**Assessment of *Tribolium castaneum*-Induced Losses in Finger Millet Flour Quality**

**ABSTRACT**

Finger millet (Eleusine coracana) is a nutritionally rich cereal crop widely cultivated for its health benefits. However, stored grain pests such as the red flour beetle (Tribolium castaneum) pose a significant threat to its quality and storage stability. An experiment was conducted at Agricultural College, Naira, during the summer of 2021–22 to assess the losses caused by T. castaneum in three different varieties of finger millet flour. The study revealed significant variations in weight loss and uric acid accumulation among the varieties. The highest mean weight loss (33.75%) and uric acid content (4.32 mg/100 g flour) were recorded in VR-520 (Suraj), indicating its higher susceptibility to T. castaneum infestation. This was followed by VR-708 (Champavathi), which exhibited 27.95% weight loss and 3.30 mg/100 g of uric acid. The least infestation was observed in VR-847 (Sri Chaitanya), with a comparatively lower weight loss (17.54%) and uric acid content (1.46 mg/100 g). These findings suggest that VR-847 (Sri Chaitanya) has greater resistance to T. castaneum, making it a preferable choice for prolonged storage. The study emphasizes the need for proper storage management and pest control strategies to minimize post-harvest losses and maintain the nutritional quality of finger millet flour.

**Keywords**: Tribolium castaneum, weight loss, uric acid content, storage pest and post-harvest losses

**Introduction**

The post-harvest storage of grains and milled products is a crucial aspect of food security, as improper storage can lead to severe losses due to insect infestations. According to the Food and Agriculture Organization of the United Nations (FAO), 17% of the world's food production today is destroyed during storage (10% by insects and 7% by mites, rodents, and diseases). The insects that infest grains and products during storage may have originated from the farm, as pests of the plants which are later transported to the storage area. They may also have infested the agricultural products during transport, processing or storage. The growth of insect populations in stored food is attributed to the favorable conditions that often prevail during storage and to the abundant nutrients present in the foods on which the insects grow (Stathas et al., 2023).

Among the various insect pests that infest stored food products, Tribolium castaneum (Herbst), commonly known as the red flour beetle, is a major pest of stored grains and processed cereal products worldwide. It belongs to the family Tenebrionidae, which is a highly diverse group of beetles comprising over 10,000 species, out of which approximately 100 species have been identified as serious pests of stored goods (Singh and Prakash, 2015). The cosmopolitan nature of T. castaneum enables it to thrive in different climatic conditions, making it a persistent problem in storage facilities.

Tribolium castaneum is a small beetle with an elongated, flattened, and parallel-sided body, ranging in length from 3 to 10 mm. Adult beetles exhibit varying shades of coloration, including reddish-brown, dark brown, and black. These beetles are highly adaptable and polyphagous, meaning they can feed on a wide range of stored food products, including grains, flour, pulses, dried fruits, and processed food commodities. Unlike primary pests that attack whole grains, T. castaneum is classified as a secondary pest, primarily infesting damaged or processed grain products such as flour, bran, and semolina (Padin *et al*., 2002). It is particularly destructive, causing extensive damage to grains, flour, and other stored products. Infestations lead to both qualitative and quantitative losses, with significant economic implications (Sharmin et al., 2024). The larva is the most destructive stage of the beetle, consuming the endosperm of the seeds resulting in coagulating consistency, objectionable odour and reduced product quality of the flours (Ehisianya et al., 2022).

One of the major concerns associated with T. castaneum infestation is the secretion of benzoquinones from their abdominal glands. These toxic chemical secretions act as a natural defense mechanism but also lead to severe contamination of stored food products. The presence of benzoquinones imparts an unpleasant odor and alters the taste of infested food, reducing its marketability and consumer acceptability (Sreeramulu *et al*., 2017). In cases of severe infestation, the stored product undergoes significant qualitative deterioration, characterized by discoloration, mold development, and the presence of a pungent and foul smell, rendering it unfit for human consumption (White and Jayas, 2003).

