RADIATION DISINFESTATION STUDIES ON SUN DRIED FISH

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Abstract

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A large quantity of dried fish is lost in Bangladesh due to infestation by earwigs, hide beetles and copra beetles in storage godowns. The most destructive pest is the hide beetle, *Dermestes maculatus* Deg. Earwigs of different developmental stages were exposed to 0.10, 0.20 or 0.30 kGy of gamma rays for disinfestation. There was apparent damage to the control but all treated samples were in good condition and no live insect was observed 3 weeks after starting the experiment. Disinfestation studies of dried mackerel showed that eggs, larval and pupal stages of hide beetles could be inactivated at a dose of 0.20 kGy. A dose of 0.30 kGy killed all adults 2 weeks after irradiation. In the packaging studies, dried mackerel was packed in polythene pouches of different thicknesses. Two controls were maintained, i.e. dried fish with no treatment, *control*, and dried fish disinfested with heat at 60°C, *disinfested control*. In experiments with 50 μm thick polythene pouches, the dried fish of irradiation treatments with 0.10 to 1.0 kGy doses and the controls had around 20% moisture content with the exception of disinfested controls which had 13% moisture content. All irradiated samples were free from insect damage. There was heavy damage in the controls due to insects. However, all these treated fish had heavy fungal growth with the exception of the disinfested control. Similar results were obtained with pouches made of 75 μm thick polythene irradiated at doses of 0.50, 1.0, 2.0 and 4.0 kGy. In the final experiments pouches were made of 50, 75 and 100 μm thick polythene and exposed to similar radiation as in the previous experiment. In all the treatments, moisture content was reduced to 13%. Heavy insect damage was observed in the control, while all the treated samples were in excellent condition after 5 months of storage.

1. INTRODUCTION

Sun dried, smoked and salted fish is a favourite food of the Southeast Asian people. The preference, in Bangladesh, is for freshwater fish. During the peak period of catch in inland water, the surplus quantity is sun dried for off-season consumption. About 0.9 million t of fish are caught annually in Bangladesh, about 10% of which is marine. Most of the marine fish is dried.

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Heavy loss of dried fish occurs due to pest infestation in two stages, i.e. (1) in the process of drying, and (2) after storage in godowns and during transportation. At the beginning of the drying process when the fresh fish has a high moisture content, heavy blowfly infestation occurs at the drying location. In Bangladesh the blowfly is a *Lucilia* species. In laboratory samples *Drosophila* and house fly larvae were also detected. Pablo [1] stated that in the Philippines fish are infested with flesh flies of the Sarcophagidae family. Bangladesh fishermen reported that as much as 30% of the fish is lost owing to fly infestation. There is very little done in practical terms to prevent flies from infesting the fish. Occasional spraying of insecticides has been done very injudiciously with harmful results to consumers. In some cases molasses sprinkled with insecticides is used as baits to kill flies.

The real danger to sun dried fish is infestation with beetles. They attack fish during transportation, in godowns and even at the consumers' level. The most destructive pest in Bangladesh is *Dermestes maculatus* Deg. This species also occurs abundantly in Africa as reported by Azab et al. [2], Osuji [3] and Pointel and Pham Van Sam [4]. The hide beetle, the copra beetle, *Necrobia rufipes* Deg., and earwigs are also found associated with dried fish infestation in Bangladesh. Pablo [1] also reported the occurrence of *D. carnivorus* in dried fish in the Philippines. Insecticides are used very little in Bangladesh to control pests. Cleanliness is maintained as much as possible but heavy losses occur due to beetles. As a result there are tremendous price fluctuations between early and late seasons after the catch. A survey on pest infestation in a large number of godowns and market places in Bangladesh indicated that hide beetles are always associated with dried fish infestation. *Necrobia* are next in prevalence.

2. REVIEW OF LITERATURE

A number of workers have conducted research on the biology and control of dried fish insects but very few have reported on radiation disinfestation.

