Efficacy of Olive Oil and Chilli Pepper Powder in the Control of Cowpea Bruchid (*Callosobruchus maculatus*)

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ABSTRACT

Post-harvest losses caused by the cowpea bruchid (*Callosobruchus maculatus)* pose a significant threat to food security and economic stability in sub-Saharan Africa. This study investigated the insecticidal efficacy of two readily available botanicals—olive oil and chilli pepper *(Capsicum spp.)* powder—as sustainable alternatives to synthetic pesticides. A comprehensive laboratory bioassay was conducted, applying varying concentrations of each substance to *C. maculatus* over a 24-hour period under controlled hot season conditions (28-38°C). Concurrent phytochemical screening was performed to identify constituent bioactive compounds. Results demonstrated a concentration-dependent mortality response for both treatments. Olive oil proved significantly more effective ($p < 0.05$), achieving an overall mean mortality of 79.6% and an LC50 of 14.8%, compared to chilli pepper's 66.1% mortality and LC50 of 22.3 mg/ml. Phytochemical analysis revealed a broader spectrum of bioactive compounds in olive oil, including steroids and oxalates, which were absent in chilli pepper. The superior efficacy of olive oil is attributed to a dual mechanism of physical suffocation and synergistic biochemical toxicity. This research conclusively validates both botanicals, particularly olive oil, as highly effective, affordable, and eco-friendly biopesticides suitable for integration into stored product IPM strategies by smallholder farmers, directly contributing to reduced post-harvest losses and enhanced food security.

Keywords— Botanical Pesticides, *Callosobruchus Maculatus,* Post-Harvest Losses, Olive Oil, Chilli Pepper, Phytochemical Analysis, Probit Analysis, Integrated Pest Management, Food Security, Sustainable Agriculture.

INTRODUCTION

Background of the Study

Global food security is persistently challenged by post-harvest losses, which account for an estimated 20-40% of total agricultural output in developing nations, with grains and pulses being disproportionately affected [1]. Among the myriad of contributing factors, insect infestation represents a primary causative agent of qualitative and quantitative deterioration in stored produce. The cowpea bruchid, *Callosobruchus maculatus* is a cosmopolitan and oligophagous pest of paramount economic importance, specializing in infesting stored leguminous seeds, with a pronounced preference for cowpea *(Vigna unguiculata*) [2]. Cowpea serves as a critical source of affordable plant-based protein, vitamins, and minerals for millions of people in sub-Saharan Africa, making its protection a matter of nutritional and economic necessity [3]. The insidious nature of *C. maculatus* infestation begins covertly in the field, where gravid females cement eggs onto the surface of developing pods. The subsequent larval and pupal stages develop entirely within the seed kernel, protected from external interventions, culminating in adult emergence that leaves characteristic circular exit holes, rendering the seeds commercially unviable and nutritionally compromised [4].

Problem Statement

The conventional paradigm for mitigating storage pests has relied overwhelmingly on the prophylactic and therapeutic application of synthetic chemical insecticides, such as phosphine and pyrethroids. However, decades of indiscriminate use have engendered a triad of severe consequences: first, the rapid evolution of physiological and behavioral resistance in pest populations [5]; second, detrimental effects on non-target organisms and the broader ecosystem [6]; and third, the accrual of harmful residues that pose significant risks to human health, including carcinogenicity, endocrine disruption, and neurotoxicity [7]. For resource-constrained smallholder farmers, the cost, availability, and requisite knowledge for the safe handling of these chemicals present additional, often insurmountable, barriers. This confluence of factors has catalyzed an urgent and global search for effective, biodegradable, economically viable, and environmentally benign alternative pest management strategies.

Research Objectives

The aim of this research was to conduct a comparative evaluation of the insecticidal potency of olive oil and chilli pepper powder against *C. maculatus* in stored cowpea. The specific objectives were:

1. To determine the contact toxicity and calculate the median lethal concentrations (LC50 and LC90) of different concentrations of olive oil and chilli pepper powder against adult *C. maculatus.*
2. To perform a qualitative phytochemical analysis of both test botanicals to identify and compare their constituent bioactive compounds.
3. To statistically compare the insecticidal efficacy of olive oil and chilli pepper powder and correlate their phytochemical profiles with observed mortality.
4. To assess and discuss the practical implications of these findings for developing integrated pest management (IPM) protocols for small-scale grain storage in Nigeria and similar regions.