Apart from direct contamination, T. castaneum infestation also leads to substantial quantitative losses due to feeding damage and increased moisture levels, which promote fungal growth and mycotoxin production (Athanassiou *et al*., 2016). Additionally, the beetles have high reproductive potential, with females laying up to 500 eggs in their lifetime, leading to rapid population build-up under favorable conditions (Rees, 2004). The ability of T. castaneum to develop resistance to commonly used insecticides further complicates management strategies, making it one of the most challenging pests to control in stored grain ecosystems (Arthur *et al*., 2019). Given the economic significance of T. castaneum in stored product losses, extensive research has been conducted on its biology, behavior, and control measures. However, the degree of infestation and damage varies depending on the type of stored product and its susceptibility to the pest.

In addition to physical damage, the infestation by *T. castaneum* markedly affects the biochemical composition of grains. As a result, numerous consumers and owners of flour milling industries frequently report substantial economic losses due to the damaging actions of *T. castaneum*. The destructive activities of *T. castaneum* underline the urgent demand for rigorous and efficient pest management measures to sustain the quality and consistency of stored grains (Oyeniyi & Akinnuoye, 2025). This study aims to evaluate the extent of damage caused by T. castaneum in different varieties of finger millet (Eleusine coracana) flour and assess the potential resistance of these varieties against infestation. The findings from this research will contribute to the development of effective pest management strategies, ensuring the safe storage of finger millet flour and reducing post-harvest losses.

**Material and methods**

The present investigation was conducted at the Department of Entomology, Agricultural College, Naira during the year summer of 2021-22. The initial population of the test insect *T. castaneum* was collected from the go-downs of the Food Corporation of India (FCI) of Srikakulam (Srikakulam Dist), in Andhra Pradesh. The laboratory cultures of *T. castaneum* were maintained in the Department of Entomology, Agricultural College, Naira, for the present laboratory investigations.

**Experimental Location**

The present investigation was carried out in the Department of Entomology, Agricultural College, Naira, during the academic year 2021-22. The study was conducted under controlled laboratory conditions to evaluate the infestation potential and impact of *Tribolium castaneum* on different varieties of finger millet flour.

**Collection and Maintenance of *Tribolium castaneum* Culture**

The initial population of the test insect, *T. castaneum*, was collected from stored grain go-downs of the Food Corporation of India (FCI), located in Srikakulam district, Andhra Pradesh. The samples were collected from infested wheat and rice stocks using a hand sieve and an aspirator. The collected beetles were then transported to the laboratory for further rearing and experimentation.

To establish a laboratory culture, the collected adult beetles were introduced into sterilized glass containers (500 ml capacity) containing finely milled wheat flour mixed with 5% brewer’s yeast to serve as a culture medium. The containers were covered with fine muslin cloth secured with rubber bands to allow aeration while preventing escape. The cultures were maintained at a controlled temperature of 27 ± 2°C and 65 ± 5% relative humidity (RH) with a 12-hour light: dark photoperiod to simulate storage conditions. The adult beetles were allowed to oviposit, and fresh cultures were maintained by transferring newly emerged adults into fresh flour every four weeks to ensure a continuous and healthy insect population for the experiments

**Experimental Design and Setup**

The experiments were conducted in a completely randomized design (CRD) with three replications per treatment. Three different varieties of finger millet flour (VR-520, VR-708, and VR-847) were selected for the study based on their agronomic importance and commercial availability. Each variety was procured in bulk, dried at 50°C for 4 hours to eliminate pre-existing insect stages, and stored in airtight containers before use in the experiments.

For infestation trials, 200 grams of each finger millet flour variety was placed in individual plastic containers (250 mL capacity) and artificially infested with 20 pairs (20 males and 20 females) of one-week-old *T. castaneum* adults. The containers were covered with perforated lids to facilitate air circulation while preventing the escape of insects. The experimental units were maintained under standard laboratory conditions (27 ± 2°C, 65 ± 5% RH) for a period of 60 days, during which the infestation was monitored at regular intervals.

