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Application of Neem and Moringa Seed Oil as Botanical Preservative for Cowpea (*Vigna Unguiculata* L. Walp)

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ABSTRACT

Purpose: *Cowpea, a valuable grain with high protein, carbohydrate, and vitamin content, faces significant post-harvest losses due to insufficient storage, pest infestations, and inefficient processing techniques. Thus, the efficacy of a combination of neem and moringa seed oils in a 1:3 ratio, serving as botanical insecticides, to control Callosobruchus maculatus infestation in five different cowpea varieties was evaluated.*

Research Method: *The extracts were mixed at a ratio of 1:3 neem-moringa seed oils and applied mechanically to cowpea varieties in a concentration of 5.0. They were kept in plastic bowls measuring 17 cm deep by 24 cm wide, covered with muslin cloth for free-flow ventilation, and stored for 360 days.*

Findings: *The result of the data collected at every 60 days showed that the seed extracts were effective in preserving all the cowpea varieties even at 360 days. The results indicate that certain cowpea varieties, such as Ife brown (IFB), were more prone to weevil attacks, while others, like Lobia brown (BGR), shown relatively lower susceptibility. The control samples exhibited a higher number of egg-laying and weevil populations compared to the treated samples.*

Value: *The study revealed that the treatment successfully eradicated the weevil population and prevented new infestations.*

Keywords: *Botanical preservative, Callosobruchus maculatus, Cowpea varieties, Moringa seed oil, Neem seed oil .*

INTRODUCTION

Cowpea, scientifically known as *Vigna unguiculata* L. Walp, holds significant importance as a tropical legume crop with its origins in Africa. It has seamlessly integrated into the tropical cropping system, particularly in the semi-arid West Africa Savannah (Omomowo and Babalola, 2021). Cowpea is well known for its adaptability in difficult environments with limited water resources and poor soil quality. This resilience renders it a valuable crop for small-scale farmers, particularly in areas where other crops face difficulties in adaptation. Beyond its nutritional value as a seed, cowpea plays a crucial role in nitrogen fixation, enhancing soil fertility, and diminishing the reliance on synthetic fertilizers. This dual functionality points out its significance as a sustainable and resource-efficient agricultural choice (Srinivasan *et al.*, 2021). Recognized as the second most crucial food grain legume, cowpea serves as an economical protein source for humans. The grain itself is not only nutritious but also cost-effective. With protein levels ranging from 22% to 29% and carbohydrate content between 60% and 64%, cowpea also encompasses essential mineral elements and vitamins (Ilesanmi and Gungula, 2016a).Moreover, cowpea boasts a high dietary fibre content, making it an excellent option for promoting a healthy digestive system.

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Additionally, its low glycemic index ensures a gradual and controlled increase in blood sugar levels, rendering it advantageous for individuals managing diabetes or seeking to regulate their blood sugar (Sabarathinam, 2023). These nutritional attributes position cowpeas as a valuable crop for addressing malnutrition and enhancing food security, especially in areas with constrained resources. Furthermore, its versatility is evident in its ability to thrive in diverse agro-ecological conditions, making it adaptable for cultivation in various regions globally (Srinivasan *et al.*, 2021).

Despite its significant nutritional and economic value, global post-harvest losses of cowpea have been reported to surpass 45%, with the West Coast region experiencing a particularly high rate of 25%, primarily due to extensive damage caused by the cowpea bruchid (*Callosobruchus maculatus*) (Adomi *et al.*, 2023). These losses not only impact food security but also have economic implications for farmers and traders in the region. Efforts to develop effective pest management strategies and improve storage facilities are crucial to mitigating the impact of cowpea bruchid infestations and reducing post-harvest losses in the West Coast region. Cowpea holds paramount importance as a key economic and nutritional crop in West Africa, playing a vital role in enhancing food security and reducing poverty in households within the region (Aboagye *et al.*, 2017). It serves as a source of food, cash, and fodder for farming households in Nigeria, making storage challenges a critical issue in the cowpea trade within the region (Dougoud *et al.*, 2019). Storage challenges in the cowpea trade within the region need to be addressed in order to ensure food security and poverty reduction.

