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Effect of Irradiation process on mango

Tanzila Sultana, Kazi M Maraz, Arwah Ahmed, Shamima Shultana and Ruhul A Khan *

Institute of Radiation and Polymer Technology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh.

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Abstract

Mango (*Mangifera indica* L.) is one of the choicest tropical fruit of the world and rightly designated as "King" of all fruits. It is a nutritionally important fruit being a good source of vitamin A, B and C and minerals. Post-harvest losses in mangoes have been estimated in the range of 25 to 40% from harvesting to consumption stage. Improved practices and preservation have a great impact on retaining mango fruit quality and on the supply chain. Nowadays food irradiation process is an engrained technology for the preservation of foods and food products. Three different kinds of ionizing radiation are applicable for food irradiation processes (Gamma-rays which is emitted from the radio-isotopes Cobalt-60 and Caesium-137, or electron beams and X-rays). Food irradiation can be considered an evolving technique that is capable of increasing the shelf-life, deferring the ripening and senescence of fruits, and thwart of microorganism activity along with insect infestation. Irradiated food is save for human health. This review article is focusing on irradiation effects on mango and the adoption of improved practices by the farmer for export besides that of food safety.

Keywords: Mango cultivation; Improve practices; Effects of irradiation on mango; Advantages and disadvantages of irradiation on food.

1. Introduction

The mango, *Magifera Indica* L. is well known for its excellent exotic flavor and usually referred to as the king of fruit. It is a dicotyledonous plant belonging to the order sapindales in the family *Anacardiaceae.* It is a popular and economically important fruit, widely cultivated in the tropics and subtropics. Mango was originated in the Indo-Burmese region. The fruit is eaten fresh and in several other by-products, including juices, nectars and purees [1]. Ripe mangoes are best eaten as fresh fruit, usually as a dessert and are used in the production of confectionery, ice cream, and bakery products. Mango contains a variety of phytochemicals and nutrients. The fruit pulp is high in dietary fiber, Vitamin C, A, carotenoids and diverse polyphenols [2]. The fruit is rich in antioxidants and recommended to be included in the daily diet due to its health benefits such as reduced risk of cardiac disease, anti-cancer, and anti-viral activities [1]. The major mango growing countries are India, Pakistan, Bangladesh, Myanmar, Sri Lanka, Florida and Hawaii of USA, Australia, Brazil, Thailand, the Philipines, Malaysia, Vietnam, Indonesia, Fiji Islands, Egypt, Israel, South Africa, Sudan, Somalia, Kenya, Uganda, Tanzania, Niger, Nigeria, Zaire, Madagascar, Mauritius, Venezuela, Mexico, West Indies Islands, Cambodia, etc.[3]. Several factors affect mango production with postharvest losses being among the major constraints. Postharvest losses of fresh mango fruits in Tanzania have been estimated at 60%.The total postharvest losses of mango fruits encountered in all stages along the supply chain was 43.8 % with the main damage features being caused by fruit fly maggots, microbial decay and fruit softening each accounting for 8.65, 11.85 and 20.05% of the total losses, respectively [4, 5]. Post-harvest losses in mangoes have been estimated in the range of 25 to 40% from harvesting to consumption stage. If proper methods of harvesting, handling, transportation and storage are adopted, such losses could be minimized. Hence, to tap its potential to the fullest, there is a need to adopt technologies and strategies to ensure a longer post-harvest shelf-life and longer transportation times. There are several technologies, like low temperature and

* Corresponding author: Ruhul A Khan
Institute of Radiation and Polymer Technology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh.

other associated technologies such as controlled atmosphere (CA)/modified atmosphere (MA) storage, hypobaric storage, irradiated storage and storage in chemicals and by coatings [6]. Therefore, food irradiation can be considered an evolving technique that is capable of increasing the shelf-life, deferring the ripening of fruits, and thwart the foodborne ailments owing to the declining of non-spore-forming infectious microbes. Adoption of improved production practices is the key to higher production of fruits and higher incomes to farmers [7]. In this paper, the effects of irradiation process on mango preservation has been discussed also with improved practices and food safety.