**Determination of uric acid:**

This method is based on the precipitation of proteins and treatment of protein-free filtrate with uric acid and sodium cyanide and measuring the resultant blue colour colorimetrically.

Five grams of finger millet powder expected to contain 1 to 5 mg uric acid was taken and suspended in 200 ml water. The mixture was allowed to stand for 2 hours and then mixed in a waring blender for 10 minutes and centrifuged at about 2000 r.p.m. for 10 minutes. To 100 ml of clear centrifugate, 10 ml sodium tungstate solution was added and mixed. Then 10 ml of standard sulphuric acid solution was added to precipitate the proteins present in the extract. The solution was mixed and allowed to stand for 5 minutes and then filtered. 10 ml of filtrate was taken in a 50 ml volumetric flask and 5 ml of sodium cyanide solution was added followed by1 ml of Benedict’s uric acid reagent and shaken gently and made the volume with distilled water. The intensity of the colour was measured in a spectrophotometer at 520 nm. The optical density obtained was recorded as OD1. 10 ml of a standard uric acid solution containing 0.2 mg of uric acid in a 50 ml flask was taken and to that solution, 5 ml of sodium cyanide was added followed by 1 ml of Benedict’s uric acid reagent. The intensity of colour was measured in a photoelectric colorimeter using a 520 nm absorbance and recorded as OD2. A parallel test using the same quantity of good un-infested flour samples was run as a control. (FSSAI, 2015)

**Data Collection and Observations**

The following parameters were recorded to assess the extent of damage caused by *T. castaneum* in different varieties of finger millet flour:

1. **Weight Loss (%)**: The weight loss in flour due to beetle infestation was determined by weighing the flour samples before and after the experimental period using an electronic balance. The percentage weight loss was calculated using the formula:

Weight loss (%)

1. **Uric Acid Content (mg/100g flour)**: The uric acid content in the flour samples was estimated to assess contamination levels due to insect infestation. Uric acid was extracted using a standard acid digestion method and quantified spectrophotometrically at 293 nm, following the method described by AOAC (2005).

Uric acid content

1. **Adult Population Count**: The number of live and dead *T. castaneum* adults was recorded at the end of the experiment to assess population buildup in different flour varieties.
2. **Flour Quality Assessment**: Visual observations were made to record qualitative changes in flour, including color changes, odor development, and mold growth, to evaluate the degree of deterioration.

**Statistical Analysis**

The data collected from the experiments were analyzed statistically using Analysis of Variance (ANOVA) in a completely randomized design (CRD). The means were separated using the Least Significant Difference (LSD) test at a 5% probability level (P ≤ 0.05) to determine significant differences between the flour varieties. Statistical analysis was performed using SPSS version 25.0 software.

**Results and discussion**

The losses caused by Tribolium castaneum in three different varieties of finger millet (ragi) flour were assessed based on two key parameters: percentage weight loss and uric acid accumulation. A controlled storage study was conducted using three ragi varieties-VR-847 (Sri Chaitanya), VR-520 (Suraj), and VR-708 (Champavathi)—to evaluate their susceptibility to T. castaneum infestation and determine whether there were significant varietal differences in resistance to the pest. The experiment was carried out under laboratory conditions to ensure precise monitoring of infestation levels and their impact on flour quality.

**Weight Loss (Per cent)**

The data on the percentage weight loss caused by T. castaneum in different ragi flour varieties is presented in Table 1. Over a storage period of two months, the weight loss varied across the three tested varieties, ranging from 30.20% to 31.60% in VR-520, 20.20% to 22.60% in VR-708, and 7.90% to 9.80% in VR-847. The mean weight loss was recorded as highest in VR-520 (33.75%), followed by VR-708 (27.95%), while the lowest loss was observed in VR-847 (17.54%). The results indicate that among the three ragi varieties tested, VR-520 exhibited the highest susceptibility to T. castaneum infestation, resulting in maximum weight reduction. VR-708 showed moderate levels of damage, while VR-847 demonstrated the lowest weight loss, suggesting a relatively higher resistance to infestation. These results highlight the importance of varietal differences in determining the susceptibility of ragi flour to stored-product insect pests, which can be crucial for selecting resistant varieties for prolonged storage and minimizing post-harvest losses.

