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IMPACT OF RE-DRYING TREATMENT ON BEAN WEEVILS (*CALLOSOBRUCHUS MACULATUS*) AND NUTRITIONAL COMPOSITION OF INFESTED STORED COWPEAS

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Abstract

This study investigated the impact of re-drying treatments- drying at 40 °C and 60 °C, sun drying, and a non-dried control on the post-harvest quality of cowpea (*Vigna unguiculata*) and its resistance to *Callosobruchus maculatus* infestation during storage. Treated cowpea grains were stored for 84 days, with key metrics assessments including *C. maculatus* egg hatchability (28 days), adult emergence (12 days), grain damage, weight loss, and nutrient changes. Drying at 60 °C significantly reduced egg hatchability and adult beetle emergence ($p \leq 0.05$), resulting in the lowest percentage of grain damage and weight loss. Sun drying and drying at 40 °C exhibited moderate protective effects, whereas the control group showed the highest infestation and deterioration. Nutritional analysis revealed that while high-temperature drying slightly decreased protein content, it recorded the highest carbohydrate and crude fiber. These findings suggest that re-drying, especially at 60 °C, is a promising post-harvest strategy for controlling bruchid infestation and preserving cowpea grain quality during storage.

Keywords: egg-laying; storage; survivorship; re-drying; weight loss

1. Introduction

Bean weevils, identified as prevalent storage pests of cowpeas, possess the capability to inflict considerable harm upon stored crops if intervention is not executed (Nboyine *et al.,* 2024). This pest engages in feeding activities on seeds, thereby compromising their structural integrity and diminishing their overall quality (Dlamini *et al*., 2024; Ogbonnaya *et al.,* 2024). Consequential to such damage is the potentiality for notable economic detriment experienced by agrarians, coupled with a subsequent reduction in food accessibility for indigenous populations (Kabir, 2023).

The high reproductive rate and short life cycle of *Callosobruchus maculatus* are significant factors in its capacity to infest stored cowpeas (Bidar *et al.,* 2021). This pest typically deposits six to thirteen eggs per seed on the surface of cowpea grains, where the larvae subsequently hatch and bore into the seeds to consume the nutritional content therein, thereby reducing grain quality (Ventury *et al*., 2022). The larvae will undergo pupation within the seeds before emerging as adult weevils that are prepared to perpetuate the cycle through further egg-laying (Mendoza and Carrillo, 2023; Golizadeh *et al*., 2025; Hamzei *et al.,* 2023). Interventions that disrupt the life cycle of *Callosobruchus maculatus* is pivotal for devising effective control strategies to curtail their effects on stored cowpeas.

Various determinants may contribute to the infestation of bean weevils in stored cowpeas. One significant determinant is the moisture content of the beans; elevated moisture levels may create an optimal environment for the reproduction and development of weevils (Gbarage *et al*., 2024). Additionally, poorly ventilated or unsealed storage environment can also enhance infestation (Dubey *et al*., 2024).

Cowpeas, which hold nutritionally and economically significant importance as a staple crop in numerous developing nations, deliver critical nutrition and income for a multitude of individuals (Affrifah *et al*., 2021; Mekonnen *et al*., 2022; Horn *et al*., 2022; Abebe and Alemayehu, 2022). Nonetheless, the infestation of cowpeas by bean weevils during storage presents a considerable threat to food security and economic stability. Efforts directed at curbing this pest via conventional techniques, such as fumigation and utilization of insecticides, have shown restrained efficacy owing to growing insecticide resistance and ecological apprehensions (De Carvalho Brito *et al*., 2021; Salihu *et al*., 2023; Ferreira *et al*., 2024). This deficiency in dependable pest control methodologies accentuates the imperative for avant-garde and enduring solutions to mitigate bean weevil afflictions in stored cowpeas. The objectives of the study are (i) to determine the effect of periodic re-drying (at 7-day intervals) on the percent hatchability of *Callosobruchus maculatus* eggs; (ii) to evaluate the survivorship of *C. maculatus* in re-dried versus non-re-dried stored cowpeas over 84 days and (iii) to evaluate the extent of grain damage and percentage weight loss due to *C. maculatus* infestation under re-drying treatment and compare the nutritional composition (protein, carbohydrate, fat, moisture, fiber, ash) of cowpeas subjected to re-drying and those kept under normal ambient storage conditions after 84 days

