infestations as any procedure now available (Tilton and Brower, 1987). Reviews by Cornwell (1966), and Watters (1984) have listed the advantages and limitations of radiation for insect control in stored foods.

The choice of a suitable dose of radiation is particularly important in determining the conditions for radiation disinfestation of stored food. The use of very high doses of radiation causes a rapid death of most pests but greatly increase labor costs and may also cause unfavourable changes in the quality of the irradiated foods (Thayer, 1985). Lower doses of radiation are not adequate for killing the most resistant stages but can prevent any increase in the population by lethal action on the immature stages, sterilization of adults and shortening adult life (Buscarlet, 1982). Complete sterilization was achieved at 10 kard in the granary weevil (Brown *et al.*, 1972), at 18 kard in the lesser grain borer and confused flour beetle (Tilton *et al.*, 1966) and at 20 kard in the saw-toothed grain beetle (Brower and Tilton, 1972).

The use of Gamma radiation for insect disinfestation of stored dry dates was not investigated thoroughly. Ahmed (1981) found that treatment with a dose of 0.2 kGy resulted in 100% mortality in the damaging stages of the fig moth *Ephestia cautella* and the saw-toothed grain beetle *O. surinamensis.* El-Sayed and Baeshin (1982) found that a dose of 0.25 kGy was effective in preventing the development of *O. surinamensis*, and *E. cautella.* The authors recommended that the age of radiated specimens needed to be determined for effective control of insect disinfestations.

There are variations in the results of radiation against a single species. These variations are probably due to the technique used, conditions (temperature and relative humidity) where treated insects were kept before and post irradiation and the influence of age within the stages tested (Khatoon and Heathe, 1990). Therefore, the objectives of the present work were to study the biology of *Oryzaephilus surinmensis* under the experimental conditions to determine the longevity of the preadult stages and to study the effect of gamma radiation on the saw-toothed grain beetle.

Materials and Methods

Oryzaephilus surinamensis was reared on dried dates for several years at the Entomology laboratory of the Department of Plant Protection, College of Agriculture, King Saud University under controlled conditions of 28 °C and 60±5% r.h. Insects were maintained under these conditions before and during all tests and observations. Jars (11x7 cm) and dishes (9x1.5 cm) were used in the present studies. Since the larvae of this beetle hide inside the date fruits and can not be seen, the dry dates which were obtained from Asir area were ground by a blender to a semi-fine dry powder.

Biological Study

To obtain eggs, adults of *O. surinamensis* were placed for one day in 10 petri dishes with a small amount of white flour as an oviposition site. Adults were removed after 24 hrs. Eggs were collected and divided randomly into 12 replicates, each consisting of 40 eggs. Eggs were examined daily and the incubation period and hatchability were recorded.

Twenty newly-emerged larvae were placed into a petri dish containing 20 g of ground dates. Larval and pupal periods were recorded. Food was changed weekly. Twelve replicates were used for each stage.

Effects of Gamma radiation on O. surinamensis

This study was conducted to determine the effect of radiation to three-day old eggs, three-week old larvae, three-day old pupae, newly-emerged adults and four-week old adults. Doses of 0.0 (control), 0.1, 0.3, 0.5, 0.7 and 1.0 kGy were used. Four replicates (20 individuals each) were used for each dose. Insects of each replicate were confined in a petri dish. Larvae and adults were supplied with sufficient ground dates. The semi-commercial irradiation facility, CO^{60} source, at King Faisal Specialist-Hospital and Research Center was used for the irradiation treatments. Mortality of larvae and adults was assessed 2 days after treatment and thereafter at weekly intervals. Mortality of eggs and pupae was assessed at egg hatching and adult emergence, two days later and thereafter at weekly intervals. Food was provided to newly-hateched larvae and emerging adults.

