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# Effect of Temperature and Time on Thermal Disinfestation of Green Gram

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**ABSTRACT**

Insect infestation accounts for majority of losses during storage of green gram. Chemical methods to prevent these losses, though effective and widely used, lead to undesirable consequences. The present study was initiated to explore possibility of using thermal disinfestation technique to control insect-pests. The exposure temperature and time to attain 100% mortality of insects (*Callosobruchus Chinensis L.*) and eggs in green gram were studied. The different optimum temperature and time combinations for mortality of insects were found as 50°C–5 min, 55°C–1 min, and 60°C–45 s. However, 55°C–300 s and 60°C–120 s were suitable for 100% egg mortality.



India, world's largest producer of pulses, produces around 15 million tonnes annually. About 7.5% of these are lost during storage. Over 50% of such losses are due to insects/pests. Pulses are stored for about a year or until harvest of the next crop. However, during storage, they are heavily attacked by insect pests, particularly the pulse beetle (*Callosobruchus chinensis L.*) resulting in quantitative and qualitative losses in the pulses. The genus *Callosobruchus* contains many species of *bruchids* which are serious pests of pulses and have been spreading from Asia and Africa to other continents. The common method of controlling insects-pests in stored grain is by using chemical pesticides, but its residue has harmful effect on human body.

The resurgence of interest in physical control is the result of increasing restriction on the use of chemical based control programme. Before the use of chemical insecticides, physical methods were the main form of protection of stored product. Further requirement of disinfestation process are that all development stages of a major pest must be eradicated without adversely affecting the grain quality such as germination, milling, and cooking time. Disinfestation of food grains through application of heat has been attempted by some researchers. Banks and Fields (1995) and Fields and Muir (1996) reported responses of stored-product insects to different temperatures. It was reported that in the temperature range of 50 to 62°C, the mortality of insects took place in less than an hour, but beyond the temperature of 62°C the mortality took place in less than one minute. Gonen (1977 a, b) reported that temperatures in the range of 42-50°C did not have sufficient lethal effect. There was significant survival (< 95% mortality) of several species when exposed for some hours in this range of temperatures. Fields (1992) reported the results of the studies on the susceptibility of stored product pests to temperatures greater than 50°C. However, mortality results could not be readily compared because of inaccurate temperature measurements. Evans (1987) commented that grain temperature of 65°C must be attained quickly. Such temperatures can damage the baking quality of wheat, the malting quality of barley and germination of most seeds.

Thus, the temperature of the grain must be carefully measured and controlled. Wheat, containing all immature stages of *Silophilus oryzae* (L), *Rhizopertha dominica* (F) and *Sitotroga cerealla* was exposed to air temperature (60 to 80°C) in a fluidized bed heating system gave almost complete disinfestation (Dermott and Evans, 1978). Qausrani and Beckett (2003) developed and tested a continuous-flow spouted-bed disinfestor for on-farm heat disinfestation of barley. The naturally infested barley with mixed-age populations of *Rhyzopertha dominica* (F.) and *Tribolium castaneum* (Herbst) were passed through the unit. Four target grain temperatures (57, 58, 62.2 and 63.3°C) were achieved during these trials. After initial heating, the grain temperature was maintained at each temperature for 5, 3, 1 and 1 min, respectively. The heat treatment affected germination because the grain was not subsequently cooled. Vadivambai *et al.* (2007) reported a pilot-scale industrial microwave system to determine the mortality of three common species of stored-grain insects, namely *Tribolium castaneum*, *Cryptolestes ferrugineus*, and *Sitophilus granarius*.

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Mortality of insects increased with either power or exposure time, or both. Germination of wheat kernels was lower after treatment with microwave energy.

The present study was undertaken to optimize temperature-time relationship for thermal disinfestation of green gram that would be helpful to design a thermal disinfestation system.

## MATERIALS AND METHODS

This study was conducted with good quality of green gram procured from the Experimental Farm of the Central Institute of Agricultural Engineering, Nabibagh, Berasia Road, Bhopal during the year 2006-07.

### Preparation of Insect Culture

The culture of insect was taken from the stored pulses at the Central Institute of Agricultural Engineering, Bhopal. For multiplication of the insects, a quarter of jar was filled with the green gram. Twenty to thirty insects of *Callosobruchus chinensis* were placed in every jar and covered with cloth for proper aeration. The jar was held at the temperature of 27±5°C and relative humidity of 60±5% in the humidity control chamber for 4 weeks.