2. Mango cultivation

Mango trees start producing fruit 2–4 years after field planting and can continue to produce fruit for more than 100 years. Under ideal conditions, trees can grow to 2m (6.6 ft) in the first year. Tree spacing is governed by the variety and climate. Traditional spacing were wide (up to 12 x 12 m, 70 trees/ha; 40 x 40 ft, 28 trees/ac) as trees were allowed to grow to full size. In more recent times, tree spacing has been reduced and trees are maintained at smaller sizes. This facilitates pest and disease control and harvesting operations. Smaller compact varieties can be planted as close as 7 x 4 m or 375 trees/ha (23 x 13 ft., 152 trees/ac) [8,9]. July/August full flowering occur, then September/December Fruit growth occur and finally January/March full maturing of fruit and harvest take place [10]. Mangoes are affected by a range of insect pests and diseases. These, however can usually be adequately managed in commercial orchards.

2.1. Insects

Many insects live in and feed on mango trees, but only a few of these are considered major pests. Tip borers bore into and kill the young developing flushes. The pest activity is worst during hot, wet, summer seasons. Fruit fly species differ among regions. Adult flies lay eggs in near-ripe or ripe fruit, and the larvae tunnel and feed throughout the flesh, destroying and decaying it. The mango seed weevil bores into the seed early in the development of the fruit, with little or no damage to the edible fruit. In the seed, the larvae destroy the cotyledons, thus reducing seed germination. The presence of seed weevils is a major quarantine barrier for the export of mango to many countries. Other insect and mite pests of mango include fruit spotting bugs, seed caterpillars, plant hoers, flower-feeding caterpillars, thrips, leaf miners, and fruit piercing moths, termites, mites [8].

2.2. Diseases

A range of leaf, fruit, and soil diseases can affect mango, many of which can be adequately controlled with good management and judicious use of fungicides and bactericides. Anthracnose, Mango scab, Bacterial black spot, Alternaria rot, Powdery mildew, Stem end rot, Mango malformation are some example of the diseases. Adoption of smart agriculture practices need during management practices and infestation level [9].

2.3. Improved Practices of Mango Production

Table 1 Extent of adoption of various components of improved practices of Mango cultivation by farmers [11]

Improved Practices	**Fully Adopted**		**Partially Adopted**		**Not Adopted**	
	No	**%**	**No**	**%**	**No**	**%**
Summer ploughing	33	16.5	40	20.0	127	63.5
Alication of manure & fertilizer (dose)	87	43.5	-	-	113	56.5
Alication of manure & fertilizer (time)	92	46.0	-	-	108	44.0
Alication of manure & fertilizer (method)	93	76.5	-	-	107	53.5
Intercrops	52	26.0	-	-	148	74.0
Plant growth regulator	89	44.5	-	-	111	55.5
Green manure	95	47.5	-	-	105	54.5
Insect pests	96	48.0	-	-	104	52.2
Diseases	94	47.0	-	-	106	53.0
Physiological disorders	96	48.0	-	-	104	52.0
Marketing procedure	56	28.0	59	29.5	85	42.5

Adoption of improved production practices is the key to higher production of fruits and higher incomes to farmers. However, majority of farmers did not adopt such practices as summer ploughing, application of manure and fertilizers (dose, time and method), inter-crops, plant growth regulators, green manuring, insect pests and diseases, physiological disorders, and marketing procedures are shown in table (1) [11].