Results

Biology of O. surinamensis

The mean percent of hatch ranged between 85-95% with a mean of 89%. The duration of larval period ranged

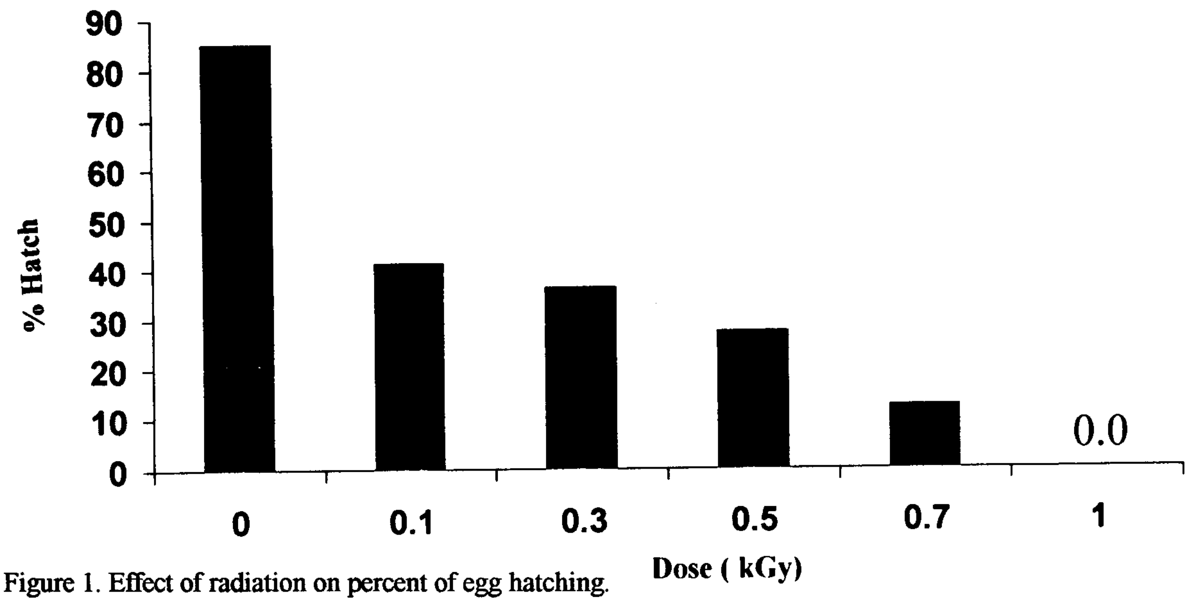

Figure 1. Effect of radiation on percent of egg hatching.

Table 1. Survivorship of irradiated larvae of *O. surinamensis* (mean ± SE).

Dose (kGy)	% larval survival after treatment		
	2d	7d	14d
0.0	100±0.0 a	87.5±3.2 a	87.5±3.2
0.1	72.5±6.6 b	25.5±3.5 b	0.0
0.3	53.7±4.2 c	15.0±4.5 c	0.0
0.5	51.2±3.1 c	11.2±3.1 cd	0.0
0.7	42.5±3.2 c	3.7±2.3 ed	0.0
1.0	18.7±4.2 d	1.2±1.2 e	0.0

Means in columns followed by the same letters are not significantly different ($P<0.05$).

between 26-49 days, with a mean of 06.03 days. Larval mortality was relatively low; the higherst larval mortality per replicate was 15%. The pupal period ranged between 4-10 days, with a mean of 7.25 days.

Effect of Gamma radiation on *O. surinamensi*

The mortality of eggs due to irradiation was relatively high.

The percentage of hatch decreased as radiation dose increased, and all eggs failed to hatch at dose of 1 kGy (Fig. 1). No larvae from irradiated eggs emerged as adults at any dosage level. Regardless of dose, larvae irradiated eggs died two days after hatching

Table 2. Percent of adult emergence and adult survivorship from irradiated pupae of *O. surinamensis* (mean±SE).

