the Twenty-First Century-Fulfilling Their Promise? », EN65CH11_Isman ARjats.cls October, vol. 1, 2019, doi: 10.1146/annurev-ento-011019.

[12] N. Zandi-Sohani, M. Hojjati, et Á. A. Carbonell-Barrachina, « Insecticidal and Repellent Activities of the Essential Oil of *Callistemon citrinus* (Myrtaceae) Against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) », Neotrop Entomol, vol. 42, no 1, p. 89 94, févr. 2013, doi: 10.1007/s13744-012-0087-z.

[13] Y. Diop, A. Faye, D. Sarr, A. Coly, et S. Ngom, « Efficacy test of *Melaleuca leucadendra* and *Callistemon viminalis* essential oils on in vitro control of a strain of *Aspergillus flavus* isolated from peanut seeds in Senegal », 2022. [En ligne]. Disponible sur: www.internationalscholarsjournals.org

[14] M. Z. Salem, H. M. Ali, N. A. El-Shanhorey, et A. Abdel-Megeed, « Evaluation of extracts and essential oil from *Callistemon viminalis* leaves: Antibacterial and antioxidant activities, total phenolic and flavonoid contents Asian Pacific Journal of Tropical Medicine *Callistemon viminalis* Essential oil Antibacterial activity Antioxidant activity Phenolic content Flavonoid content », 2013. [En ligne]. Disponible sur: www.elsevier.com/locate/apjtm

[15] Abbott W. S., « A Method of Computing the Effectiveness of an Insecticide », J Econ Entomol, vol. 18, no 2, p. 265 267, avr. 1925.

[16] L. Younoussa, F. Kenmoe, M. K. Oumarou, A. C. S. Batti, J. L. Tamesse, et E. N. Nukenine, « Combined Effect of Methanol Extracts and Essential Oils of *Callistemon rigidus* (Myrtaceae) and *Eucalyptus camaldulensis* (Myrtaceae) against *Anopheles gambiae* Giles larvae (Diptera: Culicidae) », Int J Zool, vol. 2020, 2020, doi: 10.1155/2020/4952041.

[17] D. Wilane, « ÉTUDE DE L'EFFET FUMIGANT DES HUILES ESSENTIELLES DE *CALLISTEMON VIMINALIS* (Gaertn) G. DON (MYRTACEAE), *MENTHA SPICATA* HUDS (LAMIACEAE) ET *XYLOPIA AETHIOPICA* DUNAL (ANNONACEAE) SUR LES LARVES DE DERMESTES SPP. (*COLEOPTERA-DERMESTIDAE*), PRINCIPAUX RAVAGEURS DES POISSONS SÉCHÉS », Dakar, 2011.

[18] T. I. Indira, K. H. Burhan, R. Manurung, et A. Widiana, « Enhancement of Essential Oil Yield *from Melaleuca Leucadendra* L. Leaves by Lignocellulose Degradation Pre-Treatment Using Filamentous Fungi », Journal of Bioresources and Bioproducts, vol. 6, no 4, p. 379 386, nov. 2021, doi: 10.1016/j.jobab.2021.02.010.

[19] X. Zhang et al., « Essential oil extracted from *Callistemon viminalis* via salting-out assisted hydrodistillation enhances in Vitro antioxidant and antifungal properties », Ind Crops Prod, vol. 232, p. 121248, sept. 2025, doi: 10.1016/J.INDCROP.2025.121248.

[20] A. Dwivedi, A. Pant, S. Vinay Shukla, et R. Pandey, Essential Oils and Fragrances in Cosmetics: Global Regulatory Practices and Compliance, 1re édition. Presses CRC, 2025.

[21] M. Bourkhiss1, M. Hnach, B. Bourkhiss, M. Ouhssine, A. Chaouch, et B. Satrani, « Productions végétales Effet de séchage sur la teneur et la composition chimique des huiles essentielles de *Tetraclinis articulata* (Vahl) Masters », 2009.

[22] N. Ibrahim et A. Y. Moussa, « Comparative metabolite profiling of *Callistemon macropunctatus* and *Callistemon subulatus* volatiles from different geographical origins », Ind Crops Prod, vol. 147, p. 112222, mai 2020, doi: 10.1016/J.INDCROP.2020.112222.