On a global scale, safeguarding crops from insect infestations poses a significant challenge. The conventional use of synthetic chemicals in insect-pest control raises concerns due to their inherent toxicity, which poses risks to the health of farmers, animals, and consumers alike. Synthetic chemicals are mostly dangerous because they are toxic. They can have bad effects through a number of different exposure routes, such as breathing in chemical droplets or touching your skin with dirty hands. Recognizing the adverse effects of these synthetic pesticides on human health, there is a growing emphasis on exploring botanical insecticides. Dougoud *et al.* (2019) also emphasized that botanical insecticides emerge as a practical alternative in the context of developing and subsistence agriculture, given the difficulties associated with the limited availability of synthetic pesticides and their high costs for farmers and transitional growers. Botanical insecticides, also referred to as natural insecticides, are naturally existing chemicals, specifically insect toxins that are extracted or derived from plants or minerals. These insecticides have a selective impact, affecting only the target insects without harming beneficial natural enemies (Ngegba *et al.*, 2022). This selectivity contributes to residue-free food and a safer environment. As highlighted in the study by Hikal *et al.* (2017), these natural insecticides play a crucial role in pest management. They are substances utilized to eliminate pests that pose a threat or cause damage to desired crops (Sarasan *et al.*, 2011

Botanical insecticides derived from plants present a promising substitute for synthetic chemicals in pest control. These naturally occurring compounds demonstrate effective pest management properties while exhibiting lower risks to both human health and the environment. Furthermore, botanical insecticides typically have a shorter persistence in the environment, mitigating the potential for long-term contamination (Ngegba *et al.*, 2022). This dual benefit makes them a compelling and environmentally conscious choice for pest control. They are also generally considered safer alternatives to synthetic insecticides. These alternatives are gaining traction not only for their effectiveness but also for being cost-efficient and environmentally friendly, as highlighted in the study by Hikal *et al.* (2017). They have shown promising results in controlling pests without posing significant risks to human health and the environment. According to Boursier *et al.* (2011), neem, as a botanical insecticide, exhibits various properties such as insecticidal, repulsive, anti-ovipositional, and growth-regulating effects on different types of insects. Neem functions as a natural insect repellent, deterring insects from initiating feeding. It serves as a deterrent factor during the initial stages of ingestion, acting as a feeding deterrent. Neem's effectiveness as an insecticide is attributed to its ability to inhibit feeding, regulate growth, prevent egg laying, and eliminate pathogens. The presence of azadirachtin in neem plays a crucial role in these actions, making it a powerful natural deterrent against insects (Kilani-Morakchi *et al.*, 2021; Adusei and Azupio, 2022).

Despite the acknowledged insecticidal efficacy of neem oil by numerous researchers, its widespread acceptance has been hindered due to the sulphurous odor it imparts to grains, resulting in bitterness that affects the acceptability and marketability of the produce. To address this issue, Ilesanmi and Gungula (2010) introduced a solution by blending neem oil with moringa oil, aiming to mitigate the bitter taste. Moringa, known for its stability as a natural oil, is rich in behenic acid, palmitic acid, stearic acid, and oleic acid. It also functions as a natural antibacterial agent, which is commonly used as a preservative in the food industry. Moringa oil is characterized by its odorless to nutty flavor, sweetness, non-stickiness, and resistance to rancidity (Fahad *et al.*, 2010.

A previous study by Ilesanmi and Gungula (2016a) demonstrated that a mixture of neem and moringa seed oils in a 1:3 ratio, applied at a concentration of 5.0/g of cowpea, achieved a success rate of over ninety percent in preserving cowpea. Further assessments of the proximate composition (Ilesanmi and Gungula, 2016b) and amino acid composition (Ilesanmi and Gungula, 2016c) revealed no adverse effects on these parameters. Importantly, the concentration of the oils was confirmed to be non-toxic to humans, and it did not significantly impact the palatability of stored cowpea and its products (Ilesanmi *et al.*, 2017). The results of these studies indicate that the combination of neem and moringa seed oils in a 1:3 ratio holds promise as a natural alternative for preserving cowpea, offering a viable solution without compromising its composition or taste. The absence of toxicity and adverse effects on proximate and amino acid compositions enhances its appeal as a safe and effective option for both farmers and consumers. This finding points out the potential of this natural mixture as a practical and sustainable method for cowpea preservation in agricultural and food contexts.

However, the effectiveness of this oil concentration should be tested on different varieties of cowpeas because they have different amounts of soluble sugars. These sugars are very important for how well cowpea seeds store and handle abiotic stress (Weng *et al.*, 2018). The objective of this research is to assess the potential of the neem and moringa seed oil mixture for preserving the commonly grown cowpea varieties in sub-Saharan Africa, specifically in Nigeria. The results of this investigation will provide insights into the applicability and efficacy of the oil combination and contribute to the development of sustainable pest management strategies for cowpea cultivation in Nigeria.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the laboratory of the Department of Food Science and Technology, situated in the Faculty of Agriculture at Modibbo Adama University in Yola, Adamawa State, Nigeria.