Dose (kGy)	% adult emergence	% adult survival after pupae eclosion			
		2d	7d	14d	21d
0.0	90.0±2.1 a	90.0±2.1 a	90.0±2.1 a	90.0±2.1 a	90.0±2.1 a
0.1	88.7±2.3 a	62.5±4.7 b	38.7±2.3 b	1.2±1.2 b	0.0 b
0.3	86.2±3.7 a	46.2±5.5 c	23.7±6.2 c	0.0 c	0.0 b
0.5	83.7±2.3 ab	21.2±3.7 d	0.0 d	0.0 c	0.0 b
0.7	75.0±2.8 b	15.0±2.8 d	0.0 d	0.0 c	0.0 b
1.0	63.7±5.5 c	2.5±1.4 e	0.0 d	0.0 c	0.0 b

Means in columns followed by the same letters are not significantly different (P<0.05).

Table 3. Survivorship of irradiated three-day old adults of *O. surinemensis* (mean±SE).

Dose (KGy)	% survival after treatment				
	2d	7d	14d	21d	28d
0.0	100±0.00 a	100.0±0.0 a	100.0±0.0 a	100.0±0 a	100.0±0 a
0.1	85.0±3.5 b	60.0±5.4 b	37.5±3.2 b	22.50 b	15.0±2.8 b
0.3	72.5±2.5 c	28.7±4.2 c	0.0 c	0.0 c	0.0 c
0.5	65.0±4.1 cd	25.0±5.4 c	0.0 c	0.0 c	0.0 c
0.7	56.2±5.5 de	25.0±4.6 c	0.0 c	0.0 c	0.0 c
1.0	53.7±4.2 e	17.0±3.2 c	0.0 c	0.0 c	0.0 c

Means in columns followed by the same letters are not significantly different (P< 0.05).

Table 4. Survivorship of irradiated four-week old adults of *O. surinamensis* (mean±SE).

Dose (kGy)	% survival after treatment				
	2 d	7 d	14 d	21 d	28 d
0.0	100.0±0 a	85.0±2.8 a	75.0±6.1 a	50.0±7.3 a	50.0±7.3
0.1	80.0±5.4 a	35.0±4.5 b	12.5±3.2 b	7.5±1.4 b	0.0
0.3	68.7±4.2 bc	18.7±2.3 c	0.0 c	0.0 c	0.0
0.5	61.2±4.2 cd	18.7±2.3 c	0.0 c	0.0 c	0.0
0.7	55.0±6.4 cd	12.5±3.2 c	0.0 c	0.0 c	0.0
1.0	50.0±10.8 d	12.5±3.2 c	0.0 c	0.0 c	0.0

Means in columns followed by the same letters are not signficantly different (P<0.05).

adult were most tolerant. Banhum and Crook (1966) found that eggs of *T. confusum* were most susceptible and pupae of the same species most tolerant. Tilton *et al.* (1966) found that adults of *Rhyzopertha dominica, Sitophilus oryzae, Tribolium confusum* and *Lasioderma serricorne* were most tolerant, followed by pupae, then larvae and eggs.

No dosage used in this study was high enough to produce immediate complete mortality of the adults of *O. surinamensis*. Similar results were found by Brower and Tilton (1972). But a complete sterility was achieved at a dose of 0.3 kGy or above. Zaklodoni and Ratanova (1987) reported that the sterility dose of this pest was 18 kard (=0.18 kGy); whereas, Auda (1980) found that dose of 0.7 kGy was sufficient for sterilization of the same pest. Bower and Tilton (1970) found that 0.4 kGy is a sufficient dose to control the saw-toothed grain beetle. Cornwell (1966) stated that the presence of sterile adults offers some protection against reinfestation because the sterile adults are incapable of reproducing. Moreover, the rate of food consumption of sterile adults, due to irradiation, is decreased considerably. Brower and Tilton (1973) found that wheat consumption by irradiated rice weevils and lesser grain borers during a five-week period was reduced by 90 and 97%, respectively, by a dose of 250 kard (=0.25 kGy). Therefore, the control of the pest can be obtained by using the sterilizing dose (0.3 kGy) to sterilize pupae and adults and to kill eggs and larvae before reaching the adult stage.