2. Materials and Methods

2.1 Experimental Procedure

2.1.1 Insect culture

A laboratory culture of *Callosobruchus maculatus* was established using cowpea grains in aerated 1 Liter containers maintained at 28 ± 2 °C and 65 ± 5% RH under continuous darkness/light. Freshly emerged adults (0–48 h old) were used**.**

2.1.2 Seed preparation

Clean, undamaged cowpea seeds were adjusted to 11–12% moisture content prior to use**.**

2.1.3 Evaluation of the effect of re-drying treatment on the hatchability of *Callosobruchus maculatus* on cowpea in storage

Upon acquiring the cowpea seeds, the initial phase of the experiment involved disinfesting the samples by placing them in a freezer (Thermocool Haier, HTF-319H) at -18 °C for a duration of 14 days to eliminate any insect contamination (Johnson and Valero, 2003). A quantity of 100 grams of the disinfested cowpea was measured and placed into a ziplock polythene bag measuring 15x20 cm. Subsequently, the cowpea grains were infested with 20 pairs of adult *Callosobruchus maculatus*, after which the bags were sealed in triplicates. The insects were permitted to lay eggs on the grains for a period of 3 days before their removal. On the fourth day, re-drying treatments commenced, continuing for 28 days at intervals of 7 days, as the transformation from egg to larval stage occurs 4 days post-oviposition (Salunkhe & Gaikwad, 2023). The hatchability percentage was assessed at 7-day intervals following infestation. Re-drying was conducted using a cabinet dryer at temperatures of 40 °C and 60 °C, along with one hour of sundrying. Cowpea samples were arranged on clean trays covered with fine mesh to prevent the escape of insects. The grains were incubated at room temperature and humidity to facilitate the development of the insects from the egg to larval stage. A stereomicroscope was employed to count the number of eggs on each seed, and the hatchability percentage was calculated based on the ratio of the total number of eggs laid to the number of eggs that hatched, indicated by the presence of empty egg shells.

$$\text{Egg Hatchability (\%)} = \frac{\text{Number of hatched egg}}{\text{Number of total laid egg}} x\ 100 \quad \text{......Equation 1}$$

(Alamuoye, 2019)

2.1.4 Evaluation of the effect of re-drying treatment on the survivorship of adult *Callosobruchus maculatus* on cowpea in storage

One hundred grams of dried and disinfected cowpea were placed into ziplock polythene bags measuring 15 cm by 20 cm. Subsequently, the cowpea grains were infested with 20 pairs of adult *Callosobruchus maculatus*, and the bags were sealed. A re-drying treatment was conducted at three-day intervals over a period of twelve days, with the exception of the control group, which did not undergo re-drying. The re-drying process utilized a cabinet dryer set at temperatures of 40 °C, 60 °C, and included one hour of sun drying. Insects were immobilized by refrigeration (4 °C, 4 min) before re-drying to prevent escape. Once immobilized, the cowpea samples were transferred to clean drying trays and covered with fine mesh to further inhibit insect escape. This precautionary measure was also implemented during the counting process to ensure that the insects remained contained. Prior to sealing the cowpeas in the ziplock polythene bags, the number of live adult insects was recorded.

$$\text{Survivorship (\%)} = \frac{\text{Number of live adult}}{\text{Number of total adult insects introduced}} x\ 100 \quad \text{......Equation 2}$$

(Alamuoye, 2019)

2.1.5 Evaluation of Grain Damage, Weight Loss, and Nutritional Composition after Storage

One hundred (100) grams of disinfested cowpea were placed into an 8x12 cm ziplock polythene bag. Following this, the cowpea grains were infested with 20 pairs of adult *Callosobruchus maculatus* insects, and the bags were sealed. The insects were allowed to lay their eggs on the grains for three days before their removal. The cowpea grains were stored in the ziplock polythene bags in three replicates, followed by re-drying treatments conducted over 84 days at seven-day intervals. Re-drying was performed using a cabinet dryer at temperatures of 40°C and 60°C, as well as through sundrying for one hour. At the conclusion of the 84-day period, the evaluation of the percentage of damaged grains, weight loss, and the nutritional composition of the stored cowpeas was carried out.

