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Effect of Gamma Radiation on Rate of Ethylene and Carbon Dioxide Evolution by Lemon Fruit [1, 2]

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Introduction

Freshly harvested lemon fruits show a declining respiratory rate and, therefore, have been classified as nonclimacteric fruits (1). Biale et al. (2), using a manometric technique, found no evidence for ethylene production by lemon fruits; but when Burg and Burg (4) employed a highly sensitive gas chromatograph, they found the internal atmosphere of lemon fruits contained 0.11 to 0.17 ppm ethylene. Maxie et al. (7) showed that 50 kilorads (Krad) or more of gamma radiation markedly stimulated CO_2 evolution by lemon fruits. They noted that irradiated fruit degreened much more rapidly than unirradiated fruit, suggesting that radiation stimulated the production of ethylene. The objective of this study was to evaluate further the effects of gamma radiation on the apparent ripening of lemon fruits.

Materials and Methods

Green Eureka (*Citrus limon*) lemon fruits, unwashed and unwaxed, were obtained from a packing house near Riverside, California. The fruits were placed in fiberboard boxes and transported to Davis in an insulated container. The temperature of the fruit during transit was never less than 16° nor more than 20°.

Respiration rates were measured by the method of Claypool and Keefer (5), using 4 replicates of 10 fruits per treatment. Ethylene in the air stream emerging from the jars containing the fruit was measured by gas chromatography with an Aerograph A-600 B Hi-Fy flame ionization unit fitted with a 5 foot x one-eighth inch column packed with 60/80-mesh alumina. The column temperature was 50°. The identity of ethylene was confirmed by treating samples of the air emerging from the jars of fruit with mercuric perchlorate, brominated charcoal, and aqueous potassium hydroxide (3). Ethylene is removed by the first 2 systems but not by the latter. Ethylene trapped in mercuric perchlorate was released by the method of Young et al. (12) and analyzed by gas chromatography as above. CO_2 and O_2 were measured by gas chromatography with an Aerograph A-90-P thermal-conductivity unit fitted with a 6 inch x one-quarter inch column of silica gel and a 15 foot x one-quarter inch column packed with 90 % 13X and 10 % 5X molecular sieve according to the method of Luh and Chaudry (6).

Samples of internal atmospheres were extracted from 8 to 10 fruits, as suggested by Dr. Hugh T. Freebairn. The fruits were placed underneath a large inverted funnel with a serum cap fitted over the spout. The funnel was completely filled with and submerged in a saturated solution of NaCl inside a pressure vessel. Each fruit was punctured with a needle, the vessel sealed, and a vacuum of 2 cm of mercury was pulled on the system for 1 minute. The gases extracted from the fruit filled the spout of the funnel. A gas-tight syringe fitted with a 2.5-cm needle was used to remove a gas sample from the funnel for analysis. When samples were withdrawn directly from individual fruits with a 6-cm hypodermic needle affixed to a gas-tight syringe, essentially the same analytical results were obtained.

Irradiation was done in the Mark II Experimental Food Irradiator (10) with air passing through the chamber at a rate of 6 liters per minute to preclude depletion of O_2 and the accumulation of CO_2 in the atmosphere. The dose rate in the source was approximately 300 Krad per hour. Dosimetry was done as described by Romani et al. (11).

Results

Figure 1 shows the effect of gamma irradiation at doses of 0, 25, 50, 75, and 100 Krad on the respiration rate of Eureka lemons. Immediately after treatment, all irradiated lots showed a marked increase in respiration rate. Peak values were reached on the third to fifth day after treatment.

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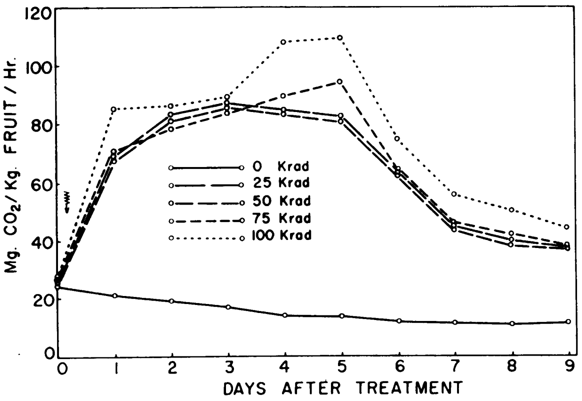

FIG. 1. Effect of gamma radiation on the evolution of CO_2 by Eureka lemon fruits.

Thereafter the rates declined, completing a rate curve similar to the autogenous climacteric found in many fruits but atypical of citrus (1). By the seventh day, irradiated samples were a bright yellow color, while unirradiated fruits were still green.

Figure 2 shows the rate of ethylene evolution by lemons subjected to doses of 0, 25, 50, 75, and 100 Krad. Within 6 hours of treatment there was a detectable production of ethylene by the irradiated fruit. This was followed, between the fourth and fifth days after treatment, by a marked increase in rate of ethylene evolution by fruits subjected to 50, 75, and 100 Krad. The rate of ethylene production by these fruits reached a peak on the fifth day after treatment. By this time the green color had started to disappear. The ethylene production of all fruits had declined to a low level by the eighth and ninth days following irradiation, while the control rate was essentially zero.