Sample Location and Preparation

All five varieties of cowpea Loabha Brown (ALT), Lobia Brown (BGR), Black Eyed Cowpeas (BLK), Ife Brown (IFB), and California Black Eyed Cowpeas (WBE) were procured from the local market in Girei Local Government Area of Adamawa State, Nigeria. Subsequently, they underwent a sorting process to eliminate broken and damaged seeds, as well as contaminants like dry pods and stones. The cleaned cowpea samples were then sun-dried to achieve a moisture level between 10% and 12%, minimizing the risk of mould infestation. The neem and moringa seeds utilized in this research were obtained from Modibbo Adama University in Yola, Nigeria. Neem seeds were handpicked from neem trees planted around the university's teaching and research areas. Moringa seeds were harvested from the university's teaching and research farm. These sourcing methods ensured the use of locally available materials for the study. This approach promoted sustainability and supported the local economy.

Extraction of Neem and Moringa Seed Oils

The cold water extraction methods described by Hussein *et al.* (2021) were adopted for the extraction of neem seed oil, while moringa seed oil was extracted by the method described by Ilesanmi *et al.* (2021). These specific extraction techniques were chosen to obtain neem and moringa seed oils in a manner consistent with established procedures in relevant literature.

Breeding of the Experimental Weevil

The extraction of weevils from already-infected cow-peas and their introduction into a sterile, uninfected cowpea environment were the two steps involved in breeding the experimental weevil. The weevils were then left to develop under ambient temperatures until the emergence of the first Filia generation (F1), as detailed by Gever and Echezona (2023). Subsequently, this cohort of weevils, carefully selected based on their sexes (male and female), was utilized for the purposes of the experiment.

Treatment and Experiment Design

This experiment was laid out on a laboratory bench in a completely randomized design (CRD) with three replications. Every variety of cowpea was weighed out and treated with $5.0\,\mu$L/g of a mixture of neem and moringa seed oils in a 1:3 ratio (Ilesanmi and Gungula, 2016b). The grains were clean and had a moisture content of between 10% and 12%. Fifteen (15ml) of the oil mixture were poured into a 20Kg capacity mixer containing 3Kg of cowpea and mixed vigorously to ensure uniform exposure of the cowpea to the oil. In three sets of 2l-capacity plastic bowls, 1Kg of the treated sample was transferred into each bowl. The untreated sample (1Kg) was poured into the same-size plastic bowl and saved as a control. Thereafter, ten male and ten female *Callosobruchus maculatus* (0 to 24 hours old) that were already starved for 24 hours were introduced into each set of the treated cowpea. Each container was then covered with 10-mesh muslin cloth to allow free air circulation and to prevent the weevil from escaping. This experimental procedure was repeated for the remaining four varieties of cowpea, and the samples were randomly positioned on the laboratory bench for observation (Figure 01). The research took place under ambient conditions with an average temperature of 25.86 (78.55) and a relative humidity of 74%.

The treatment combinations were represented as follows: ALTC, BRGC, BLKC, IFBC, and WBEC were not treated (control), while ALT1, ALT2, ALT3, BRG1, BRG2, BRG3, BLK1, BLK2, BLK3, IFB1, IFB2, IFB3, and WBE1, WBE2, and WBE3 received the same treatment of 5.0 of ratio 1:3 neem and moringa seed oils.

Data Collection

The data collected encompassed various parameters, including the total weevil populations, insect mortality, cowpea grain percentage weight loss, number of eggs laid, emergence holes, and the percentage of healthy grains at each observation interval.

Determination of Total Weevil Population The total weevil population of cowpea varieties after every 60 days of storage was recorded. This was obtained by counting and recording the number of all the live plus the dead weevils, according to the method of Ilesanmi and Gungula (2010).

Determination of Insect Mortality To assess insect mortality, all weevils, alive and dead, were separated through sieving, allowing the live ones to move out, and then counting and recording the dead weevils every 60 days over the 360-day research period.

Determination of Total Weight Loss The weight loss of both treated and untreated cowpea samples was determined by measuring and recording the difference in weight at 60-day intervals from the beginning of the experiment until the end of the 360-day storage period. The percentage weight loss was calculated as follows:

$$\frac{A-B}{A} \times 100$$

Where:

- A = weight of the sample at the commencement of the experiment.
- B = weight of the sample after 60 days of storage.