3. Mango production in the world

World mango production is spread over 100 countries that produce over 38.67 MT of fruit annually. Eighty percent of this production is based in the top nine producing nations in order of production, India (10.80Mt) , China (4,351,593 t), Thailand (2,550,600 t), Pakistan (1,784,300 t), Mexico (1,632,650 t), Indonesia (1,313, 540 t), Brazil (1,188,910 t), Bangladesh (1,047,850 t) and Philipine (823,576 t). China is the third largest mango cultivation country in the world in 2018. Mango has become the main source of income for mango farmers in eight provinces and regions such as Guangxi, Yunnan, Hainan, Sichuan. Asia accounts for approximately 76.5% of global mango production, and the Americas and Africa account for approximately 12.6 and 10.8% respectively in 2010. Approximately 3-4% of the world production is traded internationally; the rest is traded and consumed within the countries of production. The main exporting producing nations include Mexico (23% of production), Brazil (14.3%), Pakistan (3.2%), and Peru (10.3%)**.** The largest importing destinations are the European community (34%), USA (20%), Arabian Peninsula (14%) and Asia (27%). Mexico, Brazil, Peru, Ecuador and Haiti were the main suppliers of North America's imports. The export market share of the West Asian was predominated by India and Pakistan. Thailand, Indonesia and the Philipines were the main suppliers and owned more export share from South-east Asian countries. South American and Asian countries were the main source of European Union (EU) buyers. The import of fresh mango increased from 5.65 to 8.61 MT between 1999 and 2009 and the USA was the number one importer. During 2007-2009, the USA imported 1.87 MT (33% of the total world mango imports) of fresh mango. The Netherlands become the second importing country and traded 1.14 MT (13.24%), even though most of the imported mango was redistributed throughout the EU. Besides United Arab Emirates (5.69%), Saudi Arabia (4.53%), and Malaysia (4.76%) were prominent importing countries, and also the major redistributors targeted to the Middle East. Mangoes are distributed everywhere in Bangladesh. It is the most important fruit with cultivated area of about 50,610 ha and production of 118,000 t. The commercial and elite cultivars have been growing successfully in the districts of Rajshahi, Kushtia, Dinajpur and Satkhira [12, 13, 14].

Figure 1 Mango fruits of the world [8]

4. Economic value of Mango

As mango is a seasonal fruit, about 20% of fruits are processed for products such as puree, nectar, leather, pickles, canned slices, and chutney. These products experience worldwide popularity and have also gained importance in national and international market. During processing of mango, by-products such as peel and kernel are generated. Mango peels and seeds are rich in valuable bioactive compounds such as polyphenols, carotenoids, dietary fibres, enzymes phytosterols and tocopherol; whereas and the peel extract exhibits potential antioxidant properties. Processing of mango by-products reduces waste disposal problem, adds value to the product for food and other industrial use, and the isolated active component can be used in food fortification [15].

Mango kernel decoction and powder (not tannin free) are used as vermifuges and astrigents in diarrhea, hemorrhages and bleeding hemorrhoids. The fatis administered in case of stomatitis. Extract of unripe fruits and of bark, stems and leaves have shown antibiotic activity. The green unripe fruits are used in curries and pickles. The mango kernel contains about 10-15% fat depending on the varieties which is edible and is comparable with cocoa butter. Mango peel which constitutes about 10-20 percent of the fruit is rich in dietary fibre, pectin, carotenoids, polyphenols and enzymes. Good quality jelly grade pectin may be extracted from the peel [16, 17].

In addition, mango seed kernel could be used as a potential source for functional food ingredients, antimicrobial compounds and cosmetic due to its high quality of fat and protein as well as high levels of natural antioxidants. The mango stone obtained after decortication of mango seed can be utilized as adsorbent [18].

5. Food irradiation

Food irradiation is a process that exposes food to a prescribed amount of ionizing radiation. Three different kinds of ionizing radiation are applicable for food irradiation processes.

- Gamma rays from the radionuclides cobalt-60(60Co) or, less commonly, cesium-137(137Cs)
- X-rays ('bremsstrahlung') generated from machine sources (electron accelerators with converters) operated at or below an energy level of 5MeV (US7.5MeV), and
- Electron beams produced by electron accelerators operated at or below an energy level of 10 MeV [19].

