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The Optimal Irradiation of Iraqi Dates Fruit by Gamma Radiation for Disinfestation Purposes

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Abstract
Fig moth E. cautella, considered the most serious pests infest dates and cause economic losses in the field and warehouses in Iraq which produces between 600-700 thousand tons of dates annually. In order to reduce this damage different pest control methods are used and fragmentation of radiation considered one of the newest and innovative way to control this Moth that attack stored dates. Dates, Zahdi variety artificially infested by eggs of Ephestia cautella .Eggs and larvae of insect were irradiated by gamma radiation with different doses between (106 - 397.5Gy) and then irradiated dates stored at 19C^{o}, 30 and 40 days for Larvae and Eggs respectively. Fragmentation of irradiation dose of gamma were used, five periods of irradiation with three different times separating each period (5, 10, 15min). Physical and chemical properties of dates were analyzed. Results showed that the fragmentation technique is comparable with continuous irradiation and effective for eliminating the insect and keeping the dates preserved with high quality. A dose of (165Gy) and (198Gy) required for 100% hatching inability of irradiated eggs. For larvae a dose of (397.5Gy) was enough to achieve mortality of (100%), (87.50%) and (83.33) for (5, 10, 15min) separating time between each irradiation period respectively. Physical and chemical characteristics did not changed as a result of irradiation.
Keywords: Ephestia cautella, stored dates, Iraq, fragmentation of irradiation.

1. Introduction

The date palm (Phoenix dactylifera L.) plays an important economic role for Foreign Trade to many countries that are located in arid and semi-arid regions of the world. Dates are rich in certain nutrients and provide a good source of energy, due to their high carbohydrate content (70–80%). Moreover, it contains protein (2.30– 5.60%), fat (0.20–0.50%), dietary fiber (6.40–11.50%), minerals about (0.10– 916 mg/100 g dry weight), and vitamins (C, B1, B2, B3, and A) (Al-Shahib, & Marshal 2003). Iraq is considered as one of the oldest countries cultivating date palms. Palms trees and fruits are subjected to infestation by many pests and insects which can be found where ever these trees are cultivated (Al –baker 1972) (Haideri, &.El-Hafeedh 1986). The production of dates fruit in 2016 in Iraq were more than 850 thousand tons of known Iraqi dates varieties and 15 million palm trees distributed in all provinces. Fig moth (Ephestia Cautella walk.) is considered the most important insect pests which infect the dates in the field when harvest delayed and also in the stores during the storage period and it cause large economic losses (Hussain & Jafar1966). Stored dates pest and insect control was depending almost entirely on methyl bromide fumigation and it had faced a phase-out worldwide in year 2015 under the terms of the Montreal Protocol (Urbain, 1986). Recently, many researchers have been devoted their efforts for seeking an alternative to methyl bromide against insect pests in warehouses. It has been reported that irradiation by gamma radiation could provide an important and effective alternative for the export dates fumigation (Ahmed 1991) (Marcotte 1993). There are many advantages of irradiation include no undesirable residues, no resistance developed by pest insects and few significant changes in the physical and chemical characteristics or the nutritive value (Ahmed 2001) (Lapidot 1991) (Boshra & Mikhaiel 2006). In the present work, we have tested gamma radiation sensitivity of different life stages of Ephestia cautella walk. irradiation by gamma rays that released from Co60 - isotope with two energies (1.173Mev and 1332Mev) and the effectiveness of a new innovative way through the fragmentation of the irradiation period and puts it on successive and cumulative periods for the radiation doses to reduce the risk of exposure to high efficiency radioactive sources and at the same time to get results by less exposing to radiation and with the same efficiency as continuous exposure to eliminate Ephestia cautella walk. Moth and preserve the stored dates with high quality and from infection of this insect again.

2. Materials and methods of work

2.1 Insect rearing

In this research we have used insect E.cautella moth style found in Agricultural Research Center laboratories of the Ministry of Science and Technology/Iraq, that bred on Artificial food consists of 81% rods wheat, 12% Glycerol, 0.6% dibs and 1% dry yeast putted all in Sterile plastic stock with diameter (11cm) and height (30cm) Insect raised in the same way mentioned again until the end of search and placed in the laboratory room under temperature (21 C^{o} – 25 C^{o}) and relative humidity (40% - 50%).

2.2 Treatment and preserve of dates

Date fruits where placed in rectangular boxes were made by hand from Cardboard. The dimensions of its base and sides (5x6 cm) and (3x6 cm) respectively with artificially insect eggs infestation (25 eggs per 10 fruits), eggs where obtained from the raised insect.