Determination of Percentage of Healthy Grains The percentage of healthy grains was determined by weighing 20g of randomly selected cowpea grains as a representative sample from the 1kg sample in the bowl. From this 20g, the healthy grains were separated from the damaged grains, and the weight of the healthy grains was recorded.The percentage of healthy grains was then calculated as:

$$\frac{x}{x_1} \times 100$$

Where:

- x = the weight of the healthy grains.
- x_1 = the weight of the representative sample (20g).

Determination of Total Number of Eggs Laid The count of eggs laid was acquired by observing and counting the number of eggs on each infested grain. This examination was conducted using a magnifying lens on a 20g randomly selected representative sample from each container. The observations were made at 60-day intervals starting from the initiation of the experiment, following the methodology described by Ilesanmi and Gungula (2010).

Determination of Number of Emergence Holes The calculation of the number of emergence holes involved selecting a representative sample by weighing 20g of the 1kg of cowpea in each plastic container. Subsequently, the number of grain perforations was counted, and the number of perforations per grain was recorded as part of the assessment process. This method allowed for an accurate estimation of the overall number of emergence holes in the entire batch of cowpeas.

Total Emergence Holes = Summation of all perforations per infested grain

Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) according to the procedure outlined for a completely randomized design (CRD). The detection of differences among treatment means for significance was done with Duncan's multiple range tests, and the differences were considered significant

Figure 1: The Samples on the Laboratory Bench.

at a 5% probability level. Microsoft Excel spreadsheet software version 2016 was used to perform all the experimental calculations and plotting. The results were then analyzed and presented in the form of graphs and tables.

RESULTS AND DISCUSSION

The weight of cowpea seeds exhibited a consistent decline over the storage months, as depicted in Figure 02. Generally, the reduction was more noticeable in untreated samples in comparison to those subjected to treatment throughout the 12-month storage period. Nevertheless, there was a slight increase in the cowpea weight at the conclusion of the 12-month storage period compared to the weight recorded at the tenth month. These sudden increments in cowpea weight were attributed to a rise in relative humidity, increasing from 62-80% in June to 82-90% in July. Even with these changes, the treated ALT (843.05 grams), BGR (846.09 grams), and IFB (791.86 grams) cowpea varieties were better at protecting themselves from insect attacks than the treated BLK (670.68 grams) and WBE (676.44 grams) cowpea varieties. This is evident from their respective weights after the 12-month storage period when compared to the initial weight of 1000 grams. The ALT, BGR, and IFB cowpea varieties' higher weights compared to the BLK and WBE varieties indicate that the treatment effectively increased their resistance to insect attacks, according to the results. These findings point out the significance of taking into account both storage conditions and the specific cowpea variety when implementing measures for insect protection.

The untreated grains exhibited a higher weight loss compared to the treated grains (Figure 03), indicating that the mixture of neem-moringa seed oil at a ratio of 1:3 serves as an effective protectant for stored grains against storage insects. This resulted in a significant reduction in grain damage and, consequently, a lower overall weight loss.The findings of this study align with the research conducted by Ilesanmi and Gungula (2010) and Ilesanmi and Gungula (2013), who reported that the ratio 1:3 mixture of neem-moringa seed oil was the most effective in protecting cowpea seeds. This effectiveness could be attributed to the complementary nature of the two oils, where the combination enhances their protective properties more effectively than the individual oils. The present study's results are consistent with various other research findings that have explored different plant extracts against prevalent stored product insect pests. These studies have consistently demonstrated the susceptibility of insects to the contact and fumigant properties of botanical extracts (Adesina and Aderibigbe, 2021). Consequently, the neem-moringa seed oil mixture presents itself as a promising alternative to traditional synthetic insecticides and fumigants, offering an environmentally friendly approach to managing insect pests in stored agricultural produce.