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References

Ahmed, M.S.H. 1981. Investigation on insect disinfestation of dried dates by using γ radiation- A review. *Date Palm J.* 1: 107-116.

Auda, H. 1980. Dates irradiation in Iraq. *Food Irradiation information* 10: 34-40.

Larvae were sensitive to radiation, not treated larvae emerged as adults at any treatment level (Table 1). The larval survival was significantly higher in the non-irradiated than in the irradiated treatments. Larval survival decreased as radiation dose increased at two and seven days after treatment. Irradiated larvae died 14 days after treatment.

Pupae showed more resistance to radiation than eggs or larvae. Adult emergence from irradiated pupae occurred in all treatments (Table. 2). The adult emergence in the control was not significantly different from that at levels of 0.1-0.5 kGy. However, total mortality was achieved 7, 14 and 21 days after adult emergence from pupae irradiated at doses of 0.5 to 1, 0.3 and 0.1 kGy, respectively. Adults produced from treated pupae did not produce any progeny at any treatment level (Table. 2).

The sensitivity of three-day old adults to radiation is shown in table 3. No mortality was recorded in the control for 28 days after treatment. None of the dosage levels used were sufficient to cause immediate mortality. Dose of 0.3-1.0 kGy caused 100% mortality within two weeks. Adults treated with dose of 0.3 kGy or above did not produce progeny. Survival of adults treated with 0.1 kGy was greatly reduced with time. The survival was 15% at 28 days after were able to produce progeny.

Four-week old adults were more susceptible to radiation than young adults (Table 4). Doses of 0.3-1.0 kGy caused 100% mortality within two weeks, whereas dose of 0.1 kGy caused 100% mortality 28 days after treatment. Irradiated old adults were unable to produce any progeny at any dose.

Discussion

The continuous use of insecticides to control stored product pests poses major problems (Parkin, 1965). On the other hand, fumigation is increasingly restricted for toxicological and environmental reasons (Pszczola, 1997). An effective procedure for the rapid disinfestation of stored food has been needed for many years. Radiation technique offers an alternative method for pest control because it requires less time, leaves no residue and can be as affective as fumigants (Tilton and Brower, 1987).

The susceptibility of *O. surinamensis* to irradiation varies as development progresses from egg to adult. Eggs and larvae were most susceptible to irradiation and no irradiated eggs and larvae reached the adult stage; whereas, pupae and young

Banham, E.J. and Crook, L.J. 1966. Susceptibility of the confused flour beetle, *Tribolium confusm* Duv. and the rust-red flour beetle, *Tribolium castaneum.* (Herbst) to gamma radiation. Pp. 107-118 In: Cornwell, P. B.(Ed). *The Entomology of radiation disinfestation of grain.* New York: Pergamon Press.

Brower, J. and Tilton, E.W. 1970. Insect disinfestation of dried fruit by using gamma radiation. *Food Irradiation* 11: 10-14.

Brower, J. and Tilton, E.W. 1972. Comparative gamma radiation sensitivity of the saw-toothed grain beetle and the merchant grain beetle. *Environ. Entomol.* 1: 375-379.

Brower, J. and Tilton, E.W. 1973. Weight loss of wheat infested with gamma-radiated *Sitophilus oryzae* (L.) and *Rhyzopertha dominica* (F.) *J. stored Prod. Res.* 9: 37-41.

Brown, G.A.; Brower, J.H. and Tilton, E.W. 1972. Gamma radiation effect on *Stiphilus zeamais* and *S. granarius. J. Econ. Entomol.* 65: 203-205.

Buscarlet, L.A. 1982. Effects of γ irradiation on respiration and on food consumption measured through ^{22}Na in *Tribolium confusum* J. DUV. (Coleoptera: Tenebrionidae) *J. stored Prod. Res.* 19: 19-24.