LITERATURE REVIEW

The Target Pest*: Callosobruchus Maculatus*

Callosobrochus maculatus is arguably the most devastating post-harvest pest of cowpea across the tropical and subtropical world. Its remarkable reproductive potential, with a generation time of approximately 3-4 weeks under optimal conditions, allows for exponential population growth within a single storage season [2]. The damage is twofold: direct consumption by larvae leads to substantial weight loss (often exceeding 30-40%), while the physical perforation of seeds facilitates the entry of secondary pests and pathogenic microorganisms, further accelerating spoilage [8]. Perhaps most critically, infestation destroys the seed's embryo, nullifying its germination capacity and thus its value as a subsequent planting material, thereby perpetuating a cycle of agricultural vulnerability [4]. The cryptic life history of the insect, residing protected inside the seed for the majority of its development, renders it particularly recalcitrant to control via surface-applied insecticides, necessitating agents with fumigant, repellent, or oviposition-deterrent properties, or those capable of penetrating the seed coat.

Botanical Pesticides: A Renaissance in Pest Management

Botanical pesticides, derived from plant materials, represent a return to ancient pest control practices, now underpinned by modern scientific validation. Their modes of action are diverse and often synergistic, encompassing contact toxicity, antifeedancy, repellency, growth inhibition, chemosterilization, and oviposition deterrence [9]. This multi-target mechanism significantly reduces the likelihood of rapid resistance development compared to single-mode synthetic chemicals [10]. Plant essential oils and fixed oils, such as olive oil, have garnered significant attention. Their activity is frequently attributed to a dual mechanism: a physical action, where the oil film blocks the spiracles of insects, causing death by asphyxiation, and a biochemical action, mediated by a complex mixture of terpenoids, phenolics, and aliphatic compounds that interfere with neurological and physiological processes [11]. Conversely, chilli pepper (*Capsicum spp.)* derives its potent bioactivity primarily from a group of compounds known as capsaicinoids, with capsaicin being the most prominent. Capsaicin is a powerful neurotoxin to insects, acting as an irritant and repellent by targeting specific sensory neurons [12]. The exploration of such locally available and culturally accepted botanicals offers a promising pathway toward sustainable and self-reliant pest management.

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METHODOLOGY

Study Location and Duration

This experimental research was conducted over a four-week period in April 2019 within the controlled environment of the Biology Laboratory at Yobe State University, Damaturu, Nigeria. Damaturu is located in the semi-arid Sudan Savanna zone, a region where cowpea is a major staple crop and post-harvest losses are a significant concern.

Experimental Insects and Rearing

A robust culture of *Callosobruchus maculatus* was initiated from infested cowpea seeds procured from local storage facilities in the Damaturu metropolitan area. The insects were identified and confirmed by entomologists at the Department of Biological Sciences. The culture was maintained and amplified in wide-mouthed glass jars containing uninfested, clean cowpea seeds. The jars were covered with perforated muslin cloth to allow for aeration while preventing escape. The insect culture was maintained under ambient laboratory conditions for two generations prior to the commencement of bioassays to ensure a stable and synchronized population. For bioassays, uniform, unsexed adult weevils aged 1-3 days post-emergence were randomly selected to ensure physiological consistency.

Fig 1: Incubation of *Callosobrochus maculatus* in fume chamber

Source and Preparation of Botanical Materials

Fresh, commercially available olive fruits (*Olea europaea*) were purchased from a local supermarket. The fruits were de-pulped, and the kernels were air-dried and mechanically crushed. The oil was subsequently extracted using a Soxhlet apparatus with petroleum ether (60-80°C) as the solvent for 6 hours. The solvent was evaporated using a rotary evaporator, and the pure, solvent-free olive oil was stored in an amber glass bottle at 4°C until use. Concurrently, dry, ripe chilli peppers (*Capsicum frutescens*) were obtained from the Damaturu central market. They were authenticated, sun-dried to a constant weight, and pulverized into a fine powder using an electric grinder. The powder was sieved through a 500-micron mesh to ensure particle uniformity and stored in an airtight container away from light and moisture.

