Irradiated fruit: lack of feasibility

Why irradiate fresh fruit?

Irradiation would suppress decay moulds and kill insects as a quarantine measure. However, it turns out that fruits are more radiation sensitive than moulds and insects are.

Damage to fruit

Ionising radiation causes chemical changes in the structure of cell wall components, whereby cellulose, hemicellulose and pectin are irreversibly cleaved (1, 2). As a result the cell walls become leaky and calcium is released in proportion to the irradiation dose. This occurs up to 6 kGy. At higher doses up to 80% of calcium is lost (3). This calcium loss plays an important role in the softening of fruit and other plant tissues (vegetables).

There is also an increased tendency to lose water and a major reason for refrigeration of irradiated produce in transit is to prevent this water loss (1, 2). An accompanying problem is that fruits sensitive to low temperatures become even more chilling sensitive after irradiation. This was found with bananas, lemons, oranges and tomatoes at irradiation doses well below the required ones (1, 2).

Damage in transit

Because of this overall tissue softening irradiated produce is much easier damaged in transit than their unirradiated counterparts. Irradiated consignments transported over some distance like other normal fruit, arrived crushed and bruised and was unacceptable.

What are critical doses?

This very much depends on the fruit in question.

Citrus

- the irradiation dose for Australian Washington Navel and Valencia oranges should not exceed 0.30 kGy because of the risk of rind injury (4).
- Californian navel oranges irradiated with around 0.35 and 0.50 kGy showed brown pitting and rind injury plus flavour changes (5).
- Another research paper mentions three other reports where oranges irradiated at 0.50 developed brown skin blemishes and changes in flavour and odour. after 2-4 weeks storage (6).
- Hawaii Californian Valencias could tolerate up to 0.50 kGy.
- Juice and fresh sections of Marsh seedless grapefruits from Florida developed significant changes in flavour after irradiation with 0.25-0.50 kGy (7).

This little survey shows that many kinds of citrus fruit are damaged at a dose of 0.50 kGy and higher. Major citrus decay moulds like blue and green Penicillium require more than 0.50 kGy to keep them under control (0.80 and 1.20 kGy respectively). And black rot or Alternaria needs more than 3 kGy (8). This means that irradiation cannot be used to suppress decay moulds in citrus fruit.

Stone Fruits

- peaches irradiated at 0.50 kGy showed significant changes in colour; nectarines showed changes in aroma and plums showed changes in colour and texture (9).
- Californian Regina Freestone peaches irradiated with 0.65 to 0.75 kGy developed loss of flavour or an 'off-flavour' plus changes in sourness.
- Bing cherries irradiated at 0.60-0.80 kGy showed a high degree of shriveling and changes in taste (10).
- apricots could tolerate not more than 0.50 kGy else tissue softening became unacceptable (11).

The picture for stone fruit is similar to that of citrus fruit. Although stone fruit can tolerate higher radiation doses, the stone fruit decay moulds are also more tough. The greatest threat comes from brown rot caused by the mould Monilinia fructicola and requires more than 2 kGy to keep things under control.

Berries

- Boysenberries and raspberries can tolerate up to around 1 kGy.
- Strawberries on the other hand can tolerate 2 kGy and higher up to 4 kGy depending on variety (1). However, some Shasta strawberries got a 'cooked' odour and an off-flavour plus a water soaked interior at 4 kGy. No changes in appearance occurred for 4 days but then there was a gradual loss of pigment and after 10 days there was extensive bleaching (12). What makes strawberries so different from other fruits irradiation-wise is not well understood.

✐Grapes can stand irradiation depending on the variety. Thomson seedless grapes and mature Tokay grapes showed no symptoms of injury after a dose of 2 kGy. Emperor grapes could even tolerate up to 5 kGy (12). But other table grapes could only tolerate up to 0.50 kGy and displayed softening plus severe off-flavours (11).

The picture in berries differs from that of citrus and stone fruit, because strawberries form a irradiation success story: some varieties can tolerate up to 4 kGy. The major decay mould in strawberries, gray mould or Botritus cinerarea, requires around 2.5 kGy to keep under control (13). The other major strawberry disease is leak or Rhizopus stolonifer which cannot grow below 10 ☚C. So, proper refrigeration will do the job.