Conrnwell, P.B. 1966. *The Entomology of Radiation Disinfestation of grain.* New York: Pergamon Press, 236 pp.

El-Sayed, S.A. and Baeshin, N.A. 1982. Feasibility of disinfestation of date fruits produced in Saudi Arabia by Gamma irradiation. Pp 342-350 In: *Proc. First Symposium on Date Palms.* King Faisal Univ., Al-Hassa, Saudi Arabia.

Khatoon, N. and Heather, N.W. 1990. Susceptibility of *Dremestes maculatus* De Geer (Coleoptera: Dermestidae) to gamma radiation in a nitrogen atmosphere. *J. stored Prod. Res:* 26: 227-232.

Parkin, E.A. 1965. The onset of insecticides among field populations of stored product insects. *J. stored. Prod. Res.* 1: 3-8.

Pszczola, D.E. 1997. 20 ways to market the concept of food irradiation. *Food Technology* 51: 46-48.

Thayer, D.W. 1985. Application of radiant energy in pest management. *Cereal Food World* 30: 714-721.

Tilton, E.W. and Brower, J.H. 1987. Ionizing radiation for insect control in grain and grain products. *Cereal Food World* 32: 330-335.

Tilton, E.W.; Burkholder, W.E. and Cogburn, R.R. 1966. Effects of gamma radiation on *Rhyzopertha dominica, Sitophlius oryzae, Triboliuum confusum,* and *Lasioderma serricorne. J. Econ. Entomol.* 59: 1363-1368.

Watters, F.L. 1984. Potential of ionizin iradiation for insect control in the cereal food industry. Pp. 265-278 In: Baur, F.J. (Ed). *Insect Management for food storage and Processing,* St. Paul, Minnesota: American Association of Cereal Chemists.

Zakladnoi, G.A. and Ratanova, V.F. 1987. *Stored-grain pests and their control.* New Delhi: Oxonian Press, 268 pp.

استخدام أشعة جاما في مكافحة خنفساء الحبوب المنشارية ، آفة التمور المخزونة

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الملخص : أجريت دراسة أولية لدورة حياة الآفة تحت ظروف التجربة لمعرفة أطوال فترة الأطوار غير البالغة . كما استخدمت أشعة جاما لمعرفة تأثيرها على طور البيضة و اليرقة و العذراء، والحشرة الكاملة عمر ثلاثة أيام وأربعة أسابيع . والجرعات التي استخدمت هي : صفر ، ١ر٠ ، ٣ر٠ ، ٥ر٠ و ١ كيلو جراي (Kgy) . وتم حفظ الحشرات قبل وبعد التشعيع في حضانة تحت درجة حرارة ٢٨° م. انخفضت نسبة فقس البيض معنويا بزيادة جرعة التشعيع ، و لم يحدث أي فقس عند استخدام جرعة ١ Kgy . وحدث موت لجميع اليرقات الناتجة من بيض مشعع بعد يومين من الفقس . وتأثرت اليرقات بأشعة جاما و لم تتمكن من الوصول إلى طور العذراء ، وعلى العكس فقد تمكنت العذارى التي تعرضت إلى أشعة جاما من الوصول إلى طور الحشرة الكاملة إلا إنها لم تتمكن من إنتاج جيل جديد . وتعتبر الحشرات الكاملة عمر ثلاثة أيام أكثر مقاومة لأشعة جاما ، فقد تمكنت الحشرات التي تعرضت إلى جرعة ١ر٠ كيلوجراي من إعطاء جيل جديد . أما الحشرات الكاملة عمر أربعة أسابيع فقد أصبحت أفراداً عقيمة غير قادرة على إعطاء جيل جديد . وتبين من هذه الدراسة بأن جرعة ٣ر٠ كيلوجراي تسبب عقماً للحشرات الكاملة وموت اليرقات قبل وصولها لطور العذراء .