### Experimental Set-up

A fluidized bed heating system was used for the purpose. The heating system consisted of a sample treatment section, plenum chamber, electrical heating system and blowing section. The sample holder of 90x90x170 mm was accommodated in the sample treatment section of 105x105x400 mm. The square-shaped sample treatment section (100x100 mm) had a height of 300 mm. The heating chamber of 15 kW was provided with 15 heaters of 1 kW each.

### Experimental Procedure

Three temperature levels (50, 55, and 60°C) were selected for the experiments on mortality of insects. About 200 g green gram sample was taken for the study and its initial infestation level was determined by counting live insects. The sample was kept in the sample holder placed across the hot air stream after it attained the desired temperature. The time and temperature of disinfestation were recorded using stop watch and digital temperature indicator. After the pre-determined time, the sample was taken out and allowed to cool to ambient temperature by forced air using fan. The thermally treated sample was taken for analysis of insect mortality, seed germination, and milling quality. The insect mortality was determined by visual observation. The number of dead and live insects were recorded, and percentage mortality calculated.

For disinfestation of eggs, three samples of 10 g each were randomly drawn from the infested grain and total number of eggs was determined. Then, samples of 200 g each were drawn and treated at each temperature (50, 55, and 60°C) and time combinations. Treated samples were kept in different plastic boxes covered with cloth. The control (infested and untreated) samples were also kept for comparison. The insect emergence was observed and counted at the interval of one week. The total number of insect emergence was determined after 28 days. The egg mortality was calculated by comparing with untreated grain.

### Seed Germination

One hundred seeds, in three replications, were taken at random for germination test and placed in wet paper towel under room condition in the temperature range of 30 to 32°C. The spacing between seed to seed was kept as five times the width of the seed. The wet paper was properly folded and one side was kept open for growth of seedlings. Then, the rolled paper was covered with butter paper for retaining proper humidity inside the paper towel. The water was sprinkled on the paper time to time to keep it wet. After 12 days, the rolled paper was unfolded and germinated seeds were counted and germination percentage was calculated.

### Milling of Thermally Treated Green Gram

The milling study of pulses was performed in burr mill without any further pre-treatment for making *dal*. About 100 g of thermally treated sample was taken for milling process. The sample was milled for 5 seconds and *dal* was separated from broken and husk. The percentage of *dal* recovery was calculated by dividing the amount of whole split green gram from total amount of milled green gram and multiplying the fraction by 100.

## RESULTS AND DISCUSSION

### Mortality of Insect

The effect of temperature and exposure time on the mortality of *Callosobruchus chinensis* is presented in Fig. 1. It can be observed that at the temperature of 50°C, the insect mortality increased from 0 to 100% with an increase in exposure time from 60 to 300 s (Fig. 1). The relationship between exposure time and insect mortality at the air temperature of 50°C can be represented by equation 1.

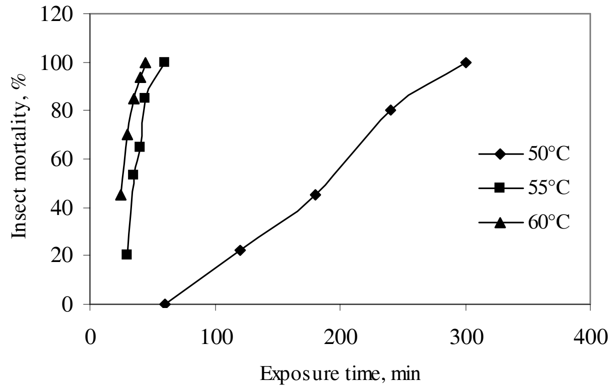


**Fig. 1: Effect of exposure time and temperature on insect mortality**

$$M = 0.43\ t - 28 \qquad (R^2 = 0.99) \qquad \ldots(1)$$

Where, M is insect mortality (%), and t is exposure time (s).

At the exposure temperature of 55°C, the insect mortality increased from 20 to 100% with an increase in exposure time from 30 to 60 s. The relationship can be represented by quadratic eq. 2.

$$M = -0.1044\ t^2 + 11.99\ t - 243.99 \quad (R^2 = 0.99) \quad \ldots(2)$$

At the exposure temperature of 60°C, increasing the exposure time from 25 to 45 s resulted in an increase in insect mortality from 45 to 100%. The increase in insect mortality with exposure time had quadratic relationship that can be represented by eq. 3.

$$M = -0.1257\ t^2 + 11.48\ t - 162.71 \quad (R^2 = 0.99 \quad \ldots(3)$$

The optimum temperature and exposure time combination for 100% insect mortality were found as 50°C - 300 s, 55°C - 60 s, and 60°C - 45 s.

