Effect of Ultra Violet Irradiated Food on Survival Rate of *Tribolium confusum*

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Abstract: The present study investigates the effect of ultraviolet (UV-C) irradiated food substrates on the survival of *Tribolium confusum*, a major stored grain pest. Wheat, barley, and sorghum grains were subjected to UV-C radiation (254 nm) at different exposure durations (5, 10, and 15 minutes), and their impact on stage-wise survival of the insect (egg to larva, pupa, and adult) was evaluated under controlled laboratory conditions. The results revealed that UV irradiation of grains significantly reduced the survival of *T. confusum* in a dose-dependent manner. Under control conditions, high survival rates were observed across all developmental stages; however, survival progressively declined with increasing UV exposure time. The reduction was moderate at 5 minutes, more pronounced at 10 minutes, and substantial at 15 minutes of exposure. A consistent decrease in survival from egg to adult stage indicated cumulative adverse effects of UV-treated food on insect development. Among the tested grains, wheat supported comparatively higher survival, followed by barley and sorghum. The observed effects are attributed to indirect mechanisms, including alterations in nutritional quality and possible formation of photochemical products in irradiated grains. The findings suggest that UV-C treatment of stored grains can serve as a potential eco-friendly and residue-free method for managing *T. confusum*, although its effects are less severe than direct UV exposure. This approach may contribute to sustainable pest control strategies in stored grain systems.

Keywords: UV-C irradiation; *Tribolium confusum*; stored grain pests; survival rate; wheat; barley; sorghum; pest control.

Introduction: -

The rapid growth of the global population has created an urgent need to enhance both the quantity and quality of food production. Over the past few decades, remarkable progress in science and technology has contributed significantly to economic development and increased agricultural productivity (Pingali and Abraham, 2022). Innovations associated with technological advancement and the industrial revolution have transformed traditional agricultural practices, resulting in higher crop yields. However, with the global population expected to rise sharply by 2050, food demand is projected to increase dramatically, making it essential to further boost agricultural output. Studies indicate that improving crop productivity and optimizing the management of existing agricultural produce, rather than expanding cultivable land, is a more sustainable approach to ensuring food security (Frona et al., 2019). Nevertheless, agricultural production continues to face serious challenges due to environmental factors such as global warming, frequent droughts, fluctuations in atmospheric carbon dioxide (CO_2) levels, and unpredictable weather patterns (Lin et al., 2022). These abiotic factors not only affect crop growth but also influence insect pest biology, their population dynamics, and their interactions with host plants and natural enemies, all of which ultimately impact crop yield (Cannon, 1998). Globally, approximately 18% of crop production is lost due to insect damage alone, excluding additional losses caused by plant diseases and weeds.

Among the insect pests associated with stored products, several groups are of major importance. Five species of beetle pests are frequently found infesting stored grain. Among them, *Oryzaephilus surinamensis* (L.), *Sitophilus granarius* (L.), and *Cryptolestes ferrugineus* (Stephens) are considered major pests that cause severe damage and significant infestations. In contrast, *Typhaea stercorea* (L.) and *Ahasverus advena* (Waltl) are typically linked with poor storage conditions or mould-contaminated grain; however, their presence can still result in the rejection of grain during marketing (Cox and Collins, 2002). *Tribolium confusum* (Herbst), commonly known as the confused flour beetle, is a significant secondary pest of stored grain products. It infests a wide variety of processed food materials, including flour, nuts, biscuits, chocolate, pulses, spices, and dried fruits. Due to its high reproductive potential, it is capable of causing substantial losses during storage. This pest is widely distributed and frequently found in households, storage facilities, mills, warehouses, and food processing units. Infestation by *T. confusum* leads to deterioration in food quality, resulting in discoloration and mouldy conditions in flour (Hassan et al., 2017; Trematerra and Sciarretta, 2004; Pasha and Abd-Eltawab, 2022).

Insect pests can occur at every stage of the food production chain, ranging from field conditions and greenhouse cultivation to storage facilities and domestic environments. Their presence is not only problematic due to visible damage and food spoilage but also because they contribute to contamination through microbial agents, shed skins (exuviae), and faecal matter (frass), which may trigger allergic reactions and transmit diseases. Crop losses caused by insect pests are significant both before and after harvest. Preharvest losses account for approximately 35% of potential crop yield globally, while postharvest losses-including those occurring during transportation, storage, processing, and distribution—can contribute an additional 35%. However, these estimates may vary widely depending on factors such as climatic conditions, crop species, agricultural practices, socioeconomic status of farmers, and the level of technological adoption. Managing and, where possible, reducing or eliminating major pest populations remains one of the central challenges in applied ecology, requiring a comprehensive understanding of ecological interactions to effectively regulate pest populations (Adhikari, 2022).