Hinton [5] reported that the hide beetle, *D. maculatus* Deg., is a pest of great economic importance and causes extensive damage to dried fish and dried animal products such as hides. Alam [6] reported that *D. maculatus* Deg. caused serious damage to dried fish in Bangladesh.

Paul et al. [7] studied the life history of *D. maculatus* Deg. at constant temperature and humidity. They reported the incubation, larval and pupal periods at 30°C and at 70% relative humidity to be 2.4, 8 and 7 days respectively. They also reported the life span of the male as 87 days and of the female as 98 days. Azab et al. [2] conducted a series of experiments investigating the biology and the factors affecting the development, adult longevity and the rate of oviposition of *D. maculatus* Deg. at different temperatures. They found that the egg stage varied from 1 to 2 days at

30°C and from 10 to 11 days at 16.8°C. The larval period lasted between 24 days at 32°C and 96 days at 19.4°C. The prepupal stage lasted from 2 to 11 days according to temperature. The pupal stage averaged 5.1 days at 29.7°C and 33.1 days at 16.4°C. The oviposition period also varied greatly (from 28 to 130 days) with variations of temperature and humidity. Osuji [3] studied the development of *D. maculatus* Deg. in dried fish under laboratory conditions. He observed that females laid eggs within 12 h of copulation and that hatching occurred at about 48 hours. After oviposition, larval development was completed in 33.5 days during which several moulds occurred. The adult emerged at about 11 days after the last instar stage, irrespective of the mode of pupation.

MacLellan [8] protected dried fish for 6 weeks against the attack of insects by using a water emulsion containing 0.018% pyrethrin and 0.36% piperonylbutoxide. Lloyd and Dyte [9] studied the susceptibility of *Dermestes* spp. to 15 contact insecticides by topical application. The organophosphorus compounds, such as dimethoate, morphothion, dicapthon, fenithrothion, fenthion, etc., were most effective in killing *Dermestes* spp. Dieldrin was the most effective compound used on *D. maculatus* but it yielded negligible mortalities with *D. lardarius* and *D. ater*.

Dyte et al. [10] observed that LD 50 of melathion for larvae of *D. maculatus* Deg. was 10 times that for larvae of *D. lardarius*. But these two species are known to have similar susceptibilities to several other organophophorus insecticides. Kane [11] reported that silica dusts of low bulk density gave promising results for the control of *Dermestes frischii* Kug, *D. ater* Deg. and *Necrobia rufipes* Deg. infesting dried fish.

Green [12] stated that a good control and subsequent protection could be achieved by dipping infested dried fish in an emulsion containing 0.02% pyrethrum or 0.0625% malathion.

Wheatley [13] used several insecticides to evaluate the most promising compounds for the control of *Dermestes* spp. He placed the insecticides in order of effectiveness as dieldrin, Carboryl, Bayer 7788, Dursban and fenthion.

Proctor [14] reported that an emulsion containing 0.018% pyrethrin and 0.036% nupiperonylbutoxide applied to smoked dried fish in Zambia prevented infestation by *Dermestes* spp. for about 8–12 weeks. He concluded that pyrethrin emulsion was economically feasible and attractive for appropriate use in Zambia.

Levinson and Baskelkousky [15] tried to introduce anti-vitamins in the diet to control the hide beetle. There was some success in arresting the development of this pest.

Shaw and Lloyd [16], on the other hand, reported that an Australian strain of *D. maculatus* when exposed to r-BHC and reared for 15 generations on fish-meal containing r-BHC showed a gradual increase in resistance. This resistance reached 26 times that of a susceptible strain by the F14 generation.

Toye [17] found that heating of dried fish at 60°C for 30 min at 4 day intervals in a simple charcoal fired oven and storage in metal containers control the pests.

Mushi and Chiang [18] observed that no growth of insects at any developmental stage occurred with dried fish containing 13% or more salt.