2.1.6 Evaluation of percent damaged grains

Fifty disinfested cowpeas were placed in an 8x12 cm ziplock polythene bag for storage. The cowpea grains, stored in ziplock polythene bags across three replicates, underwent re-drying treatments every 7 days for a total duration of 84 days, while the control samples remained untreated. At the conclusion of the 84-day period, an assessment was made to determine the percentage of damaged cowpea grains during storage.

$$Damaged\ Grains\ (\%) = \frac{Number\ of\ grains\ with\ exit\ holes}{\text{Total number of grains assessed}}\ X100 \qquad \text{Equation 3}$$

2.1.7 Weight loss determination

Weight loss evaluation was conducted following 84 days of storage. The weight loss was calculated using the formula outlined below:

$$Weight\ loss\ \% = \frac{\text{Initial weight} - Final\ weight}{\text{Initial weight}}\ X100 \qquad \text{Equation 4}$$

(Alamuoye, 2019)

2.1.8 Determination of Nutritional composition

Samples were collected from both the experimental and control groups to assess the nutritional value of cowpea after 84 days of storage. The analysis was conducted following the standard procedures outlined by the AOAC (2012). To enhance the reliability of the findings, the experiment was performed in triplicate.

2.2 Statistical analysis

Data were analyzed using IBM SPSS Statistics 20, 2011, one-way ANOVA ($p < 0.05$). Hochberg's GT2 was used for post hoc mean separation. (IBM SPSS, 2011)

3. Results and Discussion

3.1 Egg Hatchability After 28 Days of Storage

The impact of various re-drying methods on the hatchability of *Callosobruchus maculatus* eggs was found to be significant ($p < 0.05$). As indicated in Table 1.0, the control group (non-redried seeds) demonstrated the highest hatchability rate, averaging 87.80 ± 0.06%. In contrast, seeds subjected to re-drying in sunlight, at 40 °C, and at 60 °C exhibited markedly lower hatchability rates of 15.40 ± 0.06%, 35.30 ± 0.17%, and 10.60 ± 0.12%, respectively.

The substantial decrease in hatchability observed in the re-dried treatments can be linked to the reduction in seed moisture content and the effects of surface temperature. The higher temperature of 60 °C probably caused death in the developing embryos by affecting enzyme activity or increasing drying at the egg-seed interface. Similar detrimental effects on egg development due to high drying temperatures have been documented by Liu *et al*. (2021);

Ivimey-Cook *et al*. (2021); Ortis *et al*. (2022), who associated decreased hatchability with moisture stress and thermally induced embryonic arrest.

Although sun-drying and drying at 40 °C were less severe, they still significantly hindered hatchability compared to the control, indicating that even moderate moisture loss can adversely affect the viability of seeds for egg development. These results highlight the vulnerability of *C. maculatus* eggs to physical postharvest treatments, especially those that diminish available moisture during the early stages of embryogenesis.

3.2 Adult Survivorship After 12 Days of Storage

Adult survivorship over a 12-day period exhibited significant variation across different treatments ($p < 0.05$). The control group demonstrated the highest survivorship rate at 85.00 ± 5.77%, followed by seeds dried at 40°C (30.00 ± 2.89%), while both the 60°C and sunlight treatments resulted in 0.00 ± 0.00% survivorship (Table 1.0).

The observed decrease in adult survival correlates with increased drying intensity, indicating a direct link between seed moisture levels and the physiological condition of adult insects. Adults that were placed with seeds subjected to high drying conditions—especially those re-dried at 60°C—likely experienced rapid water loss due to low surrounding humidity and insufficient hydration from the seed substrate. This aligns with the cuticular desiccation which explains how bruchid adults can quickly lose body moisture in dry storage environments (Murdock *et al*., 2012).

Seeds dried in sunlight proved to be as desiccating as those subjected to higher temperature treatment, adversely affecting survivorship. This finding underscores the potential of natural re-drying as an effective strategy for managing bruchids in resource-constrained storage systems. These results are consistent with earlier research by Othman (2014), which noted increased adult mortality associated with lower grain moisture content.