Radiation is any energy traveling through the space in form of waves or particles. It can be classified as ionizing and nonionizing, depending on its energy. Ionizing energy has shorter wavelengths yet higher frequency and energy as compared to nonionizing energy (Fig. 2). The visible light spectrum, radio waves, microwaves, and infrared waves contain sufficient energy for molecular vibrations and excitations, but not ionization. In contrast, far UV rays, X-rays, and γ-rays contain higher energy, which can eject electrons from atoms, thus causing the ionization of molecules. Ionizing radiation can also break chemical bonds in molecules, causing alterations in the normal functioning of cells. The term "food irradiation" refers to the deliberate exposure of food to ionizing radiation [20].

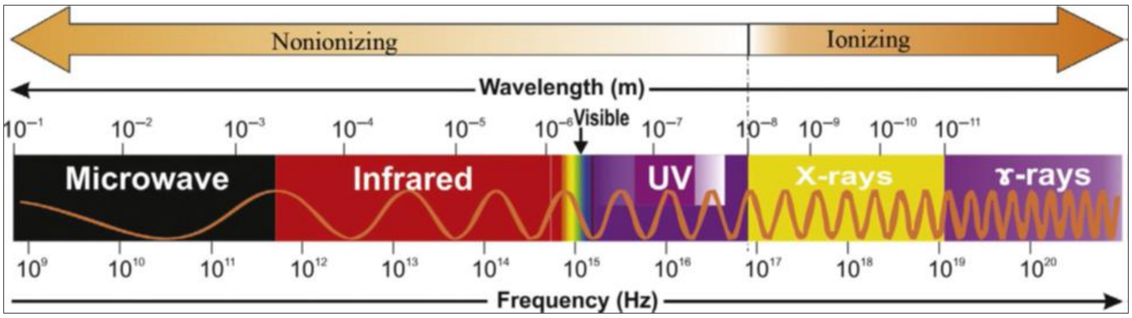

Figure 2 The types of electromagnetic radiation composing the electromagnetic spectrum [20]

The Scientific Committee of Food evaluated a number of food classes and specific food commodities and radiation doses as acceptable from a public health standpoint. They are listed in Table 2 [21].

Table 2 Radiation doses on various foods [21]

Food class		Overall average radiation dose (kGy)
Fruits		Up to 2
Vegetables		Up to 1
Cereals		Up to 1
Starchy tubers		Up to 0.2
Spices & condiments		Up to 10

6. Effect of irradiation on fruits

The purpose of irradiation is to kill or to sterilize microbes or insects by damaging their DNA. According to the Food and Drug Administration the approved dosage for irradiation treatment on fresh produce is 1 kGy (100 krad). However, 1 kGy may not be effective to kill insects, and such high doses negatively affect the quality of almost all fresh fruits. X-ray irradiation (≤1 kGy) was confirmed as an effective phytosanitary treatment for strawberries to delay decay and negative physicochemical changes and extend shelf life with acceptable sensory attributes. Irradiation has little impact on dried foods, such as spices and seasonings. Fresh fruit and vegetables are metabolically active; therefore irradiation can impact ripening as well as quality attributes [1, 22].

7. Effect of irradiation on Mango

The effectiveness of irradiation on mango fruit quality depends on irradiation dose, cultivar, and fruit maturity stage [1].

7.1. Ripening and senescence

Ripening is a process in fruits that causes them to become more palatable. In general, fruit becomes sweeter, less green, and softer as it ripens. The fruits irradiated with 0.40kGy gamma rays and stored at 9 degree C storage temperature with 90% RH recorded maximum reduction in physiological loss in weight and reduced ripening. The minimum physiological loss in weight and ripening and highest marketability of fruits was recorded from fruits irradiated with 0.40kGy gamma rays and stored at 12 degree C storage temperature with 90 RH including maximum scores on skin color, pulp color, texture, taste and overall acceptability at the end of shelf life (41.43 days) [23].