The results presented in Figure 04, indicating the

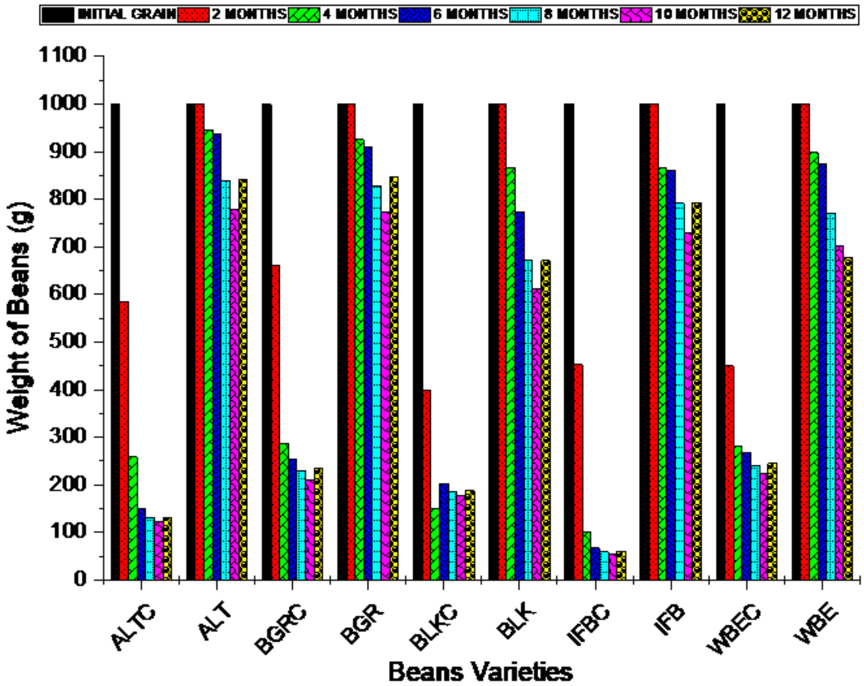

Figure 2: Weight of Cowpea Varieties After Every 2 Months of Storage

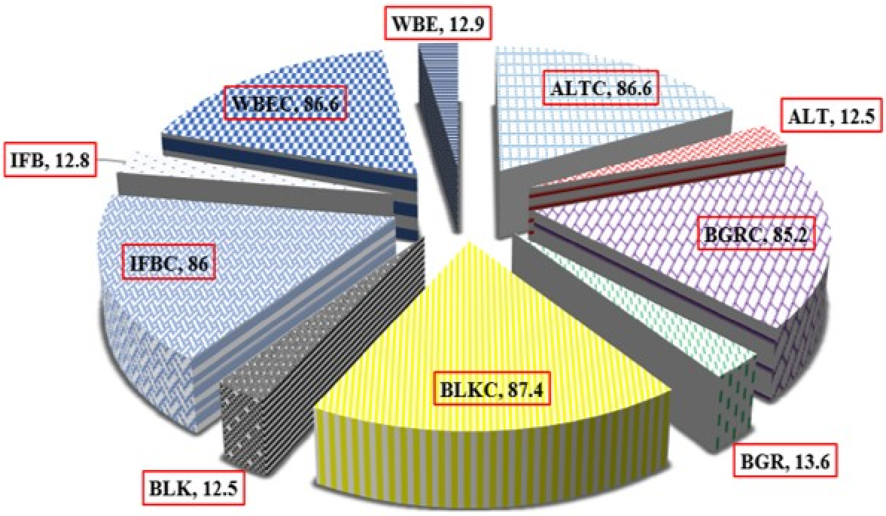

Figure 3: Percentage of Weight Loss

percentage of healthy grains, reveal that the treated cowpea varieties experienced less damage compared to their untreated counterparts. At the end of the second month of storage, it was noted that none of the untreated samples retained healthy cowpeas. Conversely, the treated samples maintained over 85% healthy grains across all evaluated cowpea varieties, demonstrating the efficacy of the botanical preservative employed.The high percentage of healthy grains in the treated samples also indicates that the preservative could be a promising solution for maintaining grain quality and reducing losses in storage. This result is consistent with studies by Kilani-Morakchi *et al.* (2021), Ngegba *et al.* (2022), Adusei and Azupio (2022), and Gever and Echezona (2023), who looked into various plant products for protecting cowpea from insect pest damage during storage.

The percentage of healthy grains for IFBC (1.46%), WEBC (2.50%), BLKC (5.74%), ALTC (10.64%), and BGRC (14.50%) indicates the susceptibility of these cowpea varieties to weevil attacks, as observed in the current study. These results indicate that specific cowpea varieties, such as IFBC, were more susceptible to weevil attacks, whereas others, like BGRC, displayed comparatively lower vulnerability. Recognizing these differences is essential for devising effective strategies to safeguard stored cowpeas against weevil infestation, taking into account the distinct characteristics of each cowpea variety. Additionally,