[23] O. O. Oyedeji, O. A. Lawal, F. O. Shode, et A. O. Oyedeji, « Chemical composition and antibacterial activity of the essential oils of *Callistemon citrinus* and *Callistemon viminalis* from South Africa », Molecules, vol. 14, no 6, p. 1990 1998, juin 2009, doi: 10.3390/molecules14061990.

[24] R. Fall, S. Ngom, A. Samb, et M. Sembène, « Activité insecticide par fumigation des huiles essentielles de *Callistemon viminalis*, *Melaleuca leucadendron* et *Hyptis suavolen* contre *Sitophilus* spp., ravageur du maïs. », J. Soc. Ouest-Afr. Chim, vol. 043, p. 31 36, 2017, [En ligne]. Disponible sur: http://www.soachim.org

[25] C. H. C. de Matos et al., « Influence of Extraction Time and Circadian Rhythm on the Content, Chemical Composition and Antifungal Activity of the Essential Oils from *Callistemon viminalis* (Myrtaceae) Leaves », ACTA Paulista de Enfermagem, vol. 36, no 6, 2025, doi: 10.21577/0103-5053.20250021.

[26] H. A. Gad, I. M. Ayoub, et M. Wink, « Phytochemical profiling and seasonal variation of essential oils of three *Callistemon* species cultivated in Egypt », PLoS One, vol. 14, no 7, juill. 2019, doi: 10.1371/journal.pone.0219571.

[27] A. Y. Asaad, « In Vitro Antimicrobial Activity of Essential Oil Derived from *Callistemon viminalis* Aerial Part », Al-Kindy College Medical Journal, vol. 19, no 1, p. 69 74, avr. 2023, doi: 10.47723/kcmj.v19i1.892.

[28] E. Isidore, H. Karim, et I. Ioannou, « Extraction of phenolic compounds and terpenes from cannabis sativa l. By-products: From conventional to intensified processes », 1 juin 2021, MDPI. doi: 10.3390/antiox10060942.

[29] A. Fatima, M. A. Ayub, N. Choobkar, M. Zubair, K. D. Thomspon, et A. Hussain, « The Effect of Different Extraction Techniques on the Bioactive Characteristics of Dill (*Anethum graveolens*) Essential Oil », Food Sci Nutr, vol. 13, no 4, avr. 2025, doi: 10.1002/fsn3.70089.

[30] N. E. Song, M. K. Kim, K. G. Lee, et H. W. Jang, « Analysis of volatile compounds in rooibos tea (*Aspalathus linearis*) using different extraction methods and their relationship with human sensory perception », Food Research International, vol. 141, mars 2021, doi: 10.1016/j.foodres.2020.109942.

[31] K. Řebíčková, T. Bajer, D. Šilha, K. Ventura, et P. Bajerová, « Comparison of Chemical Composition and Biological Properties of Essential Oils Obtained by Hydrodistillation and Steam Distillation of *Laurus nobilis* L. », Plant Foods for Human Nutrition, vol. 75, no 4, p. 495 504, déc. 2020, doi: 10.1007/s11130-020-00834-y.

[32] G. Benelli, R. Pavela, E. Drenaggi, N. Desneux, et F. Maggi, « Phytol, (E)-nerolidol and spathulenol from *Stevia rebaudiana* leaf essential oil as effective and eco-friendly botanical insecticides against *Metopolophium dirhodum* », Ind Crops Prod, vol. 155, p. 112844, nov. 2020, doi: 10.1016/J.INDCROP.2020.112844.

[33] A. C. de Oliveira et al., « Essential oil of *Piper purusanum* C.DC (Piperaceae) and its main sesquiterpenes: biodefensives against malaria and dengue vectors, without lethal effect on non-target aquatic fauna », Environmental Science and Pollution Research, vol. 29, no 31, p. 47242 47253, juill. 2022, doi: 10.1007/s11356-022-19196-w.

[34] E. Muñoz-Nuñez et al., « Insecticidal Potential of *Baccharis macraei* Essential Oils: An Ecological Approach to Their Volatile Composition in Insect Management », Agronomy, vol. 15, no 3, mars 2025, doi: 10.3390/agronomy15030509.

[35] A. A. Pereira Filho et al., « Larvicidal Activity of Essential Oils From Piper Species Against Strains of *Aedes aegypti* (Diptera: Culicidae) Resistant to Pyrethroids », Front Plant Sci, vol. 12, juin 2021, doi: 10.3389/fpls.2021.685864.