The fruits exposed to gamma rays (0.40kGy) and stored at 9°C and 12°C were remained unripe on 30th day of storage, the gamma rays @ 0.40kGy exposed fruits showed 50.10 and 52.00 per cent ripening, respectively at 9°C and 12°C storage. Unirradiated mangoes had early ripeness whereas; gamma rays exposed mangoes had a significantly delayed ripening [24].

The fruits of Alphonso mango subjected to 0.40kGy gamma rays irradiation subsequently stored at 9degree C temperature delayed the ripening process which maintained lover percentage of physiological loss in weight and ripening per cent. This was followed by the fruits treated with 0.40kGy gamma irradiation subsequently stored at 12 degree C temperature [25].

Postharvest treatment of 0.3% potassium sorbate and 1.0KGy radiation was most effective to delay ripening that resulted in extending shelf life of mango [26].

A few tropical and subtropical climatic fruits that have been reported to undergo a delay in ripening after irradiation are mango, banana and guava. Delay in ripening of fruits is usually achieved with dose of 0.2-0.5 KGy. Senescence is the phase of plant growth from full maturation to death, especially of the fruit and leaves and it's characterized by an accumulation of metabolic products, an increase in respiratory rate and a loss in dry weight. Its inhibition is another facet of possible changes induced by ionizing radiation in the post-harvest metabolism of living foods. There is poor understanding of the biochemical mechanisms underlying the delay in senescence of climatic fruits by gamma irradiation [27, 28].

7.2. Shelf life

Shelf life is the length of time for which an item remains usable, fit for consumption, or saleable. Low dose gamma irradiation of mangoes in the dose range 10 to 200 krad alone or in combination with other physical and chemical treatments (i.e. hot water dying and skin coating with 9 percent emulsion of acetylated monoglyceride) show that physiological, pathological and entomological factors can be controlled to extend the shelf-life of mangoes by one to two weeks. Organoleptic qualities of treated fruits are found to be comparable to those of unirradiated control mangoes. Texture qualities of the treated fruits are also retained at the end of 15 days after their transport over long distance [29].

Hot water and radiation treatment are affecting chemical constituents of Awais mango and the applied radiation dose at 1.0 and 0.5 k Gy are quite enough to be used for extending the shelf life of fruits and improving their chemical contents [30]. Mango is an important world fruit crop; however, its trade (national and international) is inhibited because of its perishable nature and short shelf life, which restrict its transport over large distances. Low-dose gamma irradiation appears to be a good method for shelf-life extension and for disinfestation of fruit flies and mango seed weevil. Mango is a climacteric fruit, which makes it possible to extend its shelf life by delaying the ripening process and senescence by irradiation [31].

7.3. Quality and nutrition

The effectiveness of irradiation on mango fruit quality depends on irradiation dose, cultivar, and fruit maturity stage. Fruit damage or irradiation stress can be expressed as softening, uneven ripening or surface damage. Fruits that are partially ripe were not affected by irradiation. Haden mangoes subjected to 250 Gy at 1/4 or 1/2 maturity stage did not show any problem. Keitt mangoes, subjected to 600 and 900 Gy showed retention of colour, taste and texture after 9 days in storage. Lower irradiation doses between 100 and 150 Gy affected the flavour, and doses higher than 750 Gy caused loss of ascorbic acid content in 'Irwin' and 'Sensation' mangoes [1]. No immediate visual differences between control and low dose (0.3–1 kGy) treated fruit were noticeable, however the differences became apparent with storage at physical appearance for Dushehri and Fazli variety. All the irradiated fruit of both the cultivars showed significantly higher sugar contents at the end of the storage. Low doses did not induce any significant immediate effect on the sugar content of the fruit while 'Dushehri' treated with 6–10 kGy and 'Fazli' treated with 1–10 kGy recorded significantly increased sugar content [32].