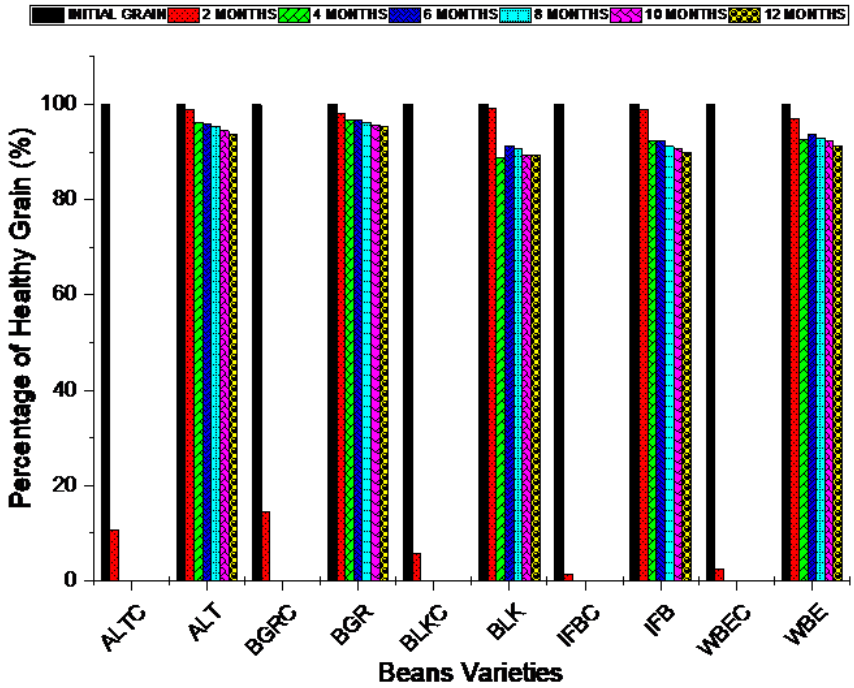

Figure 4: Percentage of Healthy Grains After Every 2 Months of Storage

Table 1: Total Number of Average Egg Laid After Every 2 Months of Storage

Samples	Initial number of Egg Laid	2 Months	4 Months	6 Months	8 Months	10 Months	12 Months
ALTC	0	47000	501	0	0	0	0
ALT	0	0	0	0	0	0	0
BGRC	0	28800	4185	0	0	0	0
BGR	0	0	0	0	0	0	0
BLKC	0	340000	359	0	0	0	0
BLK	0	0	0	0	0	0	0
IFBC	0	513500	**619**	0	0	0	0
IFB	0	0	0	0	0	0	0
WBEC	0	663500	**690**	0	0	0	0
WBE	0	0	0	0	0	0	0

pinpointing the cowpea varieties with higher susceptibility enables farmers to concentrate on implementing targeted pest management techniques tailored to those specific varieties. This awareness can contribute to minimizing reliance on broad-spectrum insecticides and encouraging the adoption of more sustainable and environmentally friendly approaches to protect stored cowpeas

Table 01 shows the total number of eggs laid after every 2 months of storage. The number of eggs laid by cowpea weevils was significantly high for the control sample, whereas no eggs were laid on the treated samples. This implies that the botanical oils effectively prevent adult bruchids from laying eggs. This is in concordance with the result obtained by Gever and Echezona (2023) when they tested the synergistic effects of neem and palm kernel oils on the cowpea weevil infestations of stored cowpea. The result they obtained revealed that the admixing of neem oil and palm kernel oil has the potential insecticidal efficacy of controlling the cowpea weevil of stored cowpea and could be used to reduce *C. maculatus* infestation of stored cowpea.

Table 2: Average number of Emergence Hole after Every 2 Months of Storage

Samples	Initial Number of Hole	2 Months	4 Months	6 Months	8 Months	10 Months	12 Months
ALTC	0	1340	1462	0	0	0	0
ALT	0	7	7	7	7	7	7
BGRC	0	127	212	0	0	0	0
BGR	0	4	4	4	4	4	4
BLKC	0	231	303	0	0	0	0
BLK	0	1	3	3	3	3	3
IFBC	0	152	152	0	0	0	0
IFB	0	1	1	1	1	1	1
WBEC	0	1600	1679	0	0	0	0
WBE	0	11	11	11	11	11	11

