Effectiveness of gamma radiation for the control of *Tribolium castaneum*, the pest of stored cashew kernels

Tree nuts are globally consumed for their desirable sensory and nutritional attributes[1]. Among dry fruits, cashew nuts (*Anacardium occidentale.* L.) are popular due to their characteristic odour and taste[2]. Among agricultural products, the total export of cashew kernels from India during 2008–09 was Rs 2,988 crores. Besides being consumed as raw, salted or unsalted products, they can be used in the production of juices, liqueurs and preserves[3]. Cashew nuts are good sources of proteins (20%), carbohydrates (23%) and fats (45%)[4]. About 61% of the fat is oleic acid (ω-9) and 17% is linoleic acid (ω-6)[5]. It has been suggested that consumption of cashew nuts may prevent cardiovascular diseases and lower low density lipoprotein without affecting high density lipoprotein[6]. Like other nuts, cashew nuts are also susceptible to infestation by moulds and insects[7].

Over 100 insects and mite species are reported to attack cashew nuts, being able to feed and multiply on the product during storage[8]. The quantity and quality of the processed cashew is often affected by insect pest, particularly the polyphagous pest, *Tribolium castaneum* (Rust red flour beetles)[9]. The larvae and adult destroy cashew nut kernels during all stages of processing, from peeling to packing. Data from major consuming countries revealed that infestation by insect pest is a severe problem in marketing the product. Insect infestation causes significant changes in the biochemical composition of the stored nuts[10].

Management of this pest using chemical pesticides is highly discouraged due to its adverse effect on living beings. Importing countries are being conscious about the use and residue limits of pesticides. Fumigants such as phosphine, methylbromide, ethylene dibromide, etc. have been commonly used for the control of *T. castaneum* while in storage[11]. The use of these chemicals, however, has been found to be highly hazardous causing serious environmental problems. This has necessitated studies on developing alternative means of control. Gamma-irradiation techniques seem to offer solutions that are desirable in many respects. Control of storage pests using irradiation techniques has been studied to a limited extent. Control of pests like *Sitotroga cereailella*, *Callosobruchus maculates*, *Sitophilus oryzae*, etc. by this technique has proved promising[12,13].

Gamma radiations are used to produce mortality or sterility in the insects. The technique can be used by irradiating the insects at doses sufficiently high to produce the desired effects. The present study observed the gamma-ray effect on this insect, and the results may be useful for commercial applications.

The laboratory culture of *T. castaneum* was maintained at room temperature. Ten adult beetles, irrespective of sex, were collected from the stock. Ten each in five replications were confined in a specimen tube of size 1.5 cm × 1.5 cm to ensure uniform radiation. Samples were exposed to gamma radiation at ambient temperature at the Gamma Irradiation facility (^{60}Co-gamma source) in the Radio Tracer Laboratory of Kerala Agricultural University, Thrissur.

The specimen tubes were exposed to six doses of irradiation ranging from 100 to 350 Gy, with an increment of 50 Gy at a dose rate. Treated beetles were transferred into culture tubes of size 8 cm × 6.5 cm and were fed with cashew kernels. Unirradiated beetles were kept as control. The development and mortality of insects were recorded daily and compared against the control, nonirradiated beetles. The results were confirmed with ten beetles in five replications.

Adult beetles were subjected to different irradiation doses – 100, 150, 200, 250, 300 and 350 Gy. The data showed that the first mortality was recorded on the third day after treatment. Mortality recorded was 8% on 3 DAI (days after irradiation) in 200, 250 and 350 Gy treatment (Table 1). Whereas with 100 Gy dose, the first mortality resulted on 6 DAI. Mortality rate increased remarkably on 9 DAI. This indicates that increase in dose leads to increase in percentage kill.

Effect of gamma radiation on *T. castaneum* irradiated during adult stage revealed that survival of adults was found to decrease with increase in radiation dose. Overall the results showed highly significant effect of irradiation on insects administered with different doses (Table 2). In the entire treated batches, except for the treatment with 100 Gy complete mortality was achieved on 21 DAI, but no insect was found dead in the untreated batch. It indicates that there is a direct proportion between the dose and mortality.

