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Effect of Gamma Irradiation on 'Fuerte' Avocado Fruits[1]

A. R. Kamali[2], E. C. Maxie[3] and H. L. Rae[3]
University of California, Davis.

***Abstract.* Gamma irradiation up to 100 Kilorad (Krad) caused no immediate visual damage to fruits of avocado *(Persea americana* Mill.). Twenty Krad or more stimulated a climacteric-like rise in respiratory rate. Rates of ethylene *(C_2H_4)* production were related directly to dose up to 40 Krad. Ten and 40 Krad delayed the climacteric peak for 3 days. Softening was delayed by 10 Krad and hastened by 40 and 100 Krad. At 100 Krad, ripening was lacking and the fruit severely injured. No benefit remained from any dose after 3 weeks of storage. Storage reduced the time required for ripening by 2 days, and enhanced the development of injury symptoms and pigment degradation.**

Several papers have described symptoms of radiation injury of avocado fruits (1, 3, 4, 8, 9, 17). Two possible applications of irradiation to avocados have been studied: disinfestation of fruit flies (1, 2) and shelf-life extension (3, 8, 9, 17). Except for Young's report (17), none of those papers specified the physiological state of the fruit at the time of irradiation, or the time required for injury symptoms to appear.

Young (17) reported that fruits irradiated to 5 and 10 Krad ripened normally, although a few days later than unirradiated fruits. Brewbaker and Ross (4) stated that fruits subjected to 5, 10, 50, and 100 Krad softened in less than half the time taken by unirradiated fruits. Bramlage and Couey (3) reported similar results.

This study was conducted to pre-climacteric avocado fruits affected: rates of ripening, respiratory activity, C_2H_4 production, and fruit firmness. The treatments were made on the day of harvest, and the fruits were evaluated before and after 3 weeks of storage at 5.0°C.

'Fuerte' avocado fruit from Fallbrook, California, were picked in the early AM, placed in fiberboard cartons, and transported by car to Davis in about 8 hr. The fruits were either used immediately in experiments at 20.0°C or cooled and stored at 5.0° for 3 weeks.

Respiratory rates were determined by the method of Claypool and Keefer (7), and rates of C_2H_4 production by the method of Maxie et al. (15). Two replicates of 5 representative fruits each were used. Aeration, with air saturated with water vapor, was continuous at a rate of 394 ml/min. After 12 hr, the initial rates of carbon dioxide (CO_2) and C_2H_4 evolution were determined. The fruits were removed from the jars and irradiated in the Mark II Experimental Food Irradiator (16) to 0, 10, 20, 30, 40 and 100 Krad at a rate of approx 159.4 Krad/hr. Fruits to be stored at 5.0°C were irradiated simultaneously.

Rates of CO_2 and C_2H_4 production were measured 3 hr after irradiation and daily thereafter until the fruits were ripe or showed decay lesions.

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[1] Received for publication October 4, 1971.
[2] Present Address: Instituí de Recherches Agronomiques, Tel AMARA, Rayak, Lebanon.
[3] Department of Pomology.

After 3 weeks, fruits stored at 5.0°C were transferred to 20.0° for ripening. Samples for measurement of CO_2 and C_2H_4 were handled as described above. Appearance, texture, and pulp quality were recorded daily on the remaining fruits.

Fruit firmness was determined with the U. C. firmness pressure tester (6) equipped with a 6 mm (1/4-inch) plunger. The firmness data are the mean of 2 replicates of 12 fruits each, 2 readings per fruit.

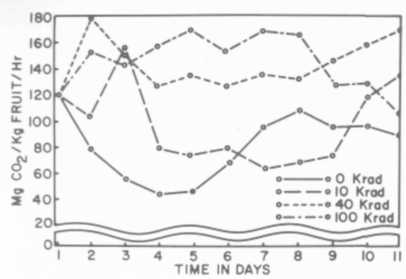

Fig. 1. Effect of gamma irradiation on the respiratory rate of 'Fuerte' avocados.

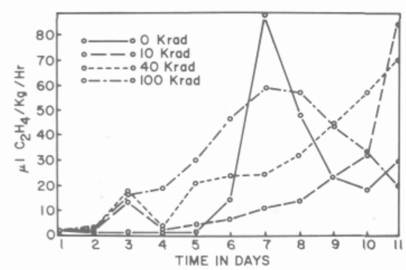

Fig. 2. Effect of gamma irradiation on rate of ethylene (C_2H_4) evolution by 'Fuerte' avocados.

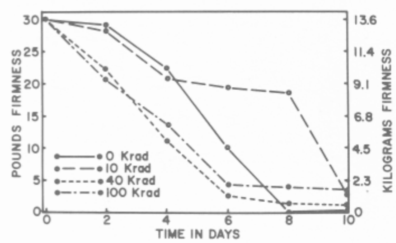

Fig. 3. Effect of gamma irradiation on firmness of 'Fuerte' avocados.

