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Phytosanitary irradiation – Development and application

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HIGHLIGHTS

- Phytosanitary irradiation is a growing use of food irradiation.
- 25,000 t of fresh produce was irradiated for phytosanitation worldwide in 2015.
- Phytosanitary irradiation has resulted in paradigm shifts applicable to other phytosanitary measures.

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ABSTRACT

Phytosanitary irradiation, the use of ionizing radiation to disinfest traded agricultural commodities of regulated pests, is a growing use of food irradiation that has great continued potential for increase in commercial application. In 2015 approximately 25,000 t of fresh fruits and vegetables were irradiated globally for phytosanitary purposes. Phytosanitary irradiation has resulted in a paradigm shift in phytosanitation in that the final burden of proof of efficacy of the treatment has shifted from no live pests upon inspection at a port of entry (as for all previous phytosanitary treatments) to total dependence on certification that the treatment for target pests is based on adequate science and is commercially conducted and protected from post-treatment infestation. In this regard phytosanitary irradiation is managed more like a hazard analysis and critical control point (HACCP) approach more consistent with food safety than phytosanitation. Thus, phytosanitary irradiation offers a more complete and rigorous methodology for safeguarding than other phytosanitary measures. The role of different organizations in achieving commercial application of phytosanitary irradiation is discussed as well as future issues and applications, including new generic doses.

1. Objective and scope

The commercial use of ionizing radiation to disinfest fresh agricultural commodities exported from areas considered at risk of infestation by quarantine pests has increased significantly in recent years and could have a far reaching impact in facilitating international trade. The objective of this paper is to provide an accurate account of the development and accomplishments of this technology and to propose what remains to be done for it to achieve its maximum potential. There has been considerable written about the technology and its application and we do not wish to repeat it here except for clarification.

2. Phytosanitation

The objective of phytosanitation is to prevent the spread of regulated pests from infested to non-infested areas. A phytosanitary treatment is required when a production area is considered infested by a regulated pest and products to be shipped out of that area are considered capable of being infested by that pest. The regulated pest does not have to be an economically controlled pest of the quarantined commodity nor does it even need to attack it. But the pest must pose an unacceptable risk of introduction via the commodity import pathway. For example, snails and slugs are often found in pallet loads of ceramic tiles imported into the USA from Italy and are considered regulated pests if they do not occur in the USA. Therefore, procedures to disinfest the tiles of the molluscs must be done if the tiles are to be imported.

Fresh fruits and vegetables can harbor many pests which without proper control could be introduced and spread widely resulting in economic loss to areas free from such pests. Fruit importing countries may require fruits and vegetables from areas

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considered to be infested with pests that threaten their agriculture to be treated according to treatment schedules authorized by them. They usually require individual treatment schedules for specific pest/commodity combinations to be applied to any import. Thus, a prospective exporting country of fruits and vegetables may be required to conduct tests to ensure the phytosanitary security of their exports.

The specific phytosanitary requirements of fruit importing countries, such as Australia, Japan, New Zealand, South Korea, and the United States, effectively become technical barriers that are difficult to overcome on a case by case basis. Thus, phytosanitary treatments which have broad spectrum to satisfy phytosanitary requirements of importing countries based on internationally agreed protocols are urgently needed, and ionizing radiation shows promise in becoming that treatment. However, key import markets, such as the European Union, Japan, South Korea, and Taiwan, do not yet accept irradiation.

2.1. *Phytosanitary irradiation*

The most commonly used phytosanitary treatments involve exposing commodities to temperatures between −0.6 and 3 °C for a number of days, 43.3–50° C for a few hours, fumigation with various chemicals such as methyl bromide, and ionizing radiation (Heather and Hallman, 2008). Phytosanitary irradiation differs from other phytosanitary treatments in that the measure of efficacy of irradiation is not acute mortality, as it is for all other commercial treatments, but prevention of further development or reproduction. This means that any regulated pests that may have been present at the moment of irradiation could still be alive when they enter the importing area.