And grapes? Because grapes are destined for long-term storage they would require almost complete inactivation of gray mould and this would need at least 10 kGy (11).

The overall conclusion must be that fruit is too radiation sensitive to use irradiation for controlling decay moulds.

Quarantine and irradiation

The major fruit flies of interest are:
Mediterranean fruit fly (Ceratitis capitata W.)
Melon fly (Dacus cucurbitae Coq.)
Oriental fruit fly (Dacus dorsalis Hendel)
Queensland fruit fly (Dacus tryoni Frog.) (14)

Fruit fly life cycle

The fruit fly cycle is as follows: eggs are laid inside the fruit right under the skin or a few mm deep into the pulp. After hatching the larvae begin to feed and burrow into the pulp. They shed their skin twice as they feed and grow. The mature larvae leave the fruit to find a suitable place for pupation often in the soil. After the adult fruit fly emerges and attains sexual maturity a new cycle is started.

Radiation sensitivity

Young eggs, larvae, pupae and adults are more radiation sensitive than older eggs, larvae, pupae and adults.

The major problem with irradiation for quarantine purpose is that a quick kill of eggs, larvae, and an occasional pupa would require doses in excess of 1 to 2 kGy for melon, oriental and Mediterranean fruit flies (15). For the Queensland fruit fly a dose of 0.80 kGy would be needed. These doses are too high for most fruits. Therefore only low doses can be used for a slow kill resulting in alive irradiated immature insects. But there is no way to distinguish between immature irradiated insects and insects not exposed to irradiation.

Similar findings were made concerning the mango weevil and radiation sensitivity of mangoes. Only the South African Kent mango is just as strawberries an irradiation success story.

The overall conclusion must be that irradiation as quarantine measure is unsuitable.

References

1. Maxie, E.C. et al. 1966. Food irradiation physiology of fruits etc. Advances in Food Research 15: 105-145.

2. Maxie, E.C. et al. 1971. Physiological limitations to irradiation of fruit. Pp. 93-100. In: Proceedings of a Panel on use of irradiation to solve quarantine problems in international food trade. Joint FAO/IAEA Division of Atomic Energy in food and agriculture, held at Honolulu, Hawaii, 7-11 Dec. 1970. Vienna IAEA.

3. Shah, J. 1966. Radiation induced calcium release etc. Nature 211: 776-777.

4. Macfarlene, J.J. et al. 1968. Effects of gamma irradiation on oranges etc. Austral. J. Exp. Agric. and Animal Husbandry 8: 625-629.

5. O'Mahony, M. et al. 1987. Sensory technique for measuring etc. J. Food Sci. 52: 348-353.

6. O'Mahony, M. et al. 1985. Sensory evaluation of oranges etc. J. Food Sci. 50: 639-646.

7. Moshonas, M.G. et al. 1982. Irradiation and fumigation effects etc. J. Food Sci. 47: 958-960.

8. Sommer, N.F. et al. 1964. Sensitivity of citrus fruit decay fungi etc. Radiation Botany 4: 317-322.

9. Moy, J.H. et al. 1983. Radiation disinfestation etc. J. Food Sci. 48: 928-931.

10. O'Mahony, M. 1985. Sensory evaluation Bing cherries etc. J. Food Sci. 50: 1048-1050.

11. Maxie. E.C. et al. 1971. Infeasibility of irradiated fruits and vegetables. HortScience 6(3): 202-204.

12. Nelson, K.E. et al. 1959. Ionizing radiation to control Botrytis rot etc. Phytopathology 49: 475-480.

13. Sommer, N.F. et al. 1966. Ionizing radiation to control etc. Advances in Food Research 15: 147-193.

14. Christenson, L.D. et al. 1960. Biology of fruit flies. Annual Review of Entomology 5: 171-192,

15. Balock, J.W. et al. 1963. Effects of gamma irradiation on etc. J. Econ. Entomol. 56(1): 42-46.

Friends of the Earth

H. Julius

www.foodirradiationwatch.org

FOOD IRRADIATION WATCH