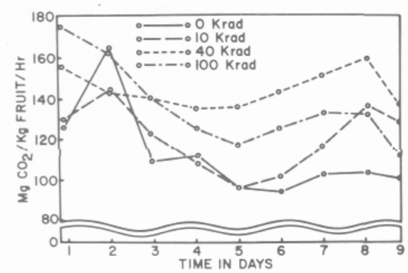

Fig. 4. Effect of gamma irradiation on respiratory rate of 'Fuerte' avocados after 21 days storage at 41°F.

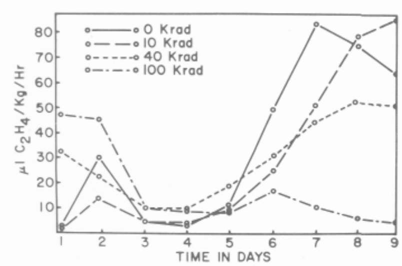

Fig. 5. Effect of gamma irradiation on rate of ethylene (C_2H_4) evolution by 'Fuerte' avocados after 21 days storage at 20.0°C.

Effects on rate of CO_2 and C_2H_4 evolution are shown for only the first experiment since results were nearly identical in both experiments. Although data were taken for 20 and 30 Krad, the differ little from those for 40 Krad. Respiratory rates increased immediately in fruits subjected to 10, 40 and 100 Krad (Fig. 1). The rates were approx proportional to dose between 0 and 40 Krad. At 10 Krad the respiratory rate was lower than in other irradiated lots 24 hr after treatment, but during the 2nd day increased to a comparable level. Except in fruits subjected to 100 Krad, the initial surge in respiratory rate was followed by a decline on the 3rd day after treatment. Between the 4th and 8th days, fruits subjected to 10-40 Krad showed little change in rate. Fruits subjected to 100 Krad showed a consistently higher respiratory rate until the 8th day, when the rate declined. There was no clearly defined climacteric in this lot. Fruits subjected to 20, 30, and 40 Krad seemed to enter the climacteric on the 8th or 9th day. Fruits subjected to 10 Krad showed a well defined climacteric rise between the 9th and 10th days. Unirradiated fruits displayed a typical climacteric, beginning on the 6th day and peaking on the 8th day.

There was an immediate burst of C_2H_4 production following irradiation to 10 Krad or more (Fig. 2). This burst was temporary in fruits subjected to 20, 30, and 40 Krad and may account for the temporary increase in respiratory rate noted above. Fruits subjected to 100 Krad showed a progressively increasing rate of C_2H_4 production, with the peak on the 7th day. All other irradiated lots showed a 2nd increase in rate between the 4th and 6th days, while the unirradiated fruits showed a climacteric-like rise between the 5th and 7th days.

Except with the 10-Krad treatment, irradiation injured the fruits, the damage increasing with dose. Fruit subjected to 20, 30, 40, and 100 Krad developed small dark-brown blotches on the skin, respectively, after 7, 6, 5, and 4 days. The symptoms appeared first at the stem end of the fruit, then spread to other portions.

Loss in firmness in irradiated fruits closely followed that in unirradiated control fruits (Fig. 3), except that softening was delayed in fruits treated with 10 Krad. Fruits treated with 20 and 40 Krad softened to a normal smooth consistency. Internal discoloration, however, made the fruit visually unacceptable. The pulp of fruits subjected to 20 Krad was normal in color except for several dark-brown vascular strands. Fruits subjected to 30 and 40 Krad showed numerous dark-brown veins, and the surrounding flesh showed a blackish coloration which worsened rapidly after the fruits were cut. The 100-Krad fruits, injured the most seriously, never ripened. Their flesh became completely dark gray even though pressure measurements showed softening.

Fig. 4 and 5 show the CO_2 and C_2H_4 production rates of fruits irradiated and stored for 3 weeks at 5.0°C. Initial respiratory rates were lower in fruits treated with 10 Krad than in fruits given 40 or 100 Krad. The respiratory rates of all lots increased after 5-7 days, though it is doubtful that this rise represents a climacteric considering the high rates immediately after storage and the lack of other evidence of ripening.

Ethylene production was initially higher in lots treated with 40 and 100 Krad than in lots given 0 and 10 Krad. The latter 2 lots showed a slight increase on the 2nd day and then declined along with the 40- and 100-Krad fruit. The rates of all lots increased between the 4th and 6th days. The peak rate in control fruits was reached during the 7th day, 1 day before fruits given 40 Krad, and 2 days before fruits given 10 Krad. Fruits treated with 100 Krad showed a low peak on the 6th day but failed to ripen, as indicated by dryness and mealiness of the flesh. These fruits had severe external symptoms of irradiation injury by the 3rd day.

On removal from 5.0°C storage, fruits given 0, 10, and 20 Krad were normal green in color, whereas fruits given 30, 40, and 100 Krad were respectively, light-green, green-yellowish, and yellowish-green, indicating degradation of chlorophyll.

Irradiated fruits stored for 3 weeks at 5.0°C required 2 days less to ripen than fruits ripened immediately after irradiation, while a difference of 1 day was noted for the control fruits. All irradiated fruits developed injury symptoms as noted above, though 1 to 2 days earlier than in fruits held at 20.0°.