The seed germination at different temperature and time combinations was found in the range of 95-99% against that of 98% for the control sample (Table 1). *Dal* recovery of thermally treated green gram at different combinations of exposure temperature and time was observed in the range of 72-74% against that of 74% for control sample (Table 1). The exposure temperature and time did not have significant effect on the seed germination and *dal* recovery at 5% level. The t-test revealed that seed germination and *dal* recovery of thermally treated green gram at different combinations of exposure temperature and time did not vary significantly with that of control sample.

## Mortality of Eggs

Effect of different temperature (50°C, 55°C and 60°C) and time exposure on the mortality of eggs of *Callosobruchus chinensis* is presented in Fig. 2. It can be observed that at the temperature of 50°C, mortality of



**Table 1. Effect of temperature and exposure time on seed germination and *dal* recovery of green gram**

| Exposure temperature (°C) | Exposure time (s) | Seed germination (%) | Dal recovery (%) |
|---|---|---|---|
| 50 | 60 | 97 | 73 |
| 50 | 120 | 97 | 74 |
| 50 | 180 | 96 | 73 |
| 50 | 240 | 96 | 73 |
| 50 | 300 | 95 | 73 |
| 55 | 30 | 98 | 73 |
| 55 | 35 | 98 | 72 |
| 55 | 40 | 97 | 74 |
| 55 | 45 | 97 | 74 |
| 55 | 60 | 97 | 73 |
| 60 | 25 | 98 | 74 |
| 60 | 30 | 99 | 74 |
| 60 | 35 | 98 | 74 |
| 60 | 40 | 97 | 73 |
| 60 | 45 | 98 | 72 |
| Control (untreated) sample | 98 | 74 | |

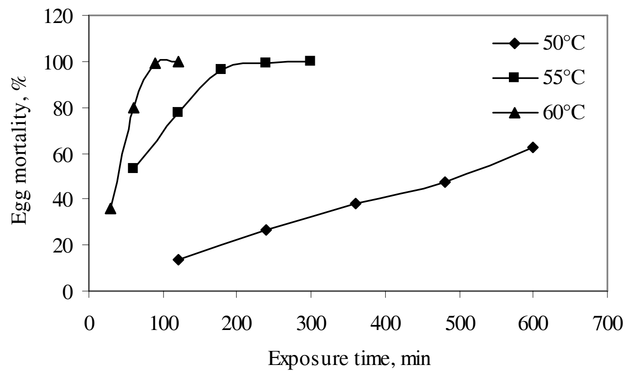


**Fig. 2: Effect of exposure time and temperature on egg mortality**

eggs increased from 13.8 to 62.3% with increase in exposure time from 120 to 600 s. However, 100% egg mortality was not achieved at this temperature. At the exposure temperature of 55°C, increasing the exposure time from 60 to 300 s resulted in an increase in egg mortality from 53 to 100% that can be represented by eq. 4.

$$M = -0.0013\ t^2 + 0.6425\ t + 19.1\ (R^2 = 0.99) \quad \ldots(4)$$

At the exposure temperature of 60°C, an increase in exposure time from 30 to 120 s resulted in an increase in egg mortality from 36.1 to 100 per cent. The relationship between exposure time and egg mortality can be represented eq. 5.

$$M = -0.119\ t^2 + 2.484\ t - 27.52 \quad (R^2 = 0.99) \quad \ldots(5)$$

The different optimum temperature and time exposure combinations for 100% egg mortality were observed as 55°C and 300 s and 60°C and 120 s. The seed germination at different exposure temperature and time combinations was found in the range of 97-99% against that of 98% for control sample. *Dal* recovery of thermally treated green gram at different combinations of exposure temperature and time was observed in the range of 72-74% against that of 74% for control sample.

It is obvious that at the same temperature, the exposure time required for 100% mortality of eggs was higher than that for insect indicating that eggs are more resistant to temperature than insects.

## CONCLUSIONS

i. The different optimum temperature and time exposure combinations for 100% insect mortality were found as 50°C - 300 s, 55°C - 60 s, and 60°C - 45 s.

ii. The different exposure temperature and time optimum combinations for 100% egg mortality were found as 55°C - 300 s and 60°C - 120 s.

iii. At the same temperature, the exposure time required for 100% mortality of egg was higher than that for insect.

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