BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
09-01A (2021) 01-11

Disinfestation of mangoes haden infested by *Anastrepha fraterculus* (Wied., 1830) (Diptera, Tephritidae) with gamma radiation

Arthur P. B[b,a]., Machi A. R[b]., Leandro R. S. R[b]., Harder L.N.C[b]., Harder M. N. C[c]., Arthur V[a,b].

[a]*Center For Nuclear Energy in Agriculture (CENA/USP), Department of Radiobiology and Environment, University of São Paulo, Box: 13416 – 000, Piracicaba – SP. Brazil*
[b] *Institute of Energy and Nuclear Research (IPEN), Department of Radiation Technology Center, University of São Paulo. Box: 05508-000, São Paulo – SP, Brazil.*
[c] *Technology College of Piracicaba/Food Technology Department, 13414-155, Piracicaba, SP, Brazil. e-mail arthur@cena.usp.br*

ABSTRACT

The objective of experiment was determinate the radiation dose for disinfestation to mango *Mangifera indica* cv. Haden, infested by *Anastrepha fraterculus* larvae. For realization of the experiment, were collected fruits in the field, which were taking to Entomology laboratory where there was an infestation by the flies in cages during 72 hours period. Waited for the development of the larvae 5 and 8 days to infestation, after the mangos were irradiated in a Cobalt-60 source with doses of: 0(control), 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1.100, 1.200 and 1.300 Gy. After the irradiation, the fruits were placed in climate chamber with 25 ±5°C of temperature and 70±5% of relative humidity. Waited the larvae exit to out of the fruit until the transformation in pupae and adult stage. By the results obtained we can concluded that the lethal dose to larvae in mangoes infested with 5 and 8 days were 600 Gy and 1.000 Gy (0.6 and 1 kGy) respectively. The dose of 50 Gy prevented the total adult emergence for both treatments.

Keywords: **gamma radiation, fruit flies, mango.**

ISSN: 2319-0612
Accepted: 2020-11-09

1. INTRODUCTION

The domestic production of traditional fruits showed a large increase in recent years, has played an important role in the export of these commodities. The Brazil is currently the third largest producer of fruits in the world, has supplied the domestic market with efficiency, importing only a small number of other countries, mainly temperate fruits. However, the country has exported very little, being the 15th in the ranking of world exports of fruit. Due to its large territory in Brazil one can find areas with different climates and ecosystems, ranging from semi-arid to temperate climates, so it allows the production of a wide variety of fruits. Due to increasing demand from importing countries and the potential of Brazil to attend this demand, the establishment of conditions more favorable to the development of the internal market in the export is need [1].

One of the most frequent and most economically important pest species for fruit farmers is the fly american south, *A. fraterculus* (Diptera, Tephritidae). The larvae of this fly, feed on the flesh of the fruit making it easier to attack and causing rot or premature fruit drop Infested by the pest. The insect pests destroy the major resources generated by agriculture. Measures to control these pests involve, among other strategies, actions to prevent the spread of exotic species to new areas [2, 3, 4]. In addition to direct damage, this pest causes problems for the export of fresh fruits, once consumer countries have strict laws, and thus require the disinfestations treatment for products that will import [1].

The Environmental Protection Agency of the United States banned in 1984, the use of ethylene dibromide (EDB), the fumigant most commonly used in the disinfestations of food. Alternative treatments are therefore required [5]. Concluded that the use of the gamma radiation is practically as a quarantine treatment for products infested with eggs and larvae of fruit flies. [6]

The advantages of irradiation on treatment with fumigants products, heat treatment or a combination of both types are: a) It is a continuous process and also more efficient b) ensures complete disinfection c) not leave residues in the fruits d) can increase shelf life, delays ripening of climacteric fruits and not climacteric and senescence of seeds (increases the storage time without deterioration of the fruit [7].

Since then, this shortfall is important because major phytosanitary treatments based on heat, cold, and methyl bromide fumigation have apparently failed, and the only way this was known was by the discovery of live insects after treatment [8]. The possibility of use of the gamma radiation as treatment for disinfestation of fruits attacked by fruit fly, was proposed by and then several researches has been conducted to the practicability of this method [9]. In Brazil [10] was the first to use gamma radiation to irradiate pupae of fruit fly *C. capitata* (Wied.), with the objective of obtain sterile insects.