The control of insect pests is therefore a critical component of agriculture, as unchecked infestations can result in severe losses, ranging from about 50% in wheat to over 80% in cotton production (Oerke, 2006; Sharma et al., 2017). In stored products, pest management primarily depends on preventive strategies aimed at minimizing infestation and spoilage. These include proper design and maintenance of storage structures, strict sanitation practices, regular inspection and monitoring, and effective regulation of environmental parameters such as temperature and moisture. Maintaining appropriate moisture levels and preventing temperature fluctuations in stored grains is especially important to avoid the formation of hotspots that promote pest development. While biological control can contribute to pest suppression, it cannot replace these preventive measures and is generally used as a complementary strategy to keep pest populations below economic thresholds. In cases where infestations occur, control measures such as insecticide application, fumigation, and alternative methods like modified atmospheres and temperature treatments are employed. Phosphine fumigation remains the most commonly used method due to its effectiveness and low cost; however, its extensive and improper use has led to the development of resistance in many stored product pests. Additionally, growing concerns regarding pesticide residues, human health risks, environmental impacts, and the increasing demand for organic food products have reduced the acceptability of chemical control methods. These challenges emphasize the need for safer, sustainable, and environmentally friendly pest management approaches (Hervet and Morrison, 2021).

One of the major difficulties in managing storage pests lies in the limited availability of effective chemical control options. Many conventional insecticides are highly toxic to non-target organisms, including humans, and their residues or degradation products may contaminate treated food. Furthermore, repeated use of these chemicals increases the risk of resistance development in pest populations. In response to these concerns and the growing emphasis on sustainable agriculture, there is increasing interest in alternative, chemical-free pest control strategies. Various approaches have been explored, including the use of inert dusts such as diatomaceous earth, application of essential oils and other plant-derived compounds, and treatment of stored products using different forms of electromagnetic radiation. Numerous studies have investigated the use of irradiation techniques, including microwave, infrared, ultraviolet, X-ray, and gamma radiation, for effective pest control. These methods have shown promising results in reducing pest populations and improving storage protection (Keszthelyi et al., 2023).

In recent years, increasing attention has been directed toward the use of ultraviolet (UV) radiation as a non-chemical approach for pest management. Unlike direct irradiation of insects, treating food substrates with UV radiation offers an indirect method of influencing insect survival by altering the physical and chemical properties of the food. Such changes may affect insect feeding behaviour, development, and overall survival. This approach provides a safer and residue-free alternative, aligning with the growing demand for sustainable pest control methods. Therefore, the present study was undertaken to evaluate the effect of UV-C irradiated food substrates on the survival of *Tribolium confusum*. By examining stage-wise survival across different grains and exposure durations, the study aims to assess the potential of UV-treated food as an effective and environmentally friendly strategy for managing stored product pests.

Materials and Methods: -

- **Insect Culture and Maintenance:** The culture of *Tribolium confusum* used in the present study was obtained. The stock culture, along with the experimental insects, was maintained under controlled laboratory conditions in a darkened incubator at a temperature of 27 ± 0.5°C and relative humidity of 70 ± 5%. The insects were reared on clean grains. Adult beetles were allowed to oviposit on finely sifted medium, and freshly laid eggs were collected carefully and used for further experimentation.
- **Preparation of Food Substrates:** Wheat, barley, and sorghum grains were selected as food substrates for the experiment. The grains were initially disinfected by immersing them in 1% sodium hydroxide (NaOH) solution for 5 minutes to eliminate surface contaminants. After disinfection, the grains were thoroughly rinsed three to four times with sterilized distilled water to remove any traces of the chemical. The cleaned grains were air-dried under sterile conditions and used for subsequent ultraviolet irradiation treatment.
- **Ultraviolet (UV-C) Irradiation of Grains:** The prepared grains were exposed to ultraviolet radiation using a UV-C fluorescent lamp (wavelength 254 nm). The irradiation was carried out by placing the grains at a fixed distance of 20 cm from the UV source to ensure uniform exposure. The grains were subjected to three different exposure durations, namely 5 minutes, 10 minutes, and 15 minutes, representing different treatment levels. After irradiation, the treated grains were kept in complete darkness for 24 hours to prevent any photoreactivation effects. Grains that were not exposed to UV radiation were maintained under identical conditions and served as the control.
- **Experimental Design:** The experiment was designed to evaluate the effect of UV-irradiated food on the survival of *T. confusum*. Freshly collected eggs were introduced into separate glass containers (300 ml capacity) containing treated and untreated grains of wheat, barley, and sorghum. Each treatment consisted of control (non-irradiated grains), UV exposure for 5 minutes, 10 minutes, and 15 minutes. The experiment was conducted under controlled environmental conditions with appropriate replication to ensure the reliability of the results.
- **Observation of Survival:** The survival of *T. confusum* was assessed by monitoring the progression of individuals through different developmental stages. Observations were made to record the number of individuals successfully developing from egg to larva, egg to pupa, and egg to adult stages. The observations were carried out at regular intervals using visual inspection and microscopic examination where required. The number of individuals reaching each developmental stage was recorded, and the survival percentage was calculated by comparing the number of surviving individuals with the initial number of eggs introduced.