Daget [19] applied ionizing radiation for the disinfestation of dried fish in sealed containers. His results led to the death or sterilization of insects without any harmful effects to the products. Boisot and Gauzit [20] reported that 30% by weight of the fish was destroyed by insect infestation and none of the conventional control methods gave any practical results. Various doses of radiation were employed by them for the preservation of dried fish. The exact dose necessary for sterilization was not determined, but was estimated to lie between 15 000 and 40 000 rad[1]. No organoleptic changes were observed at 50 000 rad. They also studied the taste and nutritional value of the dried and smoked fish after exposing them to different radiation doses ranging from 20 000 to 50 000 rad. No adverse effects were reported by them at the above mentioned doses. Pointel and Pham Van Sam [4] irradiated *D. maculatus* at doses ranging from 10 to 30 krad in order to determine the sterilization dose. There were no progeny and the life span of the insects was shortened.

3. DISINFESTATION OF *Labeo gonius* (CARP GROUP OF EARWIGS)

During the first phase of the experiments when dried fish were brought to the laboratory for disinfestation studies, a number of earwigs were also found to be associated with the infestation. With some difficulty a moderate sized population of these insects was obtained in Gonia fish (*Labeo gonius*) for use in investigations.

No attempt was made to separate earwigs into particular age groups, and a mixed population in a sample of Gonia fish was taken for irradiation. These were exposed to gamma rays from a ^{60}Co source at doses of 10, 20 and 30 krad. Each replicate had about 50 g of dried fish and each treatment was replicated four times. Observation was made after 12 days of irradiation in order to determine the number of insects, both dead and alive, present in each replicate. Table I shows the results. There was considerable damage of dried fish in the control, but almost no spoilage was observed in any of the irradiated replicates. The number of dead insects in the control was significantly less compared with other treatments (see Table I). It is obvious from the results that fish were completely disinfested with the doses of radiation used in this experiment. Further observations were made after another 3 weeks. No live insect nor any damage of the product was observed in any treatment.

4. DISINFESTATION OF DRIED MACKEREL

Mackerel is one of the important catches of marine fish in the Bay of Bengal. It is estimated that about 15% of a total catch of 80 000 t of marine fish is mackerel.

[1] 1 rad = 1.00×10^{-2} Gy.

TABLE I. RADIATION EFFECTS ON EARWIGS

Replication	Number of dead earwigs with each treatment (Dose krad*)			
	0	10	20	30
1	2(10)**	4	9	9
2	2(5)	8	8	6
3	4(4)	5	6	12
4	3(7)	7	8	7
Average	2.75	6.0[b]	7.75[b]	8.50[b]

Least significant difference between treatments at 5% level = 3.09.
Least significant difference between treatments at 1% level = 4.75.

Note: Numbers designated by unlike letters are significantly different.

* 1 rad = 1.00×10^{-2} Gy.

** Number in parentheses is number of earwigs still alive.

Most of it is dried. It is one of the most expensive dried fishes. Experiments were conducted to determine the disinfesting dose for dried mackerel associated with eggs, larvae, pupae and adults of the hide beetle, *D. maculatus* Deg.

4.1. Materials and methods

Laboratory reared insects were used for all the experiments. Mackerel was used as the food for *D. maculatus*. Prior to starting an experiment, dried mackerel for this purpose was disinfested in an oven for 24 h at 50°C. For convenience both Petri dishes (9 cm diameter) and small insect rearing jars (5 cm × 8 cm × 15 cm) had been used to maintain the experimental insect population. Petri dishes were covered with tissue papers for aeration before putting the lid on. Rearing jars were always covered with muslin which was fastened with rubber bands.