The observed loss in weight can be attributed to the increase in the adult T. castaneum population, which leads to the subsequent loss of dry matter in the flour. According to Sclar (1994), significant weight loss of up to 30-40% occurs in stored maize due to infestation by Sitophilus zeamais. The present study's findings are consistent with those of Derera *et al*. (2001), who reported a weight reduction ranging from 0.85% to 8.45% after 70 days of infestation. Similarly, Lakwah and Latif (1998) found that weight loss in maize seeds was strongly correlated with both insect population density and the duration of storage. The data from the current study indicate that the differences in the weight loss of ragi flour varieties due to T. castaneum infestation were statistically significant. This suggests that the extent of weight loss varies across different ragi varieties, further highlighting the importance of varietal resistance in minimizing the damage caused by stored-product pests.

There is no published literature concerning the per cent weight loss in flour of ragi cultivars and hence these results could not be compared with others. However, ragi flour entries included in the current studies could be classified into less susceptible, susceptible and more susceptible classes based on per cent loss in flour weight, as shown below:

a) More susceptible- VR-520

b) Susceptible- VR-708

c) Less susceptible- VR-847

According to the observations, the implementation of enhanced agricultural practices has resulted in a steady growth in food grain production in recent years. However, appropriate care is not being provided to protect food from insect pest damage. The major reason for the multiplication of stored grain pests is that favourable environmental circumstances encourage the rapid proliferation of stored grain pests, resulting in massive losses. Aside from the quantitative losses caused by feeding, the stock suffers higher qualitative losses as a result of red flour beetle filling the food products or flours with their excreta and dead carcasses.

**Table 1. Per cent weight loss under laboratory conditions**

|  |  |  |  |
| --- | --- | --- | --- |
| **TREATMENTS** | **VR-847**  **(Sri Chaitanya)** | **VR-520**  **(Suraj)** | **VR-708**  **(Champavathi)** |
| **R1** | 9.80  (18.24) | 31.20  (33.96) | 21.40  (27.56) |
| **R2** | 9.30  (17.76) | 30.20  (33.34) | 21.30  (27.49) |
| **R3** | 7.90  (16.32) | 30.40  (33.46) | 20.60  (26.99) |
| **R4** | 8.70  (17.15) | 31.60  (34.20) | 20.20  (26.71) |
| **R5** | 9.21  (17.67) | 30.60  (33.58) | 22.60  (28.39) |
| **R6** | 8.30  (16.74) | 31.40  (34.08) | 23.50  (29.00) |
| **R7** | 10.50  (18.91) | 30.70  (33.65) | 24.30  (29.53) |
| **TOTAL** | 63.71  (122.80) | 216.10  (236.27) | 153.90  (195.66) |
| **TREATMENT MEANS** | 9.10  (17.54)a | 30.87  (33.75)b | 21.99  (27.95)c |
| **G.T** | 554.72 | | |
| **G.M** | 26.415 | | |
| **C.F** | 14653.229 | | |
| **S.Em (**+**)** | 0.308 | | |
| **S.E.D** | 0.436 | | |
| **C.D**(p= 0.05**)** | 0.924 ( significant) | | |
| **C.V** | 3.087 | | |

**Fig 1. Means of weight loss in (%) with 3 different varieties of ragi flour under laboratory conditions.**

**Estimation of uric acid content in flours**

The excretion characteristics of T. castaneum, specifically the uric acid released through excreta over a period of two months, were estimated using the AOAC (Association of Official Agricultural Chemists) method under controlled laboratory conditions. The spectrophotometric analysis provided a quantitative assessment of uric acid accumulation in the infested flour samples.