Among the various treatments, re-drying at 60°C was the most effective in decreasing both egg hatchability and adult survivorship, followed by sun-drying and drying at 40°C. However, the feasibility of each method should be taken into account. While drying at 60°C is effective, it may not be practical in conventional storage environments. In contrast, sun-drying presents a more accessible option, offering moderate effectiveness without energy costs, making it appealing for smallholder farmers.

Table 1. Effects of re-drying treatments on egg hatchability and adult survivorship of *Callosobruchus maculatus* on cowpea after 28 and 12 days of storage, respectively

Treatments	Hatchability (%)	Survivorship (%)
Cabinet drying at 40^0 C	$35.30±0.17^a$	$30.00±2.89^b$
Cabinet drying at 60^0 C	$10.60±0.12^b$	$0.00±0.00^a$
Sun drying	$15.40±0.06^c$	$0.00±0.00^a$
Control	$87.80±0.06^d$	$85.00±5.77^c$

The results represent the average values of triplicate measurements ± standard error of mean. Mean values in the same column that share the same letter are not significantly different at $p≤0.05$.

3.3 Effect of Periodic Re-drying on Grain Damage and Weight Loss in Cowpea During 84-Day Storage

The effects of periodic re-drying treatments on the physical integrity of stored cowpea grains were assessed by measuring the percentage of damaged grains and the associated weight loss over an 84-day storage duration. The treatments, which included exposure to sunlight, re-drying at temperatures of 40 °C and 60 °C, as well as a control group that did not undergo re-drying, demonstrated significant differences ($p < 0.05$) in both metrics. This underscores the importance of moisture management in reducing postharvest losses primarily attributed to infestations by *Callosobruchus maculatus*.

The control group exhibited the highest level of grain damage, with 48.10 ± 0.06% of grains affected after 84 days, a figure that was markedly greater than the damage observed in the sun-dried (25.55± 0.12%), 40 °C (7.8 ± 0.12%), and 60 °C (4.7 ± 0.12%) treatments (Table 2.0).

This trend supports the hypothesis that periodic re-drying effectively lowers seed moisture to levels that are detrimental to bruchid development (Singh & Mishra, 2022). The reduced moisture content in the re-dried treatments hindered oviposition and larval growth, thus minimizing feeding damage. The treatment at 60 °C proved to be particularly effective, likely due to its direct thermal effects on insect eggs, larvae, or emerging adults, which disrupts the pest life cycle (Zhang *et al*., 2025).

Both sun-drying and the 40 °C treatment also significantly mitigated damage compared to the control, although their effectiveness was somewhat less than that of the 60 °C treatment. The moderate efficacy of sunlight drying can be attributed to its reliance on prevailing weather conditions, which may influence the consistency of the drying process.

3.4 Weight Loss of Cowpea Grains

A comparable pattern was noted in the weight loss of cowpea grains (Table 2.0). The control group exhibited the greatest average weight loss at 26.40 ± 0.06%, followed by sundried grains at 14.40 ± 0.12%, those dried at 40 °C at 11.10 ± 0.06%, and finally, grains dried at 60 °C at 6.60 ± 0.06% (Table 2.0). These weight losses are directly linked to the internal consumption of the grains by *C. maculatus* larvae and the damage caused by pest activity.

Weight loss is a more comprehensive measure of economic impact than merely assessing visible grain damage, as even minimally infested grains can suffer significant internal degradation (Stathers *et al*., 2020; Hassan *et al*., 2021). The notable decrease in weight loss associated with high-temperature re-drying highlights the dual advantages of this method: it reduces pest establishment and curtails metabolic and microbial degradation due to elevated moisture levels. The findings indicate that re-drying at 60 °C is the most effective approach for reducing both grain damage and weight loss, making it particularly suitable for controlled environments or commercial storage.