The significant increase in the number of eggs laid by cowpea weevils in the control samples was observed to be due to seed nutrients and their size variability. Ventury *et al.* (2022) reported that the presence of nutrients in stored cowpea plays a crucial role in influencing the ovipositional behaviour of *C. maculatus*. Increased concentrations of essential nutrients like proteins, carbohydrates, and lipids have been observed to potentially enhance the attractiveness of cowpeas to female beetles for oviposition. The characteristics of the seed type, such as its surface area and shape, also affect whether an egg is suitable for oviposition by *C. maculatus* (Badii *et al.*, 2013). Abdel-Fattah and Ahmed (2007) reported that the surface area of cowpea seeds varies across different varieties, with a positive correlation between the number of eggs laid per seed and its surface area. Similarly, Musa and Adeboye (2017) noted that the size of cowpea seeds may offer favourable conditions for egg deposition and the development of *C. maculatus*. Cope and Fox (2003) observed that the female *C. maculatus* assesses available resources within a seed more accurately by comparing surface area ratios between seeds of different sizes. Furthermore, they noted that female bruchids not only lay more eggs on larger grains but also distribute their eggs based on the relative mass of available grains. These observations help elucidate why eggs were not evenly distributed among the evaluated cowpea varieties, as they exhibited different surface areas and rough seed coats. Moreover, Ilesanmi and Gungula (2010) reported that the weevil was able to lay eggs on the control samples due to the lack of botanical insecticide treatment

Tiroesele *et al.* (2014) stated that nutrient availability in stored cowpeas could affect *Callosobruchus maculatus* larvae's feeding behaviour, potentially influencing the creation of emergence holes. Similarly, Szentesi (2021) observed that variations in seed coat texture among cowpea varieties can also affect larvae's penetration and emergence behaviour, potentially influencing the size and distribution of holes created by beetles. These factors were observed to have caused the increased emergence of holes by *C. maculatus* in the untreated stored cowpea varieties.

Table 03 presents the results of the weevil population on different cowpea varieties. Out of the initial 20 weevils introduced to the cowpeas, a notable increase in weevil populations was observed in the control samples compared to the treated ones. Following 2 months of storage, WBEC had the highest increase (12,154), followed by BLKC (9,366), ALTC (8,601), IFBC (8,011), and BGRC (6,526). This susceptibility order was attributed to variations in nutrient availability. These variations in nutrient availability may have influenced the growth and reproduction rates of the weevils in each cowpea variety. Tigist *et al.* (2018) and do Nascimento *et al.* (2022) have also documented a similar observation, indicating that plant compositions serve as sources of resistance against cowpea weevils. Therefore, understanding the mechanisms behind this resistance could potentially lead to the development of more sustainable pest management strategies in agriculture

The higher increase in weevil populations in the control samples suggests that these varieties may provide a more favorable environment for their survival and reproduction compared to the treated ones. However,

Table 3: Total Weevil Population after Every 2 Months of Storage

Samples	Initial Number of Weevils	2 Months	4 Months	6 Months	8 Months	10 Months	12 Months
ALTC	20	8601	6932	0	0	0	0
ALT	20	23	0	0	0	0	0
BGRC	20	6526	10496	0	0	0	0
BGR	20	23	0	0	0	0	0
BLKC	20	9366	4439	0	0	0	0
BLK	20	28	0	0	0	0	0
IFBC	20	8011	8945	0	0	0	0
IFB	20	23	0	0	0	0	0
WBEC	20	12154	3377	0	0	0	0
WBE	20	26	0	0	0	0	0

after 4 months of storage, the rankings changed, with BGRC having the highest (10,496), followed by IFBC (8,945), ALTC (6,932), BLKC (4,439), and WBEC (3,377). The decrease in nutrient availability in the stored cowpeas may have led to a decline in the survival and reproduction of weevils. This supports the findings of Ogbuefi *et al.* (2023), who noted that high infestation levels can result in a reduction of nutritional values in the cowpeas, further impacting the number of surviving weevils. By the end of 6 months of storage, no surviving weevils were found in any cowpea variety, indicating their eventual demise.

Conversely, the treated cowpea varieties exhibited no significant weevil growth, and at the 4-month mark, no weevils were present in any cowpea variety. This result shows that the oil mixtures used effectively stopped the growth of the weevil population over the course of the 12-month storage period. As a result, there were no weevils in the treated cowpea varieties. This finding highlights the potential of using the mixture of neem and moringa seed oils as a natural and efficient method for controlling weevil populations in stored cowpeas. The genetic variability within grains was also identified as a contributing factor to variations in total weevil populations. According to Lopes *et al.* (2018), the genetic diversity of grains includes many agronomic traits, such as grain size, color, texture, and the presence of proteins that protect against cowpea weevils. Therefore, the ability of *Callosobruchus maculatus* to reproduce in different types of cowpeas may be connected to the unique genotype traits of those types. These genotype traits may affect the suitability of the grains as a food source for the cowpea weevils, influencing their reproductive success. Furthermore, the presence of proteins that protect against cowpea weevils in certain types of cowpea may act as a deterrent for the insects, reducing their population size.