2.3 Eggs collecting

Eggs were collected by placing (20-30) pair adults of insect E.cautella (24-48hr) aged into sterile glass jar; lantern. In the base of the lantern there is a plastic plate (dish). covered by slight piece of cloth to ensure only the eggs fall into the dish after mating of insect adults, and the top of lantern covered by thick piece of cloth for ventilation , E.cautella adults take two days for mating and placing the eggs after that the eggs will distribute on the boxes.

2.4 Irradiation process and storage conditions

Packaged dates were exposed to different doses with different periods. Gamma chamber 900 were used in the irradiation process that containing Co^{60} as irradiation source with activity 4.878 Currie and absorbed dose 42Gy/hr. Eggs of Ephestia cautella walk. and Larvae aged 15 days and were irradiated. Fragmentation of irradiation dose of gamma were used, five periods of irradiation with three different times separating each period (5, 10, 15min).

2.5 Physiochemical characteristics of dates:-

Date palm (Phoenix dactylifera) fruits, zahdi variety were used in the present experiment. The following characteristics were studied before and after the irradiation.

- Physical characteristics: The main physical of Dates characteristics as weight loss, flavor and color. Physical observations of insect infestation were examined, recorded and calculated as percentage.
- Chemical analysis: Moisture content and pH-values and total soluble solids were determined as methods of A.O.A.C (A.O.A.C 1990). Total carbohydrates were determined as glucose by the phenol-sulfuric acid method (K.A. Michel, J.K. Gilles and F. Smith 1956).The protein was determined using Kjeldahl method (AACC 2000).

2.6 Statistical analysis

The data for percentage of alive insect stages, egg hatching and mortality were subjected to one-way analysis of variance; differences between treatment means were determined by Duncan's multiple range test at the 5% probability level. Abbott formula used for the correction of mortality for the treated samples [15].

3. Results and Discussion

3.1 Egg irradiation

Tables 1.1, 1.2, 1.3 shows the effect of gamma irradiation on eggs. Three replications (boxes) treated with radiation for each dose of gamma after (2-4) days of the infestation one used for measuring the nutritional values of irradiated dates and the other two were stored the temperature (19 C^{o} ±1) and unpacked after 40 days of irradiation and average results calculated as follows :-

Table 1.1. Percentage of adults and pupae and larvae of the insect and Eggs hatching compared with the radiation dose due to the irradiation of the eggs for (5) minutes between each period of irradiation.

Dose (Gray)	Larvae % ± SE	Pupae % ± SE	Adults % ± SE	Eggs hatching % ± SE
0	8d	80 ± 4.61a	8a	96 ± 3.46a
106.15	70 ± 3.46a	8 ± 2.30b	0a	78 ± 1.15b
123.84	54 ± 1.15b	4b	2 ± 1.15b	60c
141.54	66 ± 1.15a	8 ± 2.30b	4 ± 2.30b	78 ± 5.77b
165.62	16 ± 2.30c	0c	0c	16 ± 2.30d
198.75	0e	0c	0c	0e
265	0e	0c	0c	0e

* Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 1.2. Percentage of adults and pupae and larvae of the insect and the Eggs hatching compared with the radiation dose due to the irradiation of the eggs for (10) minutes between each period of irradiation.

Dose (Gray)	Larvae % ± SE	Pupae % ± SE	Adults % ± SE	Eggs hatching % ± SE
0	12d	80 ± 4.61a	4a	96.67 ± 3.52a
106.15	70 ± 1.15a	6 ± 1.15c	2 ± 1.15b	78 ± 3.46b
123.84	40 ± 2.30c	16 ± 4.61b	4a	60 ± 2.30c
141.54	66 ± 1.15b	0c	0c	66 ± 1.15c
165.62	0e	0c	0c	0e
198.75	0e	0c	0c	0e
265	0e	0c	0c	0e

* Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 1.3. Percentage of adults and pupae and larvae of the insect and the Eggs hatching compared with the radiation dose due to the irradiation of the eggs for (15) minutes between each period of irradiation.

Dose (Gray)	Larvae % ± SE	Pupae % ± SE	Adults % ± SE	Eggs hatching % ± SE
0	4 ± 2.30c	76 ± 4.619a	12 ± 2.30a	92 ± 4.61a
106.15	66 ± 3.46a	2 ± 1.155c	2 ± 1.15b	70 ± 5.77b
123.84	32 ± 2.30b	16 ± 4.619b	4b	52 ± 6.92c
141.54	30 ± 1.15b	6 ± 1.155c	0c	36 ± 2.30d
165.62	0c	0c	0c	0e
198.75	0c	0c	0c	0e
265	0c	0c	0c	0e

* Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

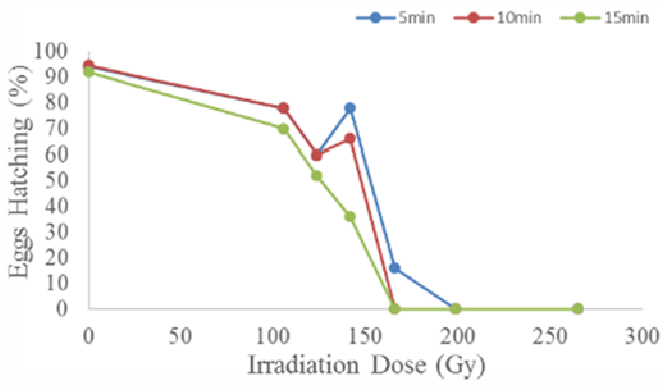

Fig 1. Percentage of Eggs hatching compared with the radiation dose due to the irradiation of the eggs for separating time (5, 10, and 15) minutes between each period of irradiation.

The results above shows that the egg is generally the most sensitive stage to radiation. A doses of (165Gy) and (198Gy) is enough for eliminating the eggs hatching ability and this result is comparable with [16], and this means that the fragmentation of irradiation dose has high effectiveness on eggs and keeping the dates preserved because of eggs sensitivity to gamma radiation.

3.2 Larvae irradiation

Tables 2.1, 2.2, 2.3 shows the effect of gamma irradiation on larvae (10-15 days) aged. Three replications (boxes) treated with radiation for each dose of gamma after (2-4) days of the infestation one used for measuring the nutritional values of irradiated dates and the other two were stored the temperature (19 C^{o} ±1) and unpacked after 30 days of irradiation and average results calculated as follows :-

Table 2.1. Percentage of adults and pupae of the insect and mortality compared with the radiation dose due to the irradiation of larvae for (5) minutes between each period of irradiation.

Dose (Gray)	Pupae % ± SE	Adults % ± SE	Mortality% ± SE	Mortality % (Corrected)
0	72 ± 2.30a	20 ± 2.30b	8 ± 0.57e	0
165.62	44 ± 2.30c	44 ± 4.61a	12 ± 6.92e	4.35
198.75	32d	44 ± 6.92a	24 ± 6.92d	17.39
265	56 ± 6.92b	8 ± 2.30c	36 ± 9.23c	30.43
298.12	40 ± 4.61c	12 ± 2.30b	48 ± 2.30c	43.48
364.37	20 ± 2.30e	8±2.30c	72 ± 4.61b	69.57
397.5	0f	0d	100a	100

* Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 2.2. Percentage of adults and pupae of the insect and mortality compared with the radiation dose due to the irradiation of larvae for (10) minutes between each period of irradiation.

Dose (Gray)	Pupae % ± SE	Adults % ± SE	Mortality% ± SE	Mortality % (Corrected)
0	16c	80 ± 2.30a	4 ± 2.30d	0
165.62	36 ± 2.30b	60 ± 4.61b	4 ± 6.92d	0
198.75	52 ± 4.61a	40c	8 ± 4.61d	4.17
265	40 ± 4.61b	36 ± 6.92d	24 ± 2.30c	20.83
298.12	44 ± 2.30b	28 ± 4.61e	28 ± 6.92c	25
364.37	24 ± 2.30c	18 ± 1.15e	58 ± 3.46b	56.25
397.5	8 ± 2.30d	4f	88 ± 2.30a	87.5

* Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 2.3. Percentage of adults and pupae of the insect and mortality compared with the radiation dose due to the irradiation of larvae for (15) minutes between each period of irradiation.

Dose (Gray)	Pupae % ± SE	Adults % ± SE	Mortality% ± SE	Mortality % (Corrected)
0	36a	60 ± 2.309a	4 ± 2.30d	0
165.62	24 ± 4.61b	64 ± 2.309a	12 ± 6.92d	8.33
198.75	24 ± 2.30b	60 ± 6.928a	16 ± 4.61c	12.5
265	36 ± 2.30a	48 ± 2.309b	16c	12.5
298.12	36 ± 6.92a	36 ± 4.619c	28 ± 11.54c	25
364.37	20 ± 2.30b	32 ± 2.309c	48 ± 0.5b	45.83
397.5	12 ± 2.30c	4d	84 ± 2.30a	83.33

* Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

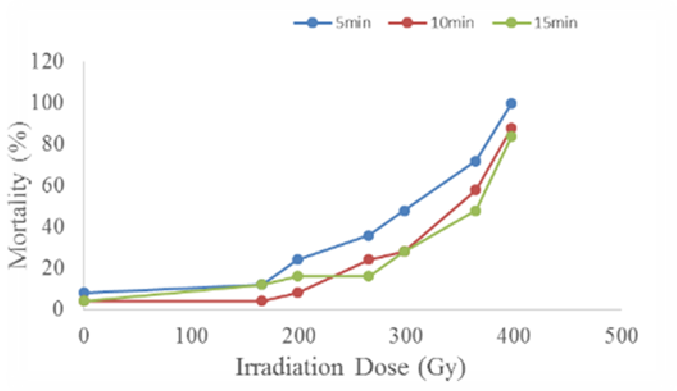

Fig 1. Mortality compared with the radiation dose due to the irradiation of the larvae for separating time (5, 10, and 15) minutes between each period of irradiation.