The effect of electron-beam ionizing radiation stress and storage on mango fruit antioxidant compounds was evaluated in a dose range of 1-3.1 kGy. Phenolic high-performance liquid chromatography (HPLC) profiles were not affected right after the irradiation process; however, an increase in flavonol constituents was observed after 18 days in storage (3.1 kGy). Total phenolics by the Folin Ciocalteu method and antioxidant capacity were not affected, while reduced ascorbic acid decreased ~50-54% during storage (≥1.5 kGy). No major changes in carotenoid HPLC profiles indicated a delay in ripening of irradiated mangoes (1-3.1 kGy) compared to nonirradiated fruits, (figure:3) [33].

Figure 3 Whole irradiated and nonirradiated mangoes before and after 18 days of storage at 15 °C [33]

In the case of irradiation, the change in the chemical composition of the food is minimal. Many of the resulting compounds are the same as those formed when food is cooked or preserved in more traditional ways. Just as vitamins vary in their sensitivity to heat, they also vary in their sensitivity to radiation. This sensitivity depends upon the conditions under which the food is irradiated. Vitamins A, B1 (thiamine), C, E and K in foods are relatively sensitive to radiation, while some other B vitamins such as riboflavin, niacin and vitamin D are not. A comparison of the chemical composition of the four varieties of mangoes (Haden, Kent, Peach and Zill) showed no statistically significant differences between the irradiated (warm water wash + 0.75 kGy) and unirradiated mangoes. A few varieties of mangoes show a substantial loss of vitamin C levels. Irradiation has no significant effect on these levels. Of the other vitamins detected in mangoes, riboflavin, thiamin and niacin are present in very small amounts, none of which show any significant change on irradiation of mangoes. No significant differences between the free and total (hydrolyzed) amino acid compositions of Kent mangoes (except for arginine and proline) have been detected, between irradiated and unirradiated samples. Irradiation doses below 3.5 kGy showed no significant changes in the protein content of Kent mangoes [34, 31].

7.4. Microorganism

Two major separate driving forces are moving adoption of food irradiation forward. One is the need to effect microbial reduction, primarily for purposes of food safety enhancement. The second major driver is the need for an effective and environmentally friendly technology to disinfest fruits and vegetables for quarantine security purposes associated with interregional trade [35]. The potential application of ionizing radiation against postharvest pathogens of fruits and vegetables is based mainly on the fact that ionizing radiation effectively damages their DNA, thus preventing them from reproducing [36]. Irradiated fruits have the added advantage of disinfestation and reduction of stem end rot and anthracnose during ripening. Doses exceeding 75 krad are, however, found to be injurious to the fruits. [29].

Although incidence of anthracnose during storage was reduced with increasing irradiation doses up to 600 Gy, 1 kGy failed to provide a complete control of anthracnose in mangoes. Integrated treatments using a dose of 750 Gy with HWT at 40 °C for 20 min or 50 °C for 5 min was effective in controlling anthracnose. The effects of gamma irradiation and disease control treatments on disease severity and post-harvest quality of several mango cultivars were investigated. In mangoes cv. Kensington Pride, irradiation doses ranging from 300-1200 Gy reduced disease, but the level of control was not commercially acceptable. Hot benomyl immediately followed by irradiation provided effective control of anthracnose *(Colletotrichum gloeosporioides)* and stem end rot *(Dothiorella dominicana)* during short-term storage (15 days at 20°C) [1,37].

7.5. Insects

Insect pests are a major limiting factor in achieving full yield potential of mango varieties. About 400 species of insect pests are known to infest mango in different parts of the world [38].