Results of this study indicate a close similarity in the radiosensitivity of the larvae and adults of other genera and species. Doses higher than 20 Gy cause mortality of *T. confusum*, while lower doses cause inhibition of development and sterility of the surviving insects[14]. Lethal and sterilizing effect of gamma radiation on eggs, larvae, pupae and adults of *Sitophilus* granaries were studied at different doses[15]. The study revealed that eggs and larvae were unable to develop adults at doses 30–500 Gy, and doses of 70 Gy at pupal and 4 weeks adults caused sterility.

Tuncbilek *et al.*[16] found that increase in radiation dose lead to increase in death in adult insects. Doses between 20 and 200 Gy killed insects in 2 weeks, while doses less than 10 Gy killed them in several weeks. Khaghani *et al.*[17] stated that mortality could be taken into account with high dose of irradiation.

Hasan[18] studied the gamma ray effect on time of death and 1–10 day-old adult insects in different species: *T. anaphe* Hinton, *T. castaneum* Herbst, *T. brevicornis* Leconte, *T. destructor* Uyttenboogaart and *T. freemani* Hinton. The results showed that all the other irradiated insects died with 40–50 Gy in 12 weeks, except 10-day-old adult insects.

Irradiation also severely inhibited the reproductive ability of adult females. Our results showed that no progeny was produced from adults. In this case inhibition of sexual ability and adult sterility will be the goal of radiation treatment for the control of stored product and quarantine pests.

In agreement with the present study, Tuncbilek *et al.*[16] showed that radiation with five doses between 20 and 180 Gy can kill adult flour beetles in 30 days.

Follett and Armstrong[19] observed that the irradiation doses of 100, 125 and 150 Gy applied to late third instars resulted in no survival to the adult stage, indicating that these doses are sufficient

Table 1. Mortality of adult beetle due to low doses of gamma irradiation

	Days after irradiation						
Dose (Gy)	3	6	9	12	15	18	21
0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
100	0.00 ± 0.00	1.60 ± 0.25	2.40 ± 0.25	3.60 ± 0.40	5.00 ± 0.45	7.00 ± 0.32	10.00 ± 0.00
150	1.20 ± 0.20	2.40 ± 0.25	4.00 ± 0.32	5.60 ± 0.51	7.40 ± 0.51	9.20 ± 0.38	10.00 ± 0.00
200	0.80 ± 0.20	2.40 ± 0.25	3.60 ± 0.81	3.80 ± 0.74	7.60 ± 0.25	9.60 ± 0.25	10.00 ± 0.00
250	0.80 ± 0.20	1.60 ± 0.25	2.00 ± 0.45	2.00 ± 0.45	7.20 ± 0.38	9.80 ± 0.20	10.00 ± 0.00
300	0.60 ± 0.25	1.20 ± 0.49	2.80 ± 0.67	4.60 ± 0.60	8.60 ± 0.25	9.80 ± 0.20	10.00 ± 0.00
350	0.08 ± 0.20	2.80 ± 0.38	3.60 ± 0.51	6.00 ± 0.40	9.00 ± 0.32	10.00 ± 0.00	10.00 ± 0.00

X ± SE, n = 10 with five replications.

Table 2. The analysis of variance of insects admitted to different doses of irradiation

SV	d*f*	SS	MS	F
Replication	4	2.53	0.63	1 NS
Treat	5	46.17	9.234	14.65 HSIG
Error	20	12.67	0.63	

NS, Not significant; HSIG, Highly significant (P < 0.01), SV, Source of variation; d*f*, Degree of freedom; SS, Sum of square; MS, Mean of square; *F*, Fischer test.

to provide quarantine security. This result was in agreement with the present study.

The present study reveals that 350 Gy can kill the pest in about 18–21 DAI and supports that low doses of irradiation can serve as disinfestation treatment and prevent further reproduction of adults.

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