Irradiation as a Quarantine Treatment in Mangos

The Big Picture:

Providing tasty, high-quality mangos to consumers is the mango industry's top goal. Mangos imported from Mexico must undergo quarantine treatment for fruit flies before being shipped to the U.S. to ensure that this pest is not transported across national borders. Currently hot water treatments are the norm for the mango industry, but irradiation offers another treatment solution.

Gamma-ray irradiation uses ionizing radiation to modify pests' DNA, making them sterile. Previous research has indicated that mangos treated with radiation at low doses fare well and do not show significant damage, but exact parameters had not been determined.

With this in mind, the National Mango Board commissioned a research study to explore the effects of irradiation on the different mango varieties. Dr. Edmundo Mercado Silva from the Universidad Autónoma de Querétaro, Querétaro, Mexico, looked at the thresholds of effective irradiation doses. He also explored how mango maturity affected quality of irradiated fruit, as well as if mango size mattered when considering irradiation. Scientists observed the specific physiological responses of the irradiated fruit including firmness, ascorbic acid content, titratable acidity, weight loss, soluble solid content, flesh color, and skin color for each variety. Storage temperature of the fruit was also monitored and considered in this study.

Researchers worked with Tommy Atkins, Haden, Kent, Keitt, Ataulfo, and Manila varieties of mangos from Mexico. Fruits were harvested in two maturity stages: ¼ maturity (25% mature, which is similar to the requirement for fruit undergoing hot water treatment) and ¾ maturity (75% mature). After the selection by maturity stage, mangos were classified by size and packaged in the same way they would be for export and then irradiated. After treatment, the fruit was palletized and transported for storage and analysis.

While researchers found that fruit size was not an important factor in response to radiation doses, the maturity stage of the fruit when irradiated, as well as the storage temperature after treatment, were extremely important. The research team also helped to narrow down the radiation doses each variety of mango could withstand without sacrificing quality.

The following results show how irradiation could be effectively used as a quarantine treatment for mangos, based on product quality.

Overall Findings:

Fruit size is not important when considering irradiation treatment for mangos. Size 8 and size 10 mangos were considered by researchers, but size had less of an impact than other factors (like storage temperature), so size was taken out of the equation for this study.

Fruit maturity at the time of irradiation is crucial – researchers recommend that mangos be irradiated at ¾ maturity (75% mature) for optimum results. Irradiating mangos at ¼ maturity (25% mature) should be avoided. Fruit that was irradiated at ¼ maturity seemed to be more susceptible to damage (skin and flesh browning) at higher storage temperatures, and

immature fruit that was irradiated also showed development of spongy tissue. Such damage would make consumers less likely to purchase mangos.

Internal damage from treatment. Data from this project indicate that all mango varieties studied were not harmed by the dose of .15 kGy – the minimum quarantine treatment required by the USDA-APHIS to control the Mexican fruit fly. It should be noted that with irradiation technology by gamma rays, the radiation is not uniformly distributed – fruit near the geometric center of the box has the minimum value of irradiation, while fruit near the radiation source shows the highest values. Thus, researchers give a range of values for irradiation. Generally speaking, this radiation dose range (.15 to .44 kGy) does not appear to harm mangos at either stage of maturity. However, researchers were able to determine even more specific radiation thresholds for each variety of mango.

- **Tommy Atkins, Haden, Keitt, and Manila varieties should be irradiated at .6 kGy or lower**, and processed at ¾ maturity (75% mature).

  - **Tommy Atkins** mangos that were irradiated at doses above .6 kGy and held under continuous storage at 10C (50F) showed no initial external color change, however, these changes showed up when the fruit was transferred from 10C (50F) to 20C (68F). Tommy Atkins fruit irradiated at .15 kGy did not show important changes in internal tissue after 19 days of storage at 20C (68F), however, this variety irradiated at .6 kGy (and higher levels) developed internal browning and spongy tissue.
    - Tommy Atkins mangos irradiated at .6 kGy or higher showed lower firmness than fruit irradiated at .15 kGy.
    - Tommy Atkins fruit stored at 10C (50F) and irradiated at .6 kGy or higher showed lower ascorbic acid content; all fruit showed lower ascorbic acid content at 20C (68F).
    - The titratable acidity of Tommy Atkins mangos was not affected by irradiation during the first 13 days of storage.
    - Fruit weight loss, total soluble solid content, and flesh and skin color did not show changes due to irradiation doses.