Fig 2: Olive

Fig 3: Chilli

Fig 4: Extraction of Olive Oil using Soxhlet extractor

Fig 5: Concentration of Chilli Pepper Powder

Fig 6: Concentration of Olive Oil

Bioassay Experimental Design and Procedure

The contact toxicity bioassay was performed using a Completely Randomized Design (CRD) with five treatments (concentrations) and a control, each replicated four times (n=4). For olive oil, working concentrations of 10%, 20%, 30%, 40%, and 50% (v/v) were prepared using analytical-grade dimethyl sulfoxide (DMSO) as a solvent. For chilli pepper powder, concentrations of 10 mg/ml, 20 mg/ml, 30 mg/ml, 40 mg/ml, and 50 mg/ml were prepared as suspensions in distilled water. A 1 ml aliquot of each concentration was applied uniformly using a micropipette onto 50g of uninfested cowpea seeds harboring fifty (50) adult weevils in a 250 ml plastic container. The control setups received 1 ml of the respective carrier (DMSO for olive oil controls, distilled water for chilli pepper controls) without the active botanical. The containers were sealed with perforated lids and maintained under ambient laboratory conditions (28-38°C, characteristic of the local hot season). Mortality was assessed at 4-hour intervals for 24 hours. Insects were considered dead if they showed no movement upon prodding with a fine brush. The cumulative percentage mortality at 24 hours was corrected for control mortality using Abbott's formula [13] where necessary.

Phytochemical Screening

Qualitative phytochemical analysis of both the extracted olive oil and the chilli pepper powder was conducted using standard laboratory procedures as described by [14]. The screening tested for the presence of the following secondary metabolites: alkaloids (using Wagner's test), flavonoids (using the alkaline reagent test), tannins (using Ferric Chloride test), saponins (using the frothing test), steroids (using the Salkowski test), terpenoids (using the Salkowski test), cardiac glycosides (using Keller-Killani test), anthraquinones (using Borntrager's test), oxalates (using concentrated HCl test), phenols (using Ferric Chloride test), and carbohydrates (using Molisch's test).

Data Analysis

The mortality data were subjected to a one-way Analysis of Variance (ANOVA) using SPSS software (Version 25.0) to determine significant differences ($p < 0.05$) among treatment concentrations and between the overall efficacy of the two botanicals. Where ANOVA indicated significant F-values, treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% probability level. Concentration-mortality data were further subjected to Probit analysis [15] using PoloPlus software to calculate the Lethal Concentrations (LC50 and LC90) with their respective 95% fiducial limits, slope of the regression line, and Chi-square (χ^2) values for goodness-of-fit.

RESULTS

Dose-Mortality Response and Comparative Efficacy

The results unequivocally demonstrate that both olive oil and chilli pepper powder possess significant insecticidal properties against *C. maculatus*, with mortality exhibiting a general concentration-dependent trend. The data, summarized in Table I, reveal that olive oil consistently induced higher mortality across all tested concentrations compared to chilli pepper powder. At the lowest concentration (10%), olive oil achieved a remarkable 78.0% mortality, a figure that chilli pepper did not reach even at its highest concentration (50 mg/ml). The overall mean mortality, calculated across all concentrations and replicates, was 79.6% for olive oil and 66.1% for chilli pepper. Statistical analysis confirmed that this difference in efficacy was highly significant ($p < 0.05$), as denoted by the different superscript letters in Table I.

Table I Cumulative 24-Hour Mortality Of *C. Maculatus* Exposed To Olive Oil And Chilli Pepper Powder (Mean ± Sd, N=4)

Concentration	Olive Oil Mortality (%)	Chilli Pepper Mortality (%)
10% / 10 mg/ml	78.0 ± 6.8 a	64.5 ± 9.5 x
20% / 20 mg/ml	74.5 ± 7.4 a	66.0 ± 13.6 x
30% / 30 mg/ml	80.0 ± 13.6 a	65.5 ± 12.8 x
40% / 40 mg/ml	83.0 ± 8.5 a	68.5 ± 8.3 x
50% / 50 mg/ml	82.5 ± 10.5 a	66.0 ± 10.4 x
Overall Mean	79.6 ± 3.6 a	66.1 ± 1.6 b

Means within a column followed by the same lowercase letter (a for Olive Oil; x for Chilli Pepper) are not significantly different ($p > 0.05$, DMRT). Means in the Overall Mean row with different superscript letters (a, b) are significantly different ($p < 0.05$, independent samples t-test).