As shown in Table 2, the uric acid content in finger millet flour infested with T. castaneum varied between 1.46 and 4.32 mg per 100 g of flour. Among the three tested varieties, the highest uric acid concentration was recorded in VR-520 (4.32 mg/100 g of flour), followed by VR-708 (3.30 mg/100 g of flour), while the lowest accumulation was observed in VR-847 (1.46 mg/100 g of flour).

The results further indicated that the increase in uric acid content was directly proportional to the adult beetle population density and the weight loss in flour caused by T. castaneum infestation. After two months of storage, the highest infestation and subsequent contamination were observed in VR-520, followed by VR-708, with VR-847 showing the least deterioration. This trend suggests that flour from VR-520 is more conducive to the growth and reproduction of T. castaneum, leading to greater excretory accumulation, whereas VR-847 exhibits a comparatively higher resistance to infestation.

These findings highlight the significance of monitoring uric acid levels as an important indicator of stored flour quality and insect infestation severity. Implementing effective storage and pest management strategies is crucial to minimizing post-harvest losses and ensuring food safety.

**Table 2. Excretion of uric acid by *Tribolium castaneum* in terms of the total amount excreted in 3 different varieties of ragi flour.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **mg/ 100 g of flour** | | |
| **VR-847 (Sri Chaitanya)** | **VR-520 (Suraj)** | **VR-708 (Champavathi)** |
| **R1** | 2.24 | 4.48 | 3.52 |
| **R2** | 1.14 | 4.24 | 3.28 |
| **R3** | 1.04 | 4.32 | 3.68 |
| **R4** | 1.12 | 4.08 | 3.28 |
| **R5** | 1.36 | 4.40 | 3.12 |
| **R6** | 1.20 | 4.16 | 3.20 |
| **R7** | 2.16 | 4.56 | 3.04 |
| **Means** | **1.46** | **4.32** | **3.30** |

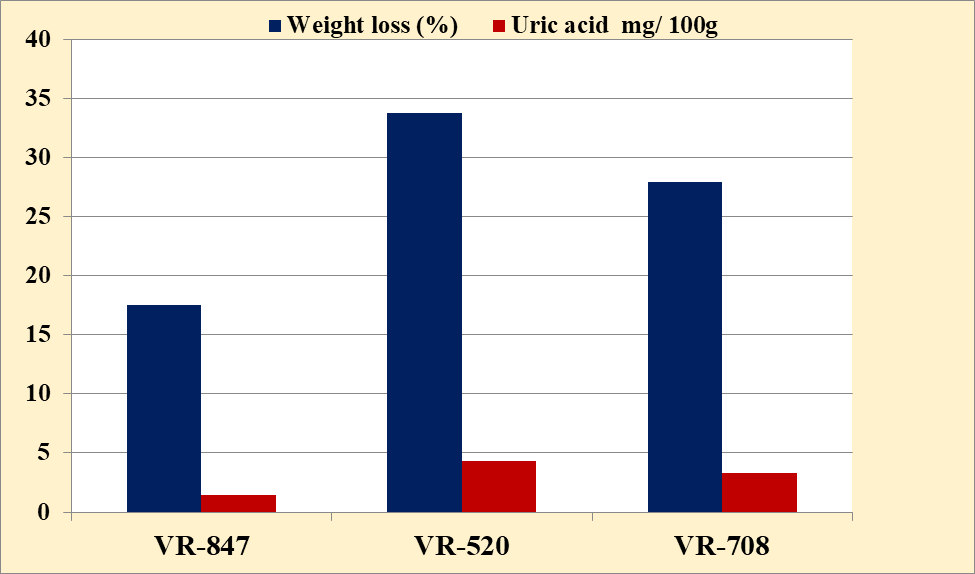
**Fig 2. Excretion of uric acid by *T. castaneum* in terms of mg/ 100g of flour.**