Table 2. Effect of re-drying on percent damaged grains and weight loss, of cowpeas in storage for 84-days

Treatments	Damaged Grains (%)	Weight Loss (%)
Cabinet drying at 40^0 C	7.80±0.12^b	11.10±0.06^c
Cabinet drying at 60^0 C	4.70±0.12^d	6.60±0.06^d
Sun drying	25.55±0.12^c	14.40±0.00^a
Control	48.10±0.06^a	26.40±0.06^a

The results represent the average values of triplicate measurements ± standard error of mean. Mean values in the same column that share the same letter are not significantly different at p≤0.05.

3.5 Effect of Periodic Re-drying Treatments on the Nutritional Composition of Cowpea Grains During 84-Day Storage

Re-drying cowpea grains at intervals of seven days had a notable effect on their nutritional profile over a storage period of 84 days ($p < 0.05$). The different treatments, which included exposure to sunlight, re-drying at temperatures of 40 °C and 60 °C, as well as a control group that was not re-dried, exhibited distinct influences on moisture retention, nutrient loss, and the overall stability of the grains.

3.5.1 Protein Content

The protein content exhibited a gradual decrease as the drying intensity increased. The control sample maintained the highest protein concentration at 23.40 ± 0.12%, followed by the 40 °C treatment at 23.10 ± 0.00%, sun drying at 23.00 ± 0.00%, and the 60 °C treatment at 22.50 ± 0.06% (Table 3). This reduction in protein levels at elevated drying temperatures and prolonged heat exposure aligns with the processes of thermal denaturation and the Maillard reaction, which impact nitrogenous compounds during extended storage and re-drying cycles (Ogori, 2022). Re-drying at 40 °C and through sunlight exposure resulted in significantly lower protein degradation, likely due to the moderate heat application, suggesting that these methods are more effective for preserving protein integrity during long-term storage.

3.5.2 Crude Fat Content

Crude fat content consistently declined across all re-drying treatments, with the most pronounced reduction noted in the 60 °C group (2.20 ± 0.00%) when compared to the control group (2.5 ± 0.06%) (Table 3.0). The processes of heat and oxygen exposure accelerate fat oxidation, and repeated drying intensifies this deterioration. The treatments involving sunlight and 40 °C exhibited intermediate fat levels (2.3 ± 0.06% and 2.40 ± 0.03%, respectively), indicating that moderate conditions help mitigate lipid degradation.

3.5.3 Moisture Content

Moisture levels were notably lower in all re-dried treatments compared to the control throughout the storage duration. After 84 days, the control group exhibited the highest moisture content at 11.40 ± 0.06%, followed by sun drying at 9.9 ± 0.00%, 40 °C drying at 9.10 ± 0.12%, and 60 °C drying at 8.10 ± 0.03% (Table 3.0). Regular re-drying effectively mitigated moisture reabsorption from the environment, particularly in high-temperature settings.

Re-drying at 60 °C consistently resulted in the lowest moisture content in the grains, thereby enhancing their resistance to microbial growth and insect infestations. Nevertheless, excessively low moisture levels could adversely impact seed viability (Ali *et al*., 2018; Awosanmi *et al*., 2022). Both sunlight and 40 °C drying methods maintain moderate moisture levels that are conducive to storage and seed preservation.

3.5.4 Carbohydrate Content

A modest yet statistically significant rise in carbohydrate levels was observed in the re-dried treatments, with measurements varying from 54.50 ± 0.06% in the control group to 59.00 ± 0.06% at 60 °C (Table 3.0). This noticeable increase is likely due to concentration effects resulting from decreased moisture and fat content, as it is unlikely that actual carbohydrate synthesis occurs during storage. These findings are consistent with the observations made by Coradi *et al*. (2022). who reported comparable alterations in their postharvest drying research.

3.5.5 Crude Fiber

The crude fiber levels exhibited consistent stability across the various treatments, with only slight fluctuations observed: control (4.30 ± 0.06%), sunlight (4.50 ± 0.12%), 40 °C (4.40 ± 0.06%), and 60 °C (4.70 ± 0.03%) (Table 3.0). This indicates that fiber, as a structural element, is not significantly influenced by different storage and drying methods. These findings further confirm the resilience of dietary fiber in legumes during postharvest processing (Aravindakshan *et al*., 2021).