  - **Haden** variety mangos did now show significant negative effects of different irradiation doses in any of the physiochemical variables considered. Haden mangos stored continuously at 10C (50F) did not show skin color change, even at higher radiation levels, however in fruit irradiated at levels higher than .56 kGy and transferred from 10C (50F) to 20C (68F) researchers observed superficial browning.
    - Skin color changes in the Haden variety after radiation could be associated with disease development, because damage was similar to anthracnose development. It's possible the radiation could cause weakness in the tissue and facilitate the development of this disease in Haden mangos, researchers say, but this factor could not be confirmed in this research.

- **Keitt** mangos exposed to .6 kGy or greater radiation developed internal browning after 19 days of storage, and Keitts were more susceptible to pathogenic disease and the development of spongy tissue than other varieites, researchers found.
  - Keitt mangos irradiated at high doses show acceleration of the fruit softening process when they are stored at 20C (68F).
  - High irradiation doses coupled with treating fruit at ¼ maturity promote greater ascorbic acid loss in the Keitt variety.
  - Temperature (not radiation doses) seemed to be the most important factor when measuring titratable acidity and soluble solid content in Keitt mangos. Keitt mangos exposed to high doses of irradiation showed a delay in the ripening process, indicating less soluble solid development.

- **Manila** variety mangos showed a high dehydration rate which limited their shelf life at 20C (68F) to only 13 days. Continuous storage at 10C (50F) delayed ripeness compared to fruit stored at 20C (68F). Researchers found that irradiation delayed skin color changes and high doses of radiation caused slight skin browning.
  - Manila variety mangos showed a trend toward increasing ascorbic acid content during storage, reaching the highest values on day 19.
  - Higher doses of irradiation in Manila mangos may affect the ripening process based on measurements of soluble solid content.

- **Kent and Ataulfo varieties can withstand up to .86 kGy radiation.** The fruit should not be irradiated above .93 kGy, researchers found. This is the maximum dose of radiation that mangos can withstand without negative effects, researchers say. Interestingly, it is lower than the current maximum dose (1.00 kGy) that the FDA recommends for irradiation quarantine treatment.
  - **Kent** variety mangos show a higher tolerance to irradiation because external damage to the skin was lower. However, a brownish background color was observed in fruit treated above 1.0 kGy and stored at 20C (68F). The flesh of Kent mangos appeared to be more tolerant to irradiation and refrigeration temperatures than other varieties, researchers found. High doses of radiation seemed to change the fruit physiology, and those changes were aggravated by storing Kents at 10C (50F). This suggests that the stress suffered by irradiation was compounded by chilling stress, which lead to increased damage of the fruit.
    - Kent mangos irradiated at high levels showed lower firmness and ascorbic acid content in short-term storage, but these effects disappeared as storage time progressed.
    - Temperature (not radiation doses) seemed to be the most important factor when measuring titratable acidity and soluble solid content in Kent mangos.

  - **Ataulfo** mangos seem to show a higher tolerance to irradiation doses when kept under continuous storage at 10C (50F) and 20C (68F). However, storage at 10C (50F) notably delayed the ripening process, researchers found. Data suggest that Ataulfo mangos could tolerate high radiation doses if the fruit is stored at 13C (55F), as mango protocols recommend.
    - Ataulfo mangos stored at 20C (68F) saw a rapid loss of firmness compared to fruit stored at 10C (50F) after irradiation. The Ataulfo softened more quickly than any other variety studied.

- Ataulfo fruit treated at high levels of radiation showed significantly lower values of ascorbic acid than in fruit with lower dose treatments.
- Higher doses of irradiation indicated ripening process changes in Ataulfo mangos, preventing the fruit from reaching higher soluble solid content.

Storage temperature for irradiated mangos has an effect on product quality. Fruit stored at 10C (50F) increased the damages caused by the irradiation treatment, and such damage was evident even when fruit was later transferred to rooms at a higher temperature of 20C (68F). The stress of radiation plus the stress of low temperatures can compound and cause increased damage to mangos, researchers found.

The dose of irradiation applied in the study did not seem to impact fruit shelf life, rather, storage temperatures were more critical in affecting mango shelf life. While this study did not intend to evaluate mango shelf life, researchers note that fruit stored at 10C (50F) had more impact on shelf life than the radiation doses.

Looking ahead:

The main quarantine method for mangos currently is hot water treatment, which works well if the proper protocol is followed carefully. One advantage of irradiation treatment is that mangos could be treated at a more mature stage (75% mature, as opposed to 25% mature, which is currently used for hot water quarantine treatment).

Irradiating mangos under the conditions indicated for each variety would ensure that mangos retain as much nutrient content and flavor as possible. For particular mango varieties – like Manila which has a particularly soft skin – irradiation offers an alternative quarantine treatment that could be very effective. Consumers who like the look, feel, and taste of mangos inevitably will buy more fruit – driving demand to a higher level.