Eggs: the hide beetle lays eggs in crevices and glues them with dried fish. It was our experience that when eggs were separated from the substratum, a large number of them were damaged. Therefore, for egg irradiation an indirect method was used. Adults were released on dried mackerel and allowed to remain for 48 h. Afterwards 40 g of dried fish were separated for each replicate. It was assumed that these samples would have eggs 0–48 h old. The samples of the dried fish with eggs so obtained were given 0 (control), 2.5, 5, 7.5, 10 or 15 krad of gamma rays. Each treatment was replicated five times.

Larvae: last instar larvae 25–28 days old (when a few started pupation) were separated from stock cultures. Fifty grams of dried mackerel were placed in a rearing jar and 20 larvae were added to it. Each jar constituted one replicate and the experiment was replicated 5 times. The larvae along with food were irradiated at 0, 2.5, 5, 7.5, 10, 15, or 20 krad. Observation was made every other day for mortality and feeding. Fresh irradiated food, which was treated at the same time as the larvae, was added only when necessary.

Pupae: pupae selected for irradiation were 2–4 days old. The numbers of replicates and individuals per treatment were the same as were used with the larvae. The pupae were given doses of 0, 5, 10, 15 or 20 krad. After the treatment these were put in Petri dishes. Daily observations were made for mortality of pupae, adult emergence and adult mortality. As adults emerged, these were transferred to small rearing jars containing treated food.

Adults: adults 6–7 days old were given doses of 0, 5, 10, 15, 20, 30 or 40 krad. The numbers of replicates and individuals per treatment were the same as were used with the larvae. Irradiated adults were housed in rearing jars. Observations on alternate days were made for feeding, mortality and production of F1 progeny, if any.

Sterility doses: pupae were separated from rearing and put individually in vials to ensure emergence of unmated adults. Males 2–3 days old were given doses of 1, 1.5, 5 or 10 krad of gamma radiation. After the treatment 5 males were combined with 5 virgin females in rearing jars (15 cm × 8 cm × 5 cm) for determination of the sterility dose.

4.2. Results

Eggs: observations were made 10 days after the treatment. The dried fish was broken down very carefully and the numbers of larvae, either dead or alive, were determined. Table II shows the results. All the larvae in treated Petri dishes were dead, although there were some cast skins. There was normal feeding by the controls, whereas feeding (as determined from the damaged fish) was increasingly reduced in the irradiated samples with increases in radiation dose. At the time of observation all larvae in the controls were present as 2nd and 3rd larval instars, whereas larvae in treated samples died in 1st and 2nd instars. That this is correct was established by the fact that the numbers of cast skins in 2.5, 5, 7, 10 and 15 krad samples were 21.4, 16.6, 10.2, 4.8 and 3.4 respectively, compared with 40 in the controls.

Larvae: results of larval mortality are shown in Table III and in Fig. 1. Larvae are quite susceptible to irradiation. It is evident from this table that a dose as low

TABLE II. RADIATION EFFECTS ON 0–48 h OLD EGGS OF *D. maculatus* Deg. (Observations 10 days after irradiation)

Replication	Number of larvae (dead or alive) with each treatment					
	0[a]	2.5	5	7.5	10	15
1	20	45	46	10	15	24
2	30	36	36	17	5	10
3	25	27	70	75	75	27
4	62	33	41	22	15	10
5	17	60	55	32	20	12
Average	30.8	40.24	49.6	31.24	17.24	16.6

[a] All larvae in the control were alive, while none was live in the irradiated groups.

TABLE III. NUMBERS OF DEAD LAST INSTAR LARVAE OF *D. maculatus* (Observation 20 days after irradiation)

Replication	Dose (krad*)						
	0[a]	2.5	5	7.5	10	15	20
1	8	16	18	8	15	18	20
2	5	16	19	18	20	10	19
3	2	20	18	18	19	20	20
4	6	18	17	20	9	19	20
5	5	12	18	20	16	20	20
Average	5.2[a]	16.4[b]	16.8[b]	15.8[b]	17.4[b]	19.8[b]	18.0[b]

Least significant difference at 5% level = 4.21.
Least significant difference at 1% level = 6.12.