The present findings align closely with the observations of Swaminathan (1977), who concluded that the uric acid content in infested food grains serves as a reliable indicator of product hygiene and acceptability, as its accumulation results from insect excreta. His study reported that wheat flour infested with T. castaneum contained significantly higher uric acid levels (37.7 mg/100 g flour) compared to gram flour (18.5 mg/100 g flour). Furthermore, a decline in the protein efficiency ratio (PER) was observed, ranging from 20-40%, depending on the type of food, insect species, and infestation duration. Additionally, the current study corroborates the findings of Farn and Smith (1963), who reported a direct correlation between the uric acid excretion rate and the population density of T. castaneum, emphasizing the role of insect activity in flour contamination. Similar trends were also documented by Rao *et al*. (1958), who demonstrated that wheat flour infested with T. castaneum exhibited a proportional increase in uric acid content relative to insect population density, particularly under storage conditions of 85.5°C and 70-75% relative humidity (RH).

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Means** | | |
| **VR-847** | **VR-520** | **VR-708** |
| **Weight loss (%)** | 17.54 | 33.75 | 27.95 |
| **Uric acid mg/100g** | 1.46 | 4.32 | 3.30 |

These findings reinforce the importance of monitoring uric acid levels as a key quality parameter for assessing the extent of T. castaneum infestation in stored flour. Implementing proper storage practices and pest management strategies is essential to minimize post-harvest losses and maintain the quality of stored food products.

**Table 3. Means of weight loss in (%) and uric acid in mg/100g of 3 different varieties of ragi flour.**



**Fig 3. Means of weight loss in (%) and uric acid in mg/100g of 3 different varieties of ragi flour.**

**Conclusion**

Stored product pests pose a significant challenge in post-harvest storage and food security, causing both qualitative and quantitative losses. The present laboratory study aimed to assess the impact of Tribolium castaneum, the red flour beetle, on three different varieties of finger millet (Eleusine coracana) flour—VR-520 (Suraj), VR-708 (Champavathi), and VR-847 (Sri Chaitanya). The findings revealed substantial differences in the susceptibility of these varieties to T. castaneum infestation.

Among the three varieties tested, VR-520 (Suraj) exhibited the highest weight loss and uric acid accumulation, indicating its greater vulnerability to infestation. This suggests that the flour of this variety is more favorable for the growth and reproduction of T. castaneum, possibly due to its nutritional composition and texture, which may support rapid insect development. In contrast, VR-708 (Champavathi) showed moderate levels of infestation, while VR-847 (Sri Chaitanya) demonstrated the least susceptibility, recording the lowest weight loss and uric acid content. These results suggest that VR-847 (Sri Chaitanya) possesses relatively better resistance to T. castaneum infestation, making it a more suitable choice for prolonged storage.

The higher uric acid content recorded in VR-520 (Suraj) is a strong indicator of severe contamination caused by insect activity, which compromises the nutritional and hygienic quality of the flour. As uric acid is a metabolic waste product of insects, its accumulation beyond permissible levels can make the flour unfit for human consumption. Additionally, a prolonged infestation can lead to off-flavors, discoloration, and mold growth, further reducing the commercial value and edibility of the flour.

The study emphasizes the importance of selecting resistant finger millet varieties for storage and consumption to minimize post-harvest losses. Since VR-847 (Sri Chaitanya) exhibited greater resistance to T. castaneum, further investigations into its physical and biochemical properties may provide insights into the factors contributing to its lower susceptibility. Implementing proper storage practices, such as maintaining optimal temperature and humidity, using insect-proof containers, and adopting integrated pest management (IPM) strategies, can further reduce infestation risks and enhance the shelf life of stored finger millet flour. Overall, this study underscores the need for effective pest management strategies to safeguard stored grains and milled products from T. castaneum infestation. Future research focusing on varietal resistance mechanisms, biological control measures, and eco-friendly pest control alternatives can contribute to sustainable post-harvest management practices in finger millet storage.

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