Gamma irradiation stimulated respiratory rate and C_2H_4 production in avocados, as reported for other fruits (10). Young (17), working with single fruits, reported that 10 Krad stimulated CO_2 and C_2H_4 production in preclimacteric avocados. Our results show that a dose of 20 Krad or more is required to stimulate the onset of the climacteric. Young (17) also reported that the amount of C_2H_4 induced by irradiation was relatively independent of dose, while we found the rates related directly to dose up to 40 Krad. The mechanism by which gamma irradiation delays ripening of avocados is not known but probably involves reduced sensitivity to the ripening hormone C_2H_4, rather than reduced capacity to produce it, since all doses stimulated its evolution. Similar results have been reported for pear (15) and banana (10).7

Avocado fruits severely injured by gamma irradiation produced high amounts of C_2H_4. This may reflect radiological breakdown of lipids, as in lemons (13). Physical injury also induces C_2H_4 production in some fruits (5), and this phenomenon may have contributed to the results with irradiated avocado. The relatively lower rates, and somewhat retarded climacteric rise in respiratory and C_2H_4 production (Fig. 1 and 2), in fruits subjected to 10 Krad was probably responsible for their delayed loss of firmness (Fig. 3).

The doses used caused no visual damage for several hr. The adverse symptoms developed during the ripening process and increased directly with dose. No external or internal injury symptom was noted on the 10-Krad fruit, confirming findings of several investigators (3, 9, 17) but differing from those of Brewbaker and Ross (4).

Avocado fruits cannot tolerate the min dose of 175 Krad reported by Maxie and Sommer (14) for significant retardation of rot development from field infections. Thus, irradiation is impractical for controlling decay of this fruit.

Literature Cited

1. Akamine, E. R., and R. Wong. 1966. Tolerance of avocados to irradiation. USAEC Report No UH235P5-2. Univ. of Hawaii, College of Trop. Agr., Honolulu, Hawaii 97-101.
2. Balock, J. W., R. K. Burditt, Jr., S. T. Seo, and E. K. Akamine. 1966. Gamma radiation as a quarantine treatment for Hawaiian fruit flies. *J. Econ. Ent.* 59:202-204.
3. Bramlage, W. J., and H. M. Couey. 1965. Gamma radiation of fruit to extend market life. *USDA Market Res. Rept.* 717.
4. Brewbaker, J. L., and E. Ross. 1966. Dosimetry, tolerance and shelf life extension related to disinfestation of fruits and vegetables by gamma irradiation. USAEC Contract No. AT(04-3)-235, Univ. of Hawaii, Honolulu, Hawaii. Monthly status letters for Feb., July, Oct. and Dec.
5. Burg, S. P. 1962. The physiology of ethylene formation. *Ann. Rev. Plant Physiol.* 13:265-302.
6. Claypool, L. L., R. B. Fridley, and R. Johns. 1966. Precision in a pressure tester.

Western Fruit Grower 20(7):18-19.

7. _________, and R. M. Keefer. 1942. A colorimetric method for CO_2 determination in respiration studies. *Proc. Amer. Soc. Hort. Sci.* 40:177-186.

8. Dennison, R. A. 1964. Effect of low level of irradiation upon the preservation of food products. USAEC Contract AT(40-1)-3097. Univ. of Fla. Project Rept. for July.

9. Kahan, R. S., M. N. Shifman, N. T. Gorodeiski, E. Eisenberg, G. Zauberman, and Y. Aharoni. 1968. Effect of radiation on the ripening of banana and avocado pears. *In* Preservation of fruit and vegetables by radiation. *Inter. Atomic Energy Agency Publ.* Vienna:3-11.

10. Maxie, E. C., and A. Abdel-Kader. 1966. Food irradiation—physiology of fruits as related to feasibility of the technology. *Adv. Food Res.* 15:105-145.

11. _________, R. Amezquita, B. M. Hassan, and C. *V.* Johnson. 1968. Effect of gamma irradiation on the ripening of banana fruits. *Proc. Amer. Soc. Hort. Sci.* 92:235-254.

12. _________, I. L. Eaks, N. E. Sommer, H. L. Rae, and S. El-Batal. 1965. Effect of gamma radiation on rate of ethylene and carbon dioxide evolution of the lemon fruit. *Plant Physiol.* 40:407-409.

13. _________, H. L. Rae, I. L. Eaks, and N. F. Sommer. 1966. Studies on radiation-induced ethylene production by lemon fruits. *Rad. Bot.* 6:445-455.

14. _________, and N. E. Sommer. 1965. Irradiation of fruits and vegetables. *In* Radiation preservation of foods. *Nat. Acad. Sci. and Nat. Res. Council Publ.* No. 1273:39-52.

15. _________, _________, C. J. Muller, and H. L. Rae. 1966. Effect of gamma radiation on the ripening of Bartlett pears. *Plant Physiol.* 41 :437-442.

16. Romani, R. J., B. J. Robinson, H. L. Rac, E. C. Maxie, and N. F. Sommer. 1963. Fruit irradiation—physiology methods. *Rad. Bot.* 3:345.

17. Young, R. E. 1965. Effect of ionizing radiation on respiration and ethylene production of avocado fruit. *Nature* 205:1113-1114.