Many insects live in and feed on mango trees, but only a few of these are considered major pests. Tip borers bore, fruit fly, mango seed weevil are the major pests of mango. Insect and mite pests of mango include fruit spotting bugs, seed caterpillars, plant hoers, flower-feeding caterpillars, thrips, leaf miners, and fruit piercing moths, termites, mites are the minor pest of mango. Tip borers bore into and kill the young developing flushes. The pest activity is worst during hot, wet, summer seasons. Fruit fly species differ among regions. Adult flies lay eggs in near-ripe or ripe fruit, and the larvae tunnel and feed throughout the flesh, destroying and decaying it. The mango seed weevil bores into the seed early in the development of the fruit, with little or no damage to the edible fruit. In the seed, the larvae destroy the cotyledons, thus reducing seed germination. The presence of seed weevils is a major quarantine barrier for the export of mango to many countries. Generic irradiation treatments have been approved in the USA to control broad groups of insects in all commodities. The approved generic doses are 150 Gy for tephritid fruit flies and 400 Gy for all insects except Lepidoptera pupae and adults (which may require higher doses) [8,39]. Mangoes infested with third instar larvae were irradiated using Co-60 gamma rays and a dose interval of 2-250 Gy to assess the irradiation dose required to prevent adult emergence of the Mexican fruit fly (*Anastrepha ludens*), the West Indies fruit fly (*A. obliqua*), the sapote fruit fly (*A. serpentina*), and the Mediterranean fruit fly (*Ceratitis capitata*) [40].

Third instars of the Queensland fruit fly, *Bactrocera tryoni* (Froggatt), were more tolerant to gamma irradiation than other stages that infest fresh fruit from Australia. A dose of 75 Gy prevented the development of adults when the eggs or larvae were irradiated in ales *(Malus domestica* L.), oranges *(Citrus sinensis* Osbeck), avocados (*Persea americana* Mill.), mangoes (*Mangifera indica* L.), tomatoes (*Lycopersicon esculentum* M ill.) and cherries (*Pru nus avium* L.) [41].

Mango seed weevil, *Cryptorhynchus mangiferae* (F.), has prevented the export of mangoes from Hawaii to the U.S. mainland for over 50 years because there were no approved quarantine treatments to control this pest. Irradiation was explored as a method to prevent adult emergence in, or to sterilize, mango seed weevil. Mixedage mango seed weevils in mangoes were irradiated with target doses of 50, 100, or 300 Gy and held for adult emergence. The 300 Gy treatment (dose range 180–310 Gy) did not prevent adult emergence. Emerging adults from the 100 and 300 Gy treatments were lethargic and short-lived, and laid no eggs indicating sterility. An irradiation quarantine treatment (100 Gy) to sterilize mango seed weevil in mangoes has been proposed [42].

Irradiation was explored as a method of quarantine disinfestation treatment for the mango pulp weevil *Sternochetus frigidus* (Fabr.). *S. frigidus* is an important quarantine pest preventing the export of mangoes from the Philiines to countries with strict quarantine regulations. Mangoes obtained from Guimaras Island are exempt from this ban as they are certified to be free from seed weevil and pulp weevil infestation. In the dose-response tests, *S. frigidus* larvae, pupae and adults in mangoes were irradiated at target doses of 25, 50, 75, 100, 150, 300 and 400 Gy. The number of eggs laid by adult females decreased with increasing dose. Treatment with irradiation doses of $\geq$75 Gy resulted in sterility in adults developing from larvae and pupae while doses of $\geq$100 Gy resulted in sterility in irradiated adults [43]. Figure 4 and 5 bear the picture of fruit fly and seed weevil respectively [44,45].

Figure 4 Mango fruit fly [44]

Figure 5 Seed weevil [45]

8. Advantages of irradiation on food

The ability of ionizing radiation to perform desired objectives as sanitary, phytosanitary and shelf-life extension makes it popular among a wide range of fruits and vegetables. Therefore, the technique helps more consumers to have access to the original taste, texture, appearance, and nutrients. A wide range of research in the area of irradiation application of fresh produce was mainly carried out for low dose treatment, because it would have minimum impact on the product quality. The FDA restricted the maximum irradiation dose level to 1 kGy in fresh produce for disinfestation and delaying senescence all over the world. Also, has classified low dose of irradiation (<1 kGy) in several dose ranges for its application in fruits and vegetables according to their respective uses such as delaying senescence and ripening, sprout inhibition and insect disinfection [46].

