



Irradiation: A comprehensive literature review about applications in mango produce.

Abstract

Gamma irradiation has been used for decontaminating foods, based on its microbicidal activity, suggesting a promising strategy for microbial control and the stimulation of nutraceutical compound production in fruits and spices. However, information on research regarding the application of mango for decontaminating pathogenic microorganisms is scarce. The present study comprises a systematic review of the application of gamma irradiation for decontaminating mangoes and mango products. Results indicate a limited number of studies focusing on gamma irradiation in various mango cultivars, including Alphonso, Kent, Keitt, Tommy Atkins, Banginapalli, Mulgoa, Neelam, Katimon, and Zebda. Doses oscillated between 0.25 and 5 kGy, with 1.0 and 1.5 kGy being the most recommended to reduce bacterial and fungal loads in mango and mango products, thereby extending shelf life from 2 weeks to 60 days. In conclusion, gamma irradiation may be a viable strategy for decontaminating mangoes from pathogenic bacteria, based on its antimicrobial properties, which also extend shelf life and preserve the nutritional and sensory qualities of the mango.

Introduction

Gamma irradiation is a powerful source of energy that has been utilized in the food industry due to the benefits it provides to the properties of irradiated foods, which preserve food quality (Wang et al., 2018). In this regard, diverse studies have evaluated the effectiveness of gamma irradiation in different food commodities such as nuts, tomato, spices including red chili, turmeric, coriander, cumin, black pepper, garlic, and ginger, essential oils, as well as cereals such as buckwheat, oat, cowpea, and rice to demonstrate its beneficial effects like extended shelf life, antimicrobial activity against food-spoilage microbes, as well as a strategy of abiotic stress for stimulation of bioactive compounds; suggesting that gamma irradiation at low doses, confer beneficial effects on the irradiated foods, without significant changes in their sensory, nutritional and functional properties (Santos et al., 2011; Alloun et al., 2019; Gyimah et al., 2020; Rahman et al., 2021; Bhat et al., 2024). Several studies have been conducted to evaluate the effect of gamma irradiation on fresh fruits as a preventive measure against post-harvest problems, such as mold growth (Jeon et al., 2016). In this regard, gamma irradiation has been evaluated and recommended as a successful quarantine strategy for mango, given the effect against fruit flies such as *Anastrepha ludens*, *Anastrepha obliqua*, *Anastrepha serpentina*, *Ceratitidis capitata*, and *Bactrocera dorsalis* (Bustos et al., 2004; Srimartpirom et al., 2017; Hernández et al., 2018). Additionally, some studies report that gamma irradiation, used as a phytosanitary treatment, does not affect the quality and properties of mango (Cruz et al., 2012; Gómez-Simuta et al., 2017). In the field of pathogenicity,

gamma irradiation exhibits a significant microbicidal effect, which has been proven, at the laboratory level, to eliminate critical foodborne pathogens, such as *Escherichia coli*, *Salmonella*, and *Listeria* (Begum et al., 2020). However, the application of gamma irradiation to reduce the pathogenic microbial load in mango is scarce. For this reason, this review aimed to conduct a systematic review of the available scientific data related to gamma irradiation in food, especially mango, to determine whether this microbial control measure might be suitable for mango against pathogenic foodborne bacteria associated with this important food commodity.

Methodology

Characteristics of the study

This study is based on a systematic review to determine the viability of using gamma irradiation in Mango, with an explicit focus on studies that evaluate the antimicrobial activity of gamma irradiation in mango, including fresh mango and mango products (Figure 1).

Literature search strategy

The present study comprises a systematic review, following the guidelines established by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009), which consists of several stages, including *search strategies*, *selection criteria*, *data extraction*, and *data analysis*. The search for findings focused on exploring academic/scientific-based databases, including *Google Scholar*, *Scopus*, *Web of Science*, and *PubMed*, for the identification, screening, and selection of documents for further analysis (Figure 1).