Note: Numbers designated by unlike letters are significantly different.
* 1 rad = 1.00×10^{-2} Gy.

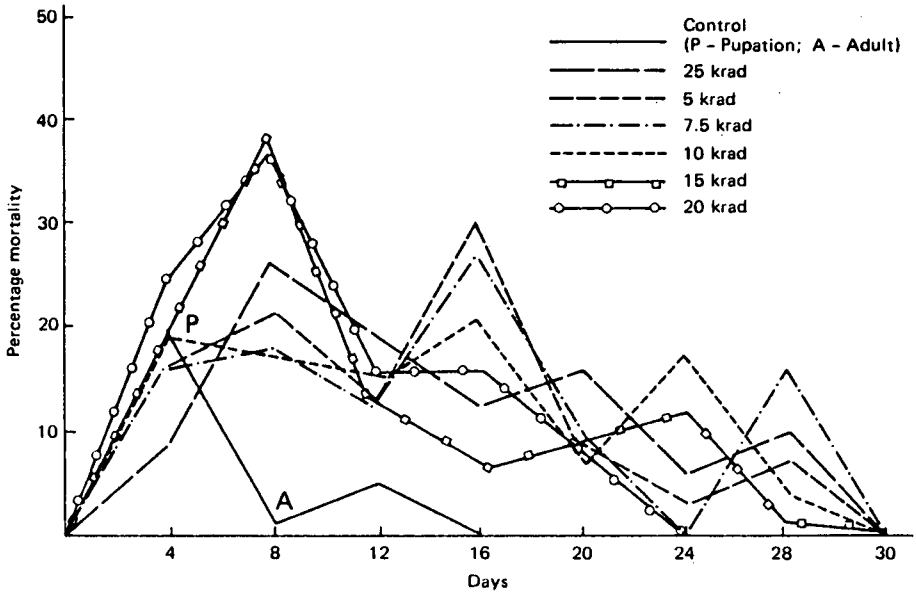

FIG. 1. Mortality of the last instar larvae of Dermestes maculatus *after exposure to gamma rays. A — Adult emergence; P — Pupation. (1 rad = 1.00 × 10^{-2} Gy.)*

as 5 krad could give 90% mortality in the larval stage compared with the observed 26% death in the control. This difference was highly significant. In addition, feeding of larvae at higher doses (10 krad and above) was almost stopped. Figure 1 shows that there is a peak of mortality on the 8th day after the treatment. Although the insects at the higher doses continued to live, they were in a moribund condition. For all practical purposes, as regards their ability to infest, they could be considered as dead. None of the irradiated insects pupated. Pupation was 74% in control and there was normal emergence of adults, which subsequently produced normal F1 progeny.

Pupae: radiation effects on pupae have been summarized in Table IV. It is evident from the table that unlike with the larvae, radiation could not drastically check adult emergence. Emergence of adults, which was 89% in control, dropped to 72% at 20 krad. There was no significant difference among the adult emergence of irradiated pupae with the exception of the 15 krad samples. The reasons for this exception cannot be explained. The percentages of deformed adults at 0, 5, 10, 15 and 20 krad were 0, 17, 32, 21, and 36% respectively. There was significant difference between the highest and the lowest irradiation treatments. All adults at 20 krad were deformed. The normal adults from the irradiated pupae were allowed to mate among themselves but no progeny were produced. Adults in the control were normal and produced normal progeny.

TABLE IV. RADIATION EFFECTS ON 2–4 DAY OLD PUPAE OF *D. maculatus*

Dose krad*	Number adult emerged	Number adult deformed	Number adults dead after 20 days of observation
Control	17.8	0	2.4[a]
5	14.24	3.4[a]	13.6[b]
10	15.00	6.4[bc]	14.4[b]
15	11.8	4.24[ab]	11.8[b]
20	14.40	7.24[c]	14.40[b]
LSD** at 5%	3.43	2.34	4.21
LSD at 1%	5.03	3.43	6.12

Note: Numbers designated by unlike letters are significantly different.