Irradiation can be used to sterilize (eliminate all microorganisms) food products at levels above 10 kGy. In the range of 1-10 kGy it can be used to pasteurize food (eliminate a significant number of microorganisms including those of public health significance). Because of the seriousness of the food safety issue and the lack of adequate control measures to ensure 100% bacteria free food, irradiation is seen as an additional tool that can be used for improving food safety [47].

9. Disadvantages of irradiation on food

Food irradiation can reduce specific food loss problems and can complement other food processes, (e.g., refrigeration) in maintaining the quality and wholesomeness of food. It can neither replace good manufacturing practice nor is it applicable to all food. For example, dairy products such as milk and butter can develop an off-flavor when treated by irradiation. Many food products, (e.g., meat, fish, chicken, etc.) have threshold doses above which organoleptic changes occur. Some of the changes can be offset. If food such as meat is treated with high sterilizing doses in the frozen state little-or-no detectable change occurs. At the doses recommended for treating food at present, irradiation of certain foods will not eliminate all micro-organisms or their toxins. Low dose irradiation will not destroy bacterial spores. Treatment of meat, poultry and fish by irradiation, as with heat pasteurization and controlled atmosphere storage, requires appropriate temperature control during storage to prevent germination and toxin production by *Clostridium botulinum.* Toxins such as mold-produced mycotoxins or staphylococcus bacterial toxin cannot be inactivated by irradiation. Therefore, foods prone to contamination by these organisms must be handled in strict adherence to good manufacturing practices (GMPs) required for each food (e.g., chilling, low moisture content, proper storage and packaging, etc.) prior to and after processing by any sub sterilizing method, including irradiation, to prevent toxin production. Viruses also cannot be destroyed by low-dose irradiation applicable for extending shelf-life of most food products. The well-developed radiation sterilization process is used to eliminate microbial spores (and certain viruses, if present). In this respect, low-dose irradiation does not differ from some other food processes such as heat pasteurization, which destroys spoilage and pathogenic bacteria but is not capable of inactivating bacterial spores, mycotoxins or staphylococcus enterotoxin [48].

9.1. Is irradiated food safe?

Food Irradiation technology has been officially accepted by international organizations due to the effectiveness in food, wholesomeness, and economic benefits. Overall, many international organizations such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the International Atomic Energy Agency (IAEA) have a less preventive tactic than the European Union. In 1981, it has been reported that 10 kGy dose level was set as the maximum dose considered to be safe and wholesome by the join expert of FAO, IAEA, and WHO committee on the wholesomeness of irradiated food and food products. The amount of radiation to which the food is exposed is carefully monitored to ensure the desired outcome is achieved without harming the food. The food itself does not become radioactive because the radiation used in the process does not have enough energy to alter the molecular structure of any of the atoms in the food. It is therefore impossible for this radiation to make the food radioactive and no radiation remains after the food has been treated. So irradiated food is safe [7, 34].

10. Conclusion

Based on all the scientific information available there is no greater health risk from irradiated food than non-irradiated food. Irradiated foods are not radioactive. No scientific studies have shown irradiated foods causes cancer. No food is 100% safe. Proper sanitation, handling, and preservation are needed for any food product [47]. In mango, nutrition is little bit change but shelf life extension, delay ripening and senescence occur. Microorganism and insects are also be reduced by irradiation. So preservation of mango by irradiation is a qualitative process for export of mango. If improved practices of mango can be maintained properly with irradiation, it would be better for mango export also.

Compliance with ethical standards

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Disclosure of conflict of interest

There is not conflict of interest.

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