From the results obtained in this study (Table 04), the mixture of neem and moringa seed oils used caused the death (mortality) of the 20 adult bruchids introduced and the newly emerged weevils in the treated samples after 2 months of storage. Also, there was a significant death rate of weevils in the untreated samples after 2 months of storage. The mortality rate observed in the treated samples points out the promise of these natural oils as a safe and effective substitute for synthetic pesticides in pest control during storage. At the end of 4 months of storage, no weevils were found in the treated samples, which justified the effectiveness of the botanical oil used for the preservation. On the other hand, the mortality rate of the untreated samples increased. This increment was observed to be due to the loss of nutrient value of the stored cowpeas and the life spans of adult bruchids. Jehajo and Shah (2023) reported that *C. maculatus* can complete one generation within 3–4 weeks at 30°C and an average relative humidity of 30%. At the end of six months of storage, no weevils were found in the samples; they were all dead. This implies that the botanical oil used for preservation successfully inhibited the growth and reproduction of *C. maculatus*. Furthermore, the complete absence of weevils in the treated samples after six months suggests that the preservation method effectively maintained the quality and safety of the stored cowpeas. Ahmad *et al.* (2022) and Ogbuefi *et al.* (2023) found that the decline in nutrient content of stored cowpeas can indirectly impact weevil mortality by affecting their ability to survive and reproduce.

Weevils, similar to other pests, rely on stored cowpeas for nourishment and moisture. If the cowpeas lose their nutrient content due to ageing or improper storage, the weevils may not consider them suitable for sustaining their populations. Moreover, spoiled

Table 4: Insects Mortality After Every 2 Months of Storage

Samples	Initial Number of Dead Insects	2 Months	4 Months	6 Months	8 Months	10 Months	12 Months
ALTC	0	4914	8720	0	0	0	0
ALT	0	23	0	0	0	0	0
BGRC	0	4331	10272	0	0	0	0
BGR	0	22	0	0	0	0	0
BLKC	0	5301	8371	0	0	0	0
BLK	0	28	0	0	0	0	0
IFBC	0	4609	6880	0	0	0	0
IFB	0	22	0	0	0	0	0
WBEC	0	8007	4380	0	0	0	0
WBE	0	26	0	0	0	0	0

Figure 5: The images of the cowpeas varieties after the 12 months of storage .

cowpeas resulting from nutrient loss could become more susceptible to mould and other pathogens, further compromising the health and lifespan of weevils (Kumar and Kalita, 2017). Furthermore, the decrease in nutrient levels of stored cowpeas can result in diminished fertility and compromised immune systems in weevils. This vulnerability may render them more susceptible to diseases and other environmental challenges, ultimately increasing their mortality rates

Figure 05 displays the images of the treated cowpea varieties after 12 months of storage. The stored cowpeas exhibited minor indications of discoloration, shrinkage, and dehydration. There were no signs of weevil infestation or mould growth, while the untreated ones had spoiled. This implies that the treated cowpea varieties showed good resistance to deterioration compared to the untreated cowpeas. In general, the treated cowpeas retained their shape and size reasonably well throughout the storage duration. The lack of weevil infestation and mould growth indicates that appropriate storage conditions were upheld. These quality characteristics may suggest that treated and stored cowpea varieties will be viable and good for consumption or sale in the future.

CONCLUSION

The effectiveness of the treatment oil in deterring weevils has been proven through the results of this study. Among the cowpea varieties examined, ALT, BGR, and IFB exhibited reduced susceptibility to infestation and damage by *C. maculatus*. Hence, these varieties are suggested for use by farmers to control *C.*

maculatus during storage. Additionally, these resistant varieties can be integrated into breeding initiatives aimed at developing varieties that are resilient to *C. maculatus* in storage. These studies highlight the importance of understanding the role of plant compositions in pest management strategies. By identifying specific plants, that exhibit resistance against cowpea weevils, farmers and researchers can develop targeted interventions to protect crops and minimize economic losses. Additionally, further investigation into the mechanisms underlying this resistance could provide valuable insights for breeding programmes aimed at developing cowpea varieties with enhanced pest resistance.

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