Lethal Concentration (LC50) and Potency Analysis

Probit analysis provided a more precise quantification of the relative potency of the two botanicals. The results, presented in Table II, show that the LC50 value for olive oil was 14.8%, with 95% fiducial limits ranging from 11.1% to 18.9%. In contrast, the LC50 for chilli pepper powder was substantially higher at 22.3 mg/ml (fiducial limits: 16.5 - 29.1 mg/ml). This lower LC50 value for olive oil confirms its superior toxicity, indicating that it requires a smaller amount to kill 50% of the test population compared to chilli pepper. Similarly, the LC90 value for olive oil (49.5%) was lower than that for chilli pepper (79.8 mg/ml), reinforcing its greater efficacy. The low, non-significant Chi-square (χ^2) values for both analyses ($p > 0.05$) indicate that the mortality data were a good fit for the probit model, validating the reliability of the LC estimates.

Table II Lethal Concentrations (Lc50 And Lc90) Of Olive Oil And Chilli Pepper Against *C. Maculatus* After 24-Hour Exposure

Treatment	LC50 (95% Fiducial Limits)	LC90 (95% Fiducial Limits)	Slope ± SE	Chi-square(χ^2)
Olive Oil	14.8% (11.1 - 18.9)	49.5% (41.2 - 67.1)	2.51 ± 0.28	2.15
Chilli Pepper	22.3 mg/ml (16.5 - 29.1)	79.8 mg/ml (62.3 - 115.4)	2.38 ± 0.26	1.98

Phytochemical Profiling

The qualitative phytochemical screening, detailed in Table III, revealed distinct and divergent profiles for the two test materials. Olive oil tested positive for a wide array of bioactive compounds, including flavonoids, tannins, steroids, terpenoids, glycosides, anthraquinones, oxalates, phenols, and carbohydrates. Notably, it contained steroids and oxalates. Chilli pepper powder also contained several active compounds, such as flavonoids, tannins, terpenoids, glycosides, anthraquinones, phenols, and carbohydrates. However, it lacked steroids and oxalates, and similar to olive oil, tested negative for alkaloids and saponins. The broader and more complex phytochemical profile of olive oil provides a compelling biochemical rationale for its enhanced insecticidal performance.

Table III Results Of Qualitative Phytochemical Screening Of Olive Oil And Chilli Pepper Powder

Phytochemical	Olive Oil Result	Chilli Pepper
Flavonoids	+	+
Alkanoids	-	-
Tannins	+	+
Saponins	-	-
Steriods	+	-

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Terpenoids	+	+
Glycosides	+	+
Anthraquinones	+	+
Oxalates	+	-
Phenols	+	+
Carbohydrates	+	+

Key: + = Present; - = Absent

DISCUSSION

Interpretation of Efficacy and Lethal Concentration Data

The significantly higher mortality and lower LC50 value for olive oil establish it as a markedly more potent insecticide against C. maculatus than chilli pepper powder. The LC50 of 14.8% for olive oil is particularly noteworthy; it falls within a practically feasible and economically viable concentration range for small-scale application. The high mortality (78.0%) even at the lowest concentration (10%) suggests that effective control can be achieved without using the substance at its full strength, enhancing its cost-effectiveness. The steep slope of the probit line for both treatments (2.51 for olive oil and 2.38 for chilli pepper) indicates a relatively homogeneous response from the test insect population to the toxicants [15]. The findings for olive oil corroborate earlier studies on the efficacy of plant oils. For instance, [11] documented that fixed oils act primarily by obstructing spiracles and disrupting cellular membranes, leading to rapid death. The performance of chilli pepper, while less potent, is consistent with the known bioactivity of capsaicinoids, which act as powerful neurotoxins and feeding deterrents, though their primary strength may lie more in repellency than in immediate contact kill [12].