When lemon fruits are subjected to gamma radiation doses of 200 Krad or more, they show bronzing of the skin within a few days. Thus, no critical experiments are practical on the long-term effects

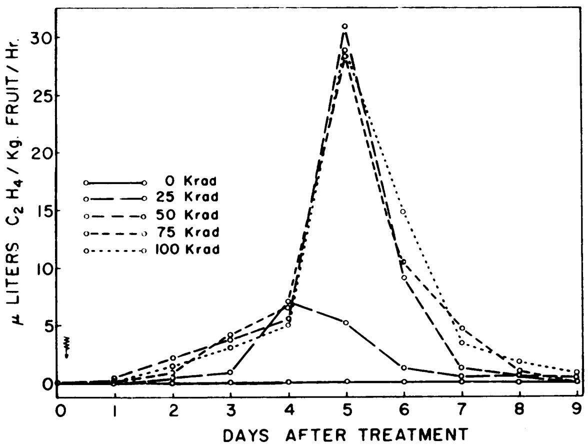

FIG. 2. Effect of gamma radiation on the evolution of ethylene by Eureka lemon fruits.

of radiation on ethylene production by fruit subjected to high doses. However, our experience indicates that the long-term production of ethylene by intact fruits is maxium following doses of 100 Krad. Above this dose, peak ethylene production is considerably lower.

As shown in figure 3, the short-term effect of gamma radiation on ethylene production by lemon fruits is a progressive increase in concentration of the gas in the internal atmosphere of the fruit as the dose increases to 600 Krad. These data, taken 30 minutes after exposure in every case, also show an increase in CO_2 concentration and a decline in O_2 concentration in the internal atmosphere of the fruit, indicating a higher respiration rate during irradation, as shown by Romani for lemons (8) and by Romani and Bowers for cherries (9).

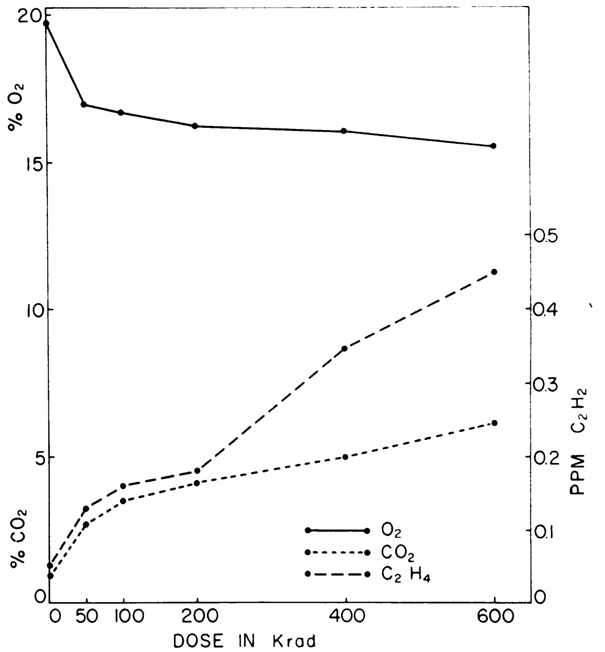

FIG. 3. Effect of gamma radiation on the concentration of ethylene, carbon dioxide, and oxygen in the internal atmosphere of Eureka lemon fruit. Samples extracted 30 minutes after irradiation.

Discussion

The data presented here could be interpreted to mean that gamma radiation can induce a climacteric in lemon fruits. Evidence in support of this argument is the rapid increase in rates of respiration, ethylene production, and degreening of irradiated fruit. One should not yet, however, label the observed phenomenon as a climacteric in the sense used in postharvest physiology. The autogenous climacteric in fruits is accompanied by biochemical events such as degradation of starch or other reserve carbohydrates, increases in amounts of soluble carbohydrates, and solubilization of pectic materials, with an associated softening of the fruit tissues. We have not as yet investigated these phenomena in lemons. Until more of the biochemical changes normally associated with the climacteric are shown to occur in irradiated lemons, we must assume that our data have not shown a true climacteric in these fruits. However, the data clearly show that the stress of gamma irradiation can induce in a typical nonclimacteric species some of the phenomena common to the climateric class of fruits (1).

We have not investigated the origin of the ethylene produced by lemon fruits subsequent to irradiation. Gamma irradiation is injurious to lemon fruits at doses as low as 50 Krad (7). The wounding of some fruits is known to stimulate ethylene production (3). Thus, the radiation-induced ethylene production may be an injury response of unknown mechanism.

We have seen no evidence in any fruit of direct chlorophyll destruction by gamma radiation at doses used in this study. The concentration of ethylene in the internal atmosphere of lemons subjected to 50 to 100 Krad is in the physiologically active range (1) within 30 minutes. The ethylene production by irradiated lemons continues to increase until the green color is lost from the fruit. Therefore, we conclude that the radiation-induced ethylene production by lemon fruits causes degreening of the fruit.

Summary

Gamma radiation induces sufficient production of ethylene gas by lemon fruits (*Citrus limon*) to cause degreening of the fruit. The rate of respiration of irradiated lemon fruit increases immediately after treatment. After a few days the increase is followed by a decline, giving a curve resembling the autogenous climacteric common to many fruits, but atypical for citrus. The production of ethylene follows the same general pattern as the respiration rate, but reaches a peak 1 or 2 days later.

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