* 1 rad = 1.00×10^{-2} Gy.

** LSD = Least significant difference.

Adults: mortalities in adults were observed during the 24 days after irradiation. Dose-response curves are shown in Fig. 2. It is evident from these curves that radiation drastically affected the longevity of adults. There are two peaks: the early peak of mortality was due to the higher doses of radiation and the late peak was due to lower doses of radiation. Table V also shows the analysed results. Over 90% mortality was obtained at a dose of 15 krad compared with 18% for the control within 14 days of the treatment. Highly significant differences existed between control and irradiated insects. Irradiated insects showed reduced feeding. Insects at 5 and 10 krad initially showed normal feeding but, afterwards, feeding was much reduced. At doses of 15 and 20 krad adults showed little feeding from the very beginning. At doses of 30 and 40 krad adults seemed to have had a shock, but they recovered after a couple of days. Feeding was almost stopped at 30 krad and there was no sign of feeding at 40 krad. However, at higher doses movement of insects was also much affected. They continued to live in a moribund condition. Control insects were all normal.

Sterility doses: it was observed that 50% sterility could be induced in males by a dose of 1 krad. A dose of 5 krad could be considered an effective dose for inducing almost 100% sterility of this pest.

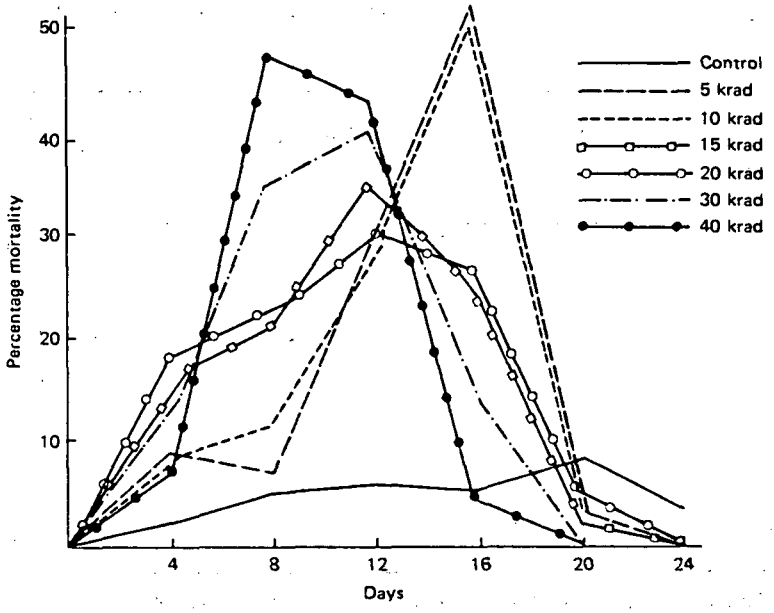

FIG. 2. Mortality of the adults of Dermestes maculatus *after exposure to gamma rays. (1 rad = 1.00 × 10^{-2} Gy.)*

5. PACKAGING STUDIES ON DRIED FISH

Dried mackerel infested with large numbers of insects were used for this experiment. However, to ensure the presence of insects, a number of insects in different developmental stages were added to the dried fish and allowed to remain for 48 h. A quantity of the fish was disinfested in an oven for 48 h at 60°C. Then 250 g of dried mackerel was packed in a number of polythene pouches and sealed without removing the air. Each polythene pouch measured 25 cm × 16 cm.

Besides the irradiated samples, two kinds of unirradiated controls were used, i.e. untreated control, *control*, and heat disinfested control, *disinfested control*. Visual examinations were made for insect damage, insect mortality, development of mould and the condition of the polythene pouches with special attention to insect punctures. The following experiments were carried out.