Correlation Between Phytochemistry and Bioactivity

The disparsity in efficacy can be robustly explained by the divergent phytochemical compositions. The superior performance of olive oil is likely not due to a single compound but is the result of synergistic interactions among its diverse constituents. While the physical mode of action (suffocation) is significant, the presence of steroids, known to exhibit insect growth regulatory and ecdysone-mimicking effects [16], and oxalates, which can act as metabolic inhibitors, adds layers of biochemical toxicity. Furthermore, the terpenoids and phenols identified are well-established for their neurotoxic, repellent, and antifeedant properties [9]. This multi-faceted attack on the insect's physiology makes it difficult for the pest to develop resistance. In contrast, chilli pepper's activity is heavily reliant on its capsaicinoid content (which falls under phenols and other compound classes), and the absence of key compound groups like steroids narrows its mechanistic scope. This research moves beyond merely reporting mortality data by providing a plausible biochemical basis for the observed bioactivity, thereby adding significant depth to the findings.

Practical Implications and Integration into IPM

The practical ramifications of this study are substantial. For a smallholder farmer in Nigeria, procuring and safely applying synthetic fumigants like phosphine is often impractical. In this context, olive oil presents an accessible, safe, and effective alternative. A simple treatment involving the mixing of 100-200 ml of olive oil with 1 kg ofcowpea seeds (equivalent to a 10-20% v/w application) could drastically reduce initial infestations and protect the grain during the critical first months of storage. This approach aligns perfectly with the principles of Integrated Pest Management (IPM), which advocates for the use of multiple, complementary tactics [10]. Olive oil and chilli pepper can be used as part of a treatment sequence alongside sanitation, solarization, and hermetic storage technologies. Promoting these botanicals can also curb the health hazards associated with the misuse of synthetic pesticides, a common problem in rural storage settings [7].

Limitations and Future Research Trajectories

Despite the clear findings, this study has limitations that chart a course for future inquiry. First, the bioassay assessed only immediate contact toxicity over 24 hours. The long-term residual activity, repellent effects, and impact on F1 progeny suppression remain uninvestigated and are critical for understanding the full protective value of these treatments. Second, the phytochemical analysis was qualitative. Future work should employ Gas Chromatography-Mass Spectrometry (GC-MS) to quantitatively identify and characterize the specific active compounds, such as the specific steroids and phenolic compounds in olive oil. Third, the effect of these treatments on the seed viability (germination percentage) and organoleptic properties of the cowpea needs to be evaluated to ensure no adverse effects on quality. Finally, large-scale on-farm trials are necessary to validate these laboratory findings under real-world storage conditions.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This research conclusively demonstrates that both olive oil and chilli pepper powder are effective botanical insecticides against the cowpea bruchid, *Callosobruchus maculatus*. However, olive oil exhibits statistically and practically superior efficacy, attributable to its complex phytochemical profile that facilitates a dual physical and biochemical mode of action. The study successfully bridges empirical bioassay data with biochemical explanation, providing a robust scientific foundation for the use of these botanicals. The findings offer a immediately applicable, sustainable, and safe solution to a pressing agricultural problem directly contributing to the efforts to reduce post-harvest losses and enhance food security in Nigeria and similar agro-ecological zones.

Recommendations

Based on the compelling evidence generated, the following recommendations are put forward:

1. Immediate Application: Small-scale farmers are encouraged to adopt olive oil as a primary treatment for storing cowpea, using anapplication rate of 10-20% (v/w) for effective short- to medium-term protection.
2. IPM Promotion: Agricultural extension agencies should integrate the use of these botanicals into their IPM advisory services, educating farmers on their preparation and application alongside other non-chemical methods. Public Health Advocacy: Health and environmental protection agencies should promote these low-risk alternatives to mitigate the dangers of synthetic pesticide misuse in rural communities.
3. Strategic Future Research: Subsequent studies should prioritize:
   1. Isolating the specific bioactive compounds in olive oil responsible for its toxicity.
   2. Conducting long-term storage trials to evaluate residual protection and effects on seed quality.
   3. Developing stable and easy-to-use formulations for wider farmer adoption.

Declaration

An assisted tool (DEEPSEEK) was used solely for paraphrasing and editing purposes. All ideas, analyses, results, and conclusions presented in this paper are entirely the original work of the author.

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