For larvae fragmentation of irradiation dose affected positively and the dose of (397.5Gy) achieved mortality of (100%), (87.50%) and (83.33) for (5, 10, 15min) separating time between each irradiation period respectively and this agreed with (Noemi Chuaqui-Offermanns 1987), which mentioned that the dose of (400Gy) is completely enough to control all stages life of Ephestia cautella walk. also noticed that as long as the time between each periods of irradiation is higher the effect of radiation decreased on the larvae of insect. Immediate killing did not happen for the larvae of the insect, the maximum rate of mortality were found after 30 days of irradiation. The storage temperature affect the ratio of mortality and it observed that the mortality increased by decreasing the storage temperature after irradiation. Results also show that the amount of non-lethal irradiation dose has affected the age of larvae and pupae resulting from irradiated eggs and larvae, as the higher radiation dose is the growth period of larvae and pupae increase.

For nutritional values of dates and the impact of radiation during intervals(5, 10, 15min) between each irradiation period showed in the following tables (1),(2),(3) respectively :-

Table1.

Dose (Gy)	Moisture content %	pH%	protein%	Total carbohydrate%	Soluble sugars%
0	14.3	7.62	1.563	66.15	15
165.625	11.7	7.01	2	67.14	13
198.75	12	6.8	1.313	65.22	13
265	11	7.9	1.75	68.01	11
298.125	16	7.8	1.563	65.2	15
364.375	11.4	7.8	1.563	60.6	13
397.5	7.3	8.2	1.75	69.02	16

Table 2.

Dose (Gray)	Moisture content %	pH%	Protein%	Total carbohydrate%	Soluble sugars%
0	15	7.71	2	64.33	12
165.625	12.5	7.51	1.125	70.49	13
198.75	13.43	7.34	1.563	68.33	16
265	10.6	7.91	1.75	65.2	17
298.125	11.7	7.32	1.313	59.19	17
364.375	10.41	7.12	1.655	61.14	14
397.5	11.01	8.05	1.67	67.02	16

Table 3.

Dose (Gray)	Moisture content %	pH%	Protein%	Total carbohydrate%	Soluble sugars%
0	15.3	7.65	1.653	67.2	16
165.625	14.3	6.11	2.1	61.67	12
198.75	11.5	7.22	1.91	62.15	12
265	12	7.8	1.72	58.9	14
298.125	11	7.7	2	69	15
364.375	11.2	7.37	1.72	62.12	17
397.5	12.5	7.82	1.67	66.81	16

It's clearly observed from the above tables that irradiation by gamma radiation does not made significant changes in nutritional values of dates. Also noticed during the research that there is no physical changes in dates as long as we stored it in lower temperature.

The above results in tables (2-1), (2-2) and (2-3) agreed with what mentioned from (Johanna G. Wellheiser 1992) that the insect disinfestation depends on several factors, including temperature and radiation dose, also give a number of fractional exposures dose causes increase in radiation tolerance by giving opportunity to repair the radiation injury between exposures (Walter M Urbain 1986). Fragmentation of irradiation dose of gamma found to take advantage of the low activity radioactive sources where it has less exposure effect for workers and ease in handling, it also includes a lower economic cost. Disinfestation by using gamma radiation was a method used to maximize quality and safety standards of fruits and this was observed on the dates in the current experiment. Radiation destroys both physical and genital functional cells, when the dose is fractionated the damaged cells may be recover through the time between each period of exposure and as long the time was the recovery of damaged cells increase or new cells may take over the function of these damaged cells and this cause reduction in radiation effectiveness on the insect, also insects capable of surviving the first period of exposure and given sufficient time to recover completely would then be able to resist more dose of the same amount without further mortality due to radiation , the amount of recovery and scale of survival are dependent on the length time of the intervals, the fractional dose, the number of intervals (fractions) (P.B.CORNWELL 1966). Low doses of gamma delay the maturity process and increase the shelf life whereas high doses of gamma effective for disinfestations and reduces spoilage, insect, microbial and pathogens(Uzma and Shagufta 2015).

In conclusion, we can rely on fragmentation of irradiation method in disinfestation of dates by using low radioactive activity sources instead of one radioactive source that have high activity and this allows the possibility of maintaining the production process in the case of source failure, also this method can provide more safety and protection from the radiation. This method allows us to use more than one physical technique like gamma and UV waves or microwaves waves for more effect.

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