This has required a paradigm shift in regulation of phytosanitation in that when live regulated pests are found upon inspection in an importing jurisdiction the lot would normally be rejected as non-compliant. The acceptance of irradiation as a phytosanitary treatment requires that plant protection organizations do not reject shipments containing live regulated pests covered by the treatment. However, that leaves phytosanitary irradiation without an independent verification of efficacy, as any quarantine pests found upon entry inspection should normally be dead for other treatment technologies. The lack of independent verification of efficacy coupled with lack of confidence in a verification system to replace that lack of efficacy was a major obstacle to early commercial implementation of phytosanitary irradiation. That is because all major treatment categories (heat, cold, fumigation) have failed at one time or another (Heather and Hallman, 2008), and this was only discovered because live pests were found upon inspection. Therefore, confidence in the efficacy of phytosanitary irradiation is based entirely on the soundness of the research supporting the regulated minimum treatment dose, the process control in achieving that dose during commercial application, and the phytosanitary safeguarding of the product after irradiation. This is accomplished by making the process control and certification of phytosanitary irradiation akin to a hazard analysis and critical control point (HACCP) approach more consistent with food safety (Hallman, 2016). In that regard phytosanitary irradiation has offered an improved way for safeguarding other phytosanitary measures, including phytosanitary systems, than phytosanitation as it is historically practised for all other measures besides irradiation. Indeed, in recent years phytosanitary systems have evolved in sophistication to resemble HACCP systems.

3. Historical development

The history of phytosanitary irradiation has been chronicled in several articles (Moy and Wong, 2002; Hallman, 2001, 2011, 2012; Hallman and Loaharanu, 2002; Follett and Griffin, 2006; Hallman and Blackburn, 2016). Phytosanitary irradiation was first envisioned in 1930, but the first commercial use did not occur until 1986 when one load of mangoes irradiated in Puerto Rico was shipped to Florida for sale to the public as a test of commercial marketing. Further shipments of mangoes were not made because starting in 1987 hot water immersion was approved and used as a replacement for the banned ethylene dibromide fumigation. The following text further details and clarifies the development of phytosanitary irradiation.

The former US Atomic Energy Commission (USAEC) as part of its wide-ranging program on peaceful uses of atomic energy sponsored food irradiation research programs in the 1960s by selecting six food items (papaya, strawberries, shrimp, mushrooms, red meat, and fish) based on their potential technical and economic feasibility and possible market acceptance. Research on phytosanitary irradiation became more intensified during this program. Irradiation of papaya was the sole proposed phytosanitary use among the six items.

The US-Food and Drug Administration (FDA) classified irradiated food as a food additive based on the Food Additives Amendment of 1958. Thus, every irradiated food product must demonstrate its wholesomeness based on defined criteria. Long term animal feeding studies on at least two animal species using diet incorporating irradiated food comprising 35% of the total diet based on dried weight were required for all irradiated foods to demonstrate their wholesomeness. Because this level of papaya consumption in animal feeding studies was impractical, revised diets were established that used only 15% fresh weight of irradiated papaya. Once the animal feeding studies were completed, the USAEC submitted a petition to the FDA to approve papaya phytosanitary irradiation in 1972. By that time the USAEC had come under increasing public opposition to nuclear energy, and in 1975 the USAEC was dissolved and many of its programs discontinued. In 1986 the FDA approved radiation disinfestation of all fresh fruits and vegetables, not only papaya, at a maximum dose of 1.0 kGy. This approval followed the milestone conclusion of the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Foods in 1980 that “Food irradiated with an overall average dose of 10 kGy causes no toxicological hazard; thus, testing of food so treated is no longer required” (WHO, 1981).

Hawaii, the early sustained innovator in phytosanitary irradiation, has received a large amount of effort by many organizations over the years to promote and develop phytosanitary irradiation. As stated above, beginning in the 1960s the USAEC chose phytosanitation of papaya as one of the six initial uses of food irradiation, built a research irradiator, and supported phytosanitary irradiation research in the state. Proposed irradiation of Hawaiian papaya was the impetus to request FDA approval of phytosanitary irradiation of fresh agricultural commodities in 1972.

At that time ethylene dibromide (EDB) was the fumigant of choice to satisfy phytosanitary requirements for disinfestation of papaya and other fruits. There was little incentive to develop new technology such as radiation disinfestation especially when food regulatory agencies had not yet approved irradiated fruits for consumption. However, renewed interest in phytosanitary irradiation emerged. When restrictions on the use of EDB were being discussed in the Environmental Protection Agency (EPA) in the USA in the early 1980s and alternative phytosanitary treatments showed questionable results, the USDA and US EPA convened a meeting in Washington D.C. to re-examine the role of phytosanitary irradiation as a phytosanitary treatment in 1982.

A second commercial market test of phytosanitary irradiation, Hawaiian papayas to California, was done in 1987. Moy and Wong (2002) chronicle these early stages of phytosanitary irradiation in Hawaii up to the construction of a commercial facility in Hilo using

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