Experiment 1. The pouches were given doses of 0, 10, 20, 50 or 100 krad of gamma rays. A disinfested control was provided. The moisture content of the disinfested control was 13% whereas that of the rest of the samples was 18%. This experiment was replicated four times. All polythene pouches were kept in an incubator maintained at 29 ± 1°C and 70 ± 5% relative humidity. The thickness of the polythene used for making pouches in this experiment was 50 μm.

TABLE V. PERCENTAGE MORTALITY OF 6–7 DAY OLD ADULTS OF *D. maculatus* AFTER 14 DAYS

Replication	Dose (krad*)						
	0	5	10	15	20	30	40
1	25	65	85	100	95	95	100
2	0	80	75	85	90	100	100
3	15	95	90	90	85	100	100
4	30	85	75	90	90	100	100
5	20	65	60	95	85	95	100
Average	18^{a}	78^{b}	77^{b}	92^{cd}	89^{c}	98^{cd}	100^{d}

Least significant difference at 5% level = 9.96.
Least significant difference at 1% level = 14.47.

Note: Numbers designated by unlike letters are significantly different.
* 1 rad = 1.00×10^{-2} Gy.

Experiment 2. Pouches were made of polythene having a thickness of 75 μm. These were given doses of 0, 100, 200 or 400 krad. As in experiment 1, a disinfested control was provided. The moisture content of the disinfested control was 13%. All other samples had a 20% moisture content. The experiment was replicated five times.

Experiment 3. Dried mackerel was kept in an oven at about 60°C for 24 h. The final moisture content was 13%. Pouches were made from polythene having thicknesses of 50, 75 and 100 μm. Each thickness was replicated five times. The same doses of radiation were given as in experiment 2 with the same two controls.

6. RESULTS AND OBSERVATIONS

Experiment 1. In the control samples (untreated) normal feeding of insects occurred. After 45 days fungus started developing in all but one of the replicates. All control (untreated) packages were completely spoiled due to the heavy growth of fungus and insect damage 65 days after the treatment. Live insects in all their developmental stages were observed. Observations were continued for up to 100 days. Few live insects were found. One package was punctured by insects.

At 10 krad up to 45 days the condition of the pouches was good, but with slight insect damage. Very few living insects were seen, and they were in moribund condition. Slight development of mould was noticed after 65 days, but all insects were dead. After usage, slight insect damage was noticed due to earlier feeding of insects but all insects were dead. Slight mould development was observed. In the final examination, after 100 days, it was noticed that 75% of the samples were totally spoiled due to mould.

At 20 krad after 65 days no apparent insect damage was noticed except in one pouch. Fungus started developing in all replicates after 45 days of storage. Spoilage was considered only moderate after 65 days of storage. At the end of the experiment it was observed that 50% of the product was totally spoiled owing to fungal growth. Very slight insect damage was observed in one replicate.

At 50 krad the condition of the product was good up to 65 days, then fungus started developing. No live insects were found after 15 days, and there was no insect damage in any of the replicates, although the product had some indication of fungal development. After 100 days 75% of the product was completely spoiled due to fungal growth. The condition of the packages was very good; there were no punctures due to insects. The disinfested control was very good from the beginning. At the end of the experiment there was no insect damage nor any fungal development. The pouches were in excellent condition.

Experiment 2. Observation after 2 weeks showed the presence of insects in all developmental stages in the controls. There were also *Necrobia rufipes*. No dead insect was found in the pouches. There was enormous feeding by the insects. There was no development of fungus nor insect puncture of the pouches. During the same period, dead insects were observed at 50, 100, and 200 krad with no development of fungus. Slight damage by insects was noticed in one replicate each of the doses of 50 and 100 krad. The condition of the samples at a dose of 400 krad was very good. There was no indication of insect damage or of fungal development. The pouches in all treatments were in good condition. Disinfested control was also in the same condition as the 400 krad sample.