3.5.6 Ash Content

The ash content, which reflects the total mineral content, exhibited a slight yet significant reduction as the intensity of re-drying increased. The control sample had the highest ash content at 3.9 ± 0.12%, followed by sunlight exposure at 3.7 ± 0.06%, re-drying at 40 °C at 3.6 ± 0.06%, and finally, 60 °C at 3.5 ± 0.06% (Table 3). This decline may be attributed to the volatilization of certain minerals or losses incurred from prolonged exposure to heat and air (Asiedu *et al*., 2021; Ntswane *et al*., 2024). Although the reductions are minor, they indicate a need for caution when implementing high-temperature postharvest methods.

While re-drying periodically at 60 °C effectively controlled moisture levels, it also led to the most significant nutrient losses, particularly in protein and fat. In contrast, re-drying under sunlight and at 40 °C yielded more favorable results, maintaining nutritional quality while adequately reducing moisture to safe storage levels. Practically, re-drying using sunlight is a viable and economical choice for smallholder farmers, providing reasonable protection against spoilage with minimal nutrient degradation. The 40 °C method could be suitable for semi-industrial storage systems where energy consumption is manageable. Although the 60 °C treatment is effective for disinfestation, it may not be the best option for preserving the complete nutritional profile of cowpea grains during long-term storage.

Table 3. Effect of 7 days interval re-drying on the nutritional composition of stored cowpea grains after 84 Days

Treatments	Nutritional Composition					
	Protein	Crude Fat	Moisture	Carbohydrate	Crude Fiber	Ash
Control (No Redrying)	23.40±0.12^{c}	2.50±0.06^{b}	11.40±0.06^{d}	54.50±0.03^{a}	4.30±0.06^{a}	3.90±0.12^{ab}
Redried at 40^{0} C	23.10±0.00^{bc}	2.40±0.03^{ab}	9.10±0.12^{b}	57.40±0.00^{c}	4.40±0.06^{ab}	3.60±0.06^{b}
Redried at 60^{0} C	22.50±0.06^{a}	2.20±0.00^{a}	8.10±0.03^{a}	59.00±0.06^{d}	4.70±0.03^{b}	3.50±0.06^{ab}
Sundried	23.00±0.00^{b}	2.30±0.06^{ab}	9.90±0.00^{c}	56.60±0.06^{b}	4.50±0.12^{ab}	3.70±0.06^{a}

The results represent the average values of triplicate measurements ± standard error of mean. Mean values in the same column that share the same letter are not significantly different at $p \leq 0.05$.

4. Conclusion

Re-drying cowpea seeds through exposure to sunlight, as well as treatments at 40 °C and 60 °C, significantly diminished the hatchability of *C. maculatus* eggs and the survival rate of adult beetles when compared to untreated controls. These results underscore the effectiveness of re-drying, particularly at 60 °C, as a viable postharvest disinfestation method. Nonetheless, due to considerations of accessibility and the preservation of seed integrity, sun-drying remains a practical and environmentally friendly alternative for managing bruchid pests in cowpea storage systems.

Re-drying cowpea grains at intervals of seven days notably decreased both the proportion of damaged grains and weight loss over a storage period of 84 days. The treatment at 60 °C provided the most substantial protection, followed by the 40 °C treatment and sun-drying. Implementing periodic re-drying is a straightforward, cost-effective, and efficient strategy for controlling storage pests, particularly *C. maculatus*, and should be regarded as an essential element of postharvest preservation methods for cowpeas.

The application of re-drying treatments at seven-day intervals had a significant impact on the nutritional profile of cowpea grains stored for 84 days. While drying periodically at 60 °C effectively reduced moisture levels, it also resulted in notable losses of protein and fat content. In contrast, treatments using sunlight and 40 °C were more successful in maintaining nutritional quality, indicating their appropriateness for sustainable postharvest management. It is crucial for smallholder farmers and storage facility managers to adopt redrying method to ensure grain preservation for long-term cowpea storage as it ensures effective pest control and reduced rejection rates due to infestation.

5. Recommendation

Although re-drying at elevated temperatures demonstrates effective pest suppression. However, excessive or prolonged exposure to heat could compromise seed viability for future planting. Subsequent research is recommended with a focus on germination rates following treatment to ensure a balance between pest control and seed preservation.

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