Observed the effects of gamma radiation on the development of eggs, larvae and pupae of three species of fruit flies: *Dacus dorsalis* (Handel, 1912), *Dacus curcubitae* (Coq. 1899) and *C. capitata* (Wied.). With the results concluded that doses between 15 and 20 krad are effective in the treatment of quarantine to disinfestation of fresh fruits [11]. Worked with fruit flies *C. capitata*, infested grapefruit and mangoes. The dose of 21 krad of gamma radiation was necessary to inhibit the emergence of adults of these insects in infested fruit and packaged for export [12].

Irradiating papayas and mangoes with doses up to 2 kGy observed that the natural variations in the ascorbic acid content, carotene and other physiological changes produced by the normal ripening fruits were higher than any changes induced by gamma radiation [13]. Recommend doses between 10 and 20 krad of gamma radiation for disinfestation of pomelos we can attacked by fruitflies *A. suspensa* (Loew.), and doses in this range will not cause injuries in the irradiated fruit [14]. Concluded that doses between 40 and 60 krad of gamma radiation are actually able to induce disinfestation of infected oranges with *C. capitata* without causing injury to the fruit [15].

The potential use of gamma radiation from cobalt-60 as a quarantine treatment for control of *A. suspensa* in grapefruit was researched by [16]. These authors concluded that doses of 0.15 and 0.30 kGy induced a mortality rate of 99.80 and 99.94%, respectively, and the emerged adults were ster-

ile. Changes in color or flavor in the fruits not were observed at the different doses of gamma radiation.

Irradiated with increasing doses of gamma radiation, the last stage larvae and pupae with 30 hours of age of *A. obliqua*. They concluded that doses which induced the total lethality of insect larvae and pupae were: 75 and 10 Gy, respectively, for adults that emerged of pupae irradiated, the sterilizing dose was 10 Gy for disinfestation these fruits [17]. Irradiated with increasing doses of gamma radiation last stage larvae of *A. obliqua* within *Spondia purpurea*. The authors concluded that the dose lethal to larvae was of 300 Gy. Already the dose that prevented the full emergence of adults from these irradiated larvae were 20 Gy [18]. Irradiated with increasing doses of gamma radiation *Eugenia uvalha* infested with larvae of the last instar of *A. fraterculus*. The results obtained concluded that the dose to disinfest of the fruits was 500 Gy and which prevented total adult emergence was 50 Gy [19].

Irradiated pupae of *Anastrepha obliqua*. with ages of 240 hours, near the emergence of adults. The results showed that the dose that induced total mortality for pupae was 300 Gy. Already the dose of 200 Gy decreased adult emergence in 63% [20]. Determine the desinfestation dose of gamma radiation in *Averrhoa carambola* infested with larvae of *A. obliqua* and founded that 50 Gy was sterilizing dose for this species [21]. Irradiating apples infested with larvae of the fruit-fly-South American *A.raterculus*, prevented the emergence of adults with 25 Gy dose [22]. Use a dose of 70 Gy and induce 100% sterility in males and females of *A. fraterculus* [23].

The dose of gamma radiation sterilization for male of *A. fraterculus* was 70 Gy and female a lower dose of 40 Gy, the female are more radiosentivity to gamma radiation doses consider that a generic PI dose for the genus *Anastrepha* could be 70 Gy [24,25]. This dose would satisfy the maximum degree of quarantine security that may be required by plant protection organizations of 99.9968% efficacy (probit 9) at the 95% level of confidence level if the study by [26]. The purpose of this study was to determine the dose of disinfestation to Haden mangoes attacked by larvae of *Anastrepha fraterculus* by gamma radiation

2. MATERIAL AND METHODS

The experiment was performed in the laboratory of the Section of Entomology - CENA/USP, Piracicaba-SP, Brazil. To the experiment were collected fruits in field, mangoes "Haden" in the region of Pirapora city, MG. and sent to Sao Paulo. After 3 days of the harvest, were taken to the laboratory of Entomology, Department of Biosciences of USP and placed in cages measuring 50 x50 x 100 cm, with about 2000 adult flies on the inside where they were kept for 72 hours to allow the oviposition of the flies on mangoes.