Development of mould was noticed in all treatments 4 weeks after the treatment. Fungal development continued in all treatments except in the disinfested control. The experiment was stopped after 90 days. During this period the controls were totally destroyed owing to insect feeding and fungal development. A few insects in developmental stages were still alive. All other samples, except the disinfested control, had heavy fungal growth and in the final examination it was observed that 40–60% of the product was totally spoiled. The disinfested control was in very good condition with no insect puncture. Dead insects were found in all irradiated samples and both *D. maculatus* and *N. rufipes* were present.

Experiment 3. Observations were made for 45 days. There was heavy insect damage in the control. No fungus developed and no insect damage was observed in

any of the other samples. Insects in irradiated samples appeared to be dead. There was no damage in pouches of any thickness. The condition of packages was very good in all treatments except the control.

7. DISCUSSION

The disinfestation experiment with *Labeo gonius* was successful, but we could not establish whether earwigs were the result of primary infestation or originated from rejected dried fish in godowns. Their presence, however, could be damaging to fish, as was demonstrated in the experiment. After 1 month, even in the control all earwigs disappeared, indicating that dried mackerel was not a suitable medium for their growth.

Eggs of *D. maculatus* were most susceptible to radiation. Even a dose of 2.5 krad prevented the eggs from developing into fully mature larvae. A dose of 5 krad inactivated 90% of the larvae within 2 weeks. Feeding stopped at 10 krad and above. A dose above 10 krad could control larval infestation. The possibility of further infestation is prevented since there was no adult emergence in any of the treated larvae.

Irradiation at pupal stage could not check adult emergence even at lower doses (Table IV). There was no significant difference among the treatments with the exception of the control and the 15 krad.

It was observed that, as the dose increased, the percentage of deformities in adults also increased. All the adults which emerged from 20 krad samples were deformed. In addition, all normal adults from irradiated pupae were sterile. Feeding of these adults was also drastically reduced and, as such, these could be considered harmless in the dried fish. From the dose–response curves of Fig. 2, it appears that longevity of adults was much affected by radiation, thereby curtailing the period of capability to infest. A dose of 15 krad killed 90% within 2 weeks; but to check spoilage instantaneously, a dose of 30 krad was needed. From the results of the experiment it appears that a dose of 20 krad could also be considered sufficient for practical purposes, since the feeding of adults with this treatment was negligible.

It is apparent from the above mentioned discussion that it is possible to disinfest dried fish of earwigs and hide beetles by the use of gamma rays. Radiation disinfestation of dried fish of hide beetles has been reported by Daget [19], Boisot and Gauzit [20] and Pointel and Pham Van Sam [4]. Their overall results are in agreement with the present experiments. But it should be pointed out that the number of individuals used by Pointel and Pham Van Sam for their investigations with larvae, pupae and adults were less than half those used in our experiment. Some numbers (i.e. 4 or 5 pupae per replicate) were not even comparable. It may be concluded that beetles of all stages can be inactivated with doses of 20 to 30 krad. This dose range

falls well within the permissible dose limits used in the disinfestation of cereals and cereal products in many countries.

The three experiments reported in this study on the radiation disinfestation of dried fish show that doses of 50 krad and above are sufficient to kill all insects present. Therefore, in meeting the overall requirements for preservation of dried fish, in addition to the use of irradiation at the indicated doses to obtain insect disinfestation, and in addition to the use of effective packaging to prevent reinfestation, it is also necessary to dry the fish adequately to prevent spoilage due to mould growth. The packaging requirements to prevent reinfestation result in a situation somewhat different from that which exists with the present practice of using jute bags, which are quite airy and, as a consequence, cause less of a problem with mould growth.

All thicknesses of polythene used were insect resistant although there were a few punctures in pouches of 50 μm thickness. A 75 μm thickness seems to be satisfactory for practical use. Considering the Bangladesh requirements, polythene is a good packaging material which is abundantly produced locally. Probably after jute bags, polythene bags are lowest in cost.

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