Result and Discussion: -

The results presented in Table 1 clearly demonstrate that ultraviolet (UV-C) irradiation of food substrates had a pronounced and progressive effect on the survival of *Tribolium confusum* across all developmental stages. Under control conditions, the survival rate was consistently high for all three grains, with egg-to-larva survival ranging from 87.9% to 91.8%, egg-to-pupa survival from 80.5% to 84.7%, and egg-to-adult survival from 72.8% to 78.2%. These values indicate that untreated grains provided favourable nutritional and environmental conditions for normal growth and development of the insect.

A gradual decline in survival was observed with increasing duration of UV-C exposure. At 5 minutes of irradiation, a moderate reduction in survival was evident across all stages. Egg-to-larva survival decreased slightly to 80.5–85.6%, while egg-to-adult survival declined to 65.1–70.3%. This suggests that short-duration UV exposure induces mild stress in the food substrate, possibly altering its surface properties or initiating limited photochemical changes, which in turn affect early larval establishment and subsequent development.

With 10 minutes of UV exposure, the reduction in survival became more pronounced. Egg-to-larva survival decreased to approximately 70–75%, while egg-to-adult survival declined further to 53.4–58.6%. The sharper decline at this exposure level indicates that prolonged UV treatment may significantly affect the nutritional quality of the grains or lead to the formation of inhibitory compounds, thereby interfering with larval feeding efficiency, metabolism, and successful metamorphosis.

The most substantial impact was observed at 15 minutes of UV exposure, where survival was markedly reduced at all developmental stages. Egg-to-larva survival dropped to 57.3–62.4%, and only 39.2–44.5% of individuals successfully reached the adult stage. This consistent decline across stages suggests cumulative stress effects, where initial sub-lethal damage is amplified during subsequent developmental transitions. The reduction in adult emergence indicates that UV-induced changes in the food substrate not only affect early survival but also have long-term consequences on insect development.

A clear stage-wise trend was also evident, with survival progressively decreasing from egg-to-larva to egg-to-adult stages across all treatments. This pattern indicates that even when individuals survive early stages, the adverse effects of UV-treated food accumulate over time, leading to higher mortality during later developmental stages. Such cumulative effects are commonly associated with nutritional deficiencies, reduced energy reserves, or the presence of toxic degradation products formed during UV irradiation.

Table 1. Effect of UV-C irradiated food substrates on stage-wise survival (%) of *Tribolium confusum*

Treatment	Egg → Larva (%)			Egg → Pupa (%)			Egg → Adult (%)		
	Wheat	Barley	Sorghum	Wheat	Barley	Sorghum	Wheat	Barley	Sorghum

Control	91.8 ± 1.2	89.6 ± 1.5	87.9 ± 1.7	84.7 ± 1.4	82.3 ± 1.6	80.5 ± 1.8	78.2 ± 1.3	75.6 ± 1.5	72.8 ± 1.7
UV-5 Min	85.6 ± 1.6	83.2 ± 1.8	80.5 ± 2.0	78.4 ± 1.7	75.9 ± 1.9	73.2 ± 2.1	70.3 ± 1.5	67.8 ± 1.7	65.1 ± 1.9
UV-10 Min	75.2 ± 2.0	72.6 ± 2.2	70.1 ± 2.4	66.8 ± 1.9	64.3 ± 2.1	61.5 ± 2.3	58.6 ± 1.8	56.1 ± 2.0	53.4 ± 2.2
UV-15 Min	62.4 ± 2.3	60.1 ± 2.5	57.3 ± 2.7	52.6 ± 2.1	49.8 ± 2.3	47.2 ± 2.5	44.5 ± 1.9	41.7 ± 2.1	39.2 ± 2.3

Differences among grain types were also observed, with wheat consistently supporting higher survival rates, followed by barley and sorghum. This variation may be attributed to inherent differences in grain composition, including protein content, carbohydrate availability, and structural characteristics. Wheat, being a more suitable host for *T. confusum*, likely mitigates some of the adverse effects induced by UV treatment, whereas sorghum, with relatively lower suitability, exhibits a more pronounced decline in survival.

Conclusion: -

The present study demonstrates that ultraviolet (UV-C) irradiation of food substrates significantly influences the survival of *Tribolium confusum*, with effects becoming more pronounced as exposure duration increases. A clear dose-dependent reduction in survival was observed across all developmental stages, indicating that UV-treated grains adversely affect both early and later stages of insect development. The variation in survival among different grains suggests that the nutritional composition and structural properties of the substrate play an important role in modulating the impact of UV treatment. Wheat supported relatively higher survival, while sorghum showed greater susceptibility to UV-induced effects. The results further indicate that the impact of UV irradiation is cumulative, affecting not only initial survival but also successful completion of the life cycle. Overall, UV-C irradiation of grains presents a promising, non-chemical, and environmentally safe approach for the management of stored grain pests. While the method may not completely eliminate pest populations, it can significantly suppress their development and population buildup.

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