After infestation the mangoes were taken to the laboratory of Entomology of CENA / USP, Piracicaba-SP, and irradiated in Cobalt-60 source type Gammabean-650 with activity of 1.8 x 10 Bq and a dose rate of approximately 3.00 kGy / hour. The mangoes were irradiated after the period 5 and 8 days of infestation, each treatment consisted of five replicates, a total of 5 treatments. The doses of gamma radiation employed were as follows: 0 (control), 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1.000, 1.100, 1.200 and 1.300 Gy.

After irradiation the mangoes were placed in plastic bags of 2000 mL, in the bags small holes were made so there would gas exchange. On the inside of plastic bags was placed a layer of sugar cane bagasse to facilitate the larvae pupation sites. Later the pupae were placed in glass tubes were placed with cotton cover, to the adult emergence. The experiment was conducted in a climatic chamber at 25 ± 5 ° C of temperature and 70 ± 5% relative humidity.

3. RESULTS AND DISCUSSION

In Table 1 we can observe that from the dose of 200 Gy the irradiation induced deleterious effect on the larvae inside the fruit, decreasing the number of larvae that became in pupae. However, the total lethality in larvae of 5 days after infestation was only obtained in the dose of 600 Gy (0.6 kGy). The dose of 50 Gy was sufficient to inhibit the emergence of adults. The results are according with [17, 18, 19, 20, 21, 22].

Table 1. Average number of dead larvae, pupae and adult emergence of *A. fraterculus* irradiated in the larval stage inside "Haden" mangoes with increasing doses of gamma radiation (5 days after infestation).

	Dose (Gy)							
	0	50	100	200	300	400	500	600
Stage								
Larvae	1.4a	2.6b	2.6b	5.4c	4.2c	3.0b	0.2d	0.0e
Pupae	18.0a	14.6b	10.6c	0.4d	0.2d	0.0e	0.0e	0.0e
Male	7.6a	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b
Female	7.4a	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b

* Equal letters in line do not differ statistically at the 5% level of significance in the Tukey test.

In Table 2 we can observed that the total lethality (LD_{100}) to larvae of 8 days of age inside the fruits was obtained with a dose of 1.000 Gy (1.0 kGy), because larvae there was no transformation into pupae. The deleterious effects in pupae were obtained with doses from of 200 Gy, and lethal dose was 600 Gy. The dose that prevented the adult emergence complete for both was 50 Gy. The results are according with [17, 18, 19, 20, 21, 22].

Table 2. Average number of dead larvae, pupae and adult emergence of *A. fraterculus* irradiated in the larval stage inside "Haden" sleeves with increasing doses of gamma radiation (8 days after infestation).

	Dose (Gy)											
	0	50	100	200	300	400	500	600	700	800	900	1000
Stage												
Larvae	1.2a	3.0b	3.8b	4.0b	5.8c	7.0d	6.4d	7.8d	7.0d	2.6b	1.4a	0.0e
Pupae	18.8a	15.6b	11.8c	3.2d	0.4e	0.4e	0.6e	0.0f	0.0f	0.0f	0.0f	0.0f
Male	6.6a	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b
Female	6.4a	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b

* Equal letters in line column do not differ statistically at the 5% level of significance in the Tukey test.

These results when compared with other authors in the study of larva mortality showed that older larvae are more resistant the radiation. However, is necessary take into account the conditions of the fruit (water content, texture, stage of maturation) can be an important factor in relation to those caused effects on larval development of insects [26, 27, 28]. This can also be directly related the radiation doses required to eliminate the larvae of several varieties of fruits.

4. CONCLUSION

According to the results obtained under the conditions of this experiment we can conclude that: To mangoes infested with *A. fraterculus* and irradiated with 5 and 8 days after infestation, the dose that inhibited the transformation of the larvae in pupae were 400 and 600 Gy, and the lethal dose to larvae inside the fruits were 600 and 1.000 Gy, respectively. The dose of 50 Gy prevented the total adult emergence for both the larvae age.

REFERENCES

[1] PIMENTEL C. R. M.; ALVES R. E.; FIGHEIRAS H. A.C. Mercado internacional de manga: Situação atual e Perspectiva. In: PIMENTEL C. R. M. (Eds.), Frutas do Brasil: **Manga Pós-colheita**. Embrapa Agroindústria Tropical, Fortaleza. 2000.

[2] PIMENTEL D.; MCNAIR S.; JANECKA J.; WIGHTIMAN J.; SIMMONDS C.; O'CONNELL C.; WONG E.; RUSSEL L.; ZERN J.; AQUINO T.; TSOMONDO T. Economic and environmental threats of alien plant, animal, and microbe invasions. **Agric. Ecosys. Environ**. 84, 1–20, 2001.

[3] LIEBHOLD A. M.; TOBIM P. C. Population ecology of insect invasions and their management. **Annual Review Entomology**. 53, 387–408, 2008.

[4] NORROBOM A. L.; KORYTICOWSKI C. A. New species of and taxonomic notes on *Anastrepha* (Diptera: Tephritidae). **Zootaxa**, New Zealand, v. 2740, p. 1-23, jan. 2011.

[5] THOMAS P.;. MOY J. H. Radiation preservation of foods of plant origin. III. Tropical fruits: Bananas, mangoes, and papayas. **Critical Reviews in Food Science and Nutrition**.v. 23, 2, 1986

[6] BURDIT, J.. A. K. International Atomic Energy Agency, Vienna (Austria); Food and Agriculture Organization of the United Nations, Rome (Italy); 143 p; Sep 1982; p. 57-87**; Seminar on food irradiation for developing countries in Asia and the Pacific;** Tokyo (Japan); 9 - 13 Nov 1981; IAEA-TECDOC—271.

[7] MOY J. H. Radurization and Radicitacion: Fruits and Vegetables. In "**Preservation of Food by Ionizing Radiation***"*. Ed E.S. Josephson, M.S. Peterson. v.3, p. 83. CRC Press, Boca Raton, FL. 1983.

[8] HARTHER N. W.; HALLMAN G. J. **Pest management and phytosanitary trade barriers**. CABI, Wallingford, United Kingdom. 2008.

[9] BALOCK J. W.; CHRISTENSON J. D.; BUR G. O. Effect of gamma rays from cobalt 60 on immature stages of the oriental fruit fly (Dacus dorsalis Hendel) and possible application to commodity treatment problems. In: **ANNUAL MEETING HAWAIIAN ACADEMIC SCIENCE**, 31. Honolulu, 1956. Proceedings. Hawalian Academic Science. 1956. p.18.

[10] GALLO D. Radioisótopos no controle de pragas. **O Solo**. Piracicaba, 1:30-1,1960.

[11] BALOCK J. W.; BURDITT J. A. K.; CHRISTENSON, L. D. Effects of gamma radiation on various stages of three fruit fly species. **Journal of Economic Entomology**.College Park, 56(1):42-6, 1963.

[12] BURDITT A. K.; SEO S. T. Dose requirement for quarantine treatment of fruit flies with gamma irradiation In: **INTERNATIONAL ATOMIC ENERGY AGENCY**. Desinfestation of fruits by irradiation. Vienna, 1971. p.33-41. (Pane) Proceedings series.

[13] THOMAS A. C.; BEYERS M.. Gamma irradiation of subtropical fruits. 11. A comparison of the chemica1 changes occurring during normal ripening of mangoes and papayas with changes produced by gamma irradiation. **Journal of Agricultural and Food Chemistry** Easton, 2(1):157-63, 1979.

[14] BURDITT A. K. Jr.; HOSHONAS H. G.;. HATTON T. T.; SPALDING D.H.; WINDEGUTH D. L.; SHAW P. E. Low-dose· irradiation as a treatment for grape fruit and mangoes infested with Caribbean Fruit fly larvae. Washington, USDA/Agriculture Research Service, 1981. 9p. **Agriculture Research Results**, 10.

[15] FESUES I.; KADAS L.; KALMAN B. Protection of oranges by gamma radiation against *Ceratitis capitata* (Wied.). **Acta Alimentaria**, 10(4): 293-9, 1981.

[16] SPALDING D. H.; DAVIS D. F. Potential for gamma radiation as a quarantine treatment for Caribbean fruit fly in citrus. In: J. H. Moy: **Radiation desinfestation of food and agricultural products**. Hono1ulu, University of Hawaii Press, p.160-5, 1985.

[17] ARTHUR V.; DOMARCO R. E.; WIENDL F. M.; SILVA A. C. Influência da radiação gama do Cobalto-60 em larvas e pupas de *Anastrepha obliqua* (Mac., 1835) (Dip., Tephritidae). In: Reunião Anual da Sociedade Brasileira Para o Progresso da Ciência, 40., São Paulo,1988. Resumos. **Ciência e Cultura**, São Paulo, 40 (7, sup1.):21,jul., 1988.

[18] ARTHUR V. Determinação da dose letal para larvas de *Anastrepha obliqua* no interior de frutos de *Spondia purpurea*. In: Congresso brasileiro de Entomologia, 12, Belo Horizonte, 1989. Resumos. Belo horizonte, **Sociedade Entomológica do Brasil**, 1989. p.501.

[19] ARTHUR V.; DOMARCO R. E.; WIENDL F. M.; SILVA A. C.; LEME M. H. A. Desinfestação de Eugenia uvaia infestadas por *Anastrepha fraterculus* (Wied., 1830) (Dip., Tephritidae), através da radiação gama. In: Reunião Anual da Sociedade Brasileira Para o Progresso da

Ciência, 41, Fortaleza, 1989. Resumos. **Ciência e Cultura**, São Paulo, 41(7, sup1.):11, jul., 1989.

[20] SILVA A. C.; ARTHUR, V.; SILVA E. B.; DOMARCO R. E. Influência da radiação gama do Cobalto-60 em pupas de *Anastrepha obliqua*. (Dip., Tephritidae). In: Congresso Brasileiro de Entomologia, 12, Belo Horizonte, 1989. Horizonte, **Sociedade Entomológica Brasileira**, p.519, 1989.

[21] ARTHUR V.; WIENDL F. M. Desinfestação de *Averrhoa carambola* infestada por *Anastrepha obliqua* (Macquart, 1835) (Diptera:Tephritidae) através de radiação gama. **Scientia Agricola**. 51(2): 216-221, 1994.

[22] ARTHUR V.; WIENDL F. M. Desinfestação de maçãs atacadas por *Anastrepha fraterculus* (Wied.) (Diptera: Tephritidae) através das radiações gama do cobalto-60. **Anais da Sociedade Entomologia do Brasil,** 25 (1996), p. 157–159.

[23] ALLINGHI A.; GRAMAJO C.; WILLINK E.; VILARDI J. Induction of sterility in *Anastrepha fraterculus* (Diptera: Tephritidae) by gamma radiation. **Florida Entomologist**, 90 (1): 96-102, 2007.

[24] KAMIYA A. C. **Criação massal em dieta líquida e radioesterilização da mosca-sul-americana** *Anastrepha fraterculus* **(Wied., 1830) (Diptera: Tephritidae***)*. Dissertação. Centro de Energia Nuclear na Agricultura, Universidade de São Paulo. 71 p. 2010.

[25] HALLMAN G. J. Rationale for a generic phytosanitary irradiation dose of 70 Gy for the genus *Anastrepha* (Diptera: Tephritidae). **Florida Entomologist**, 96(3):989-990.2013.

[26] KANESHIRO K. Y. Gamma radiation treatment for desinfestation of the medfly in thirty-five varieties of California -Grown Fruit In: J.H. Moy. **Radiation disinfestation on food and agricultural products**. Honolulu, University of Hawaii at Manoa, p.28-109, 1985.

[27] ARTHUR P. B. ; VILLAVICENCIO A. L.C. H. ; HARDER M. N. C. ; MACHI A. R.; LEANDRO R. S. R. ; ARTHUR V. Sterilizing of *Alphitobius diaperinus* (Panzer, 1797) (Coleoptera: Tenebrionidae) irradiated in pupa stage. In: **INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE**, 2019, Santos, Annals, Comissão Nacional de Energia Nuclear, 8p. 2019.

[28] MACHI A. R. **Efeitos da radiação ionizante nas fases do ciclo evolutivo de** *Aedes aegypti* **L. visando o seu controle através da técnica do inseto estéril.** 2019. 75 p**.** Tese (Douto-

rado em Tecnologia Nuclear) Instituto de Pesquisas Energéticas e Nucleares – IPEN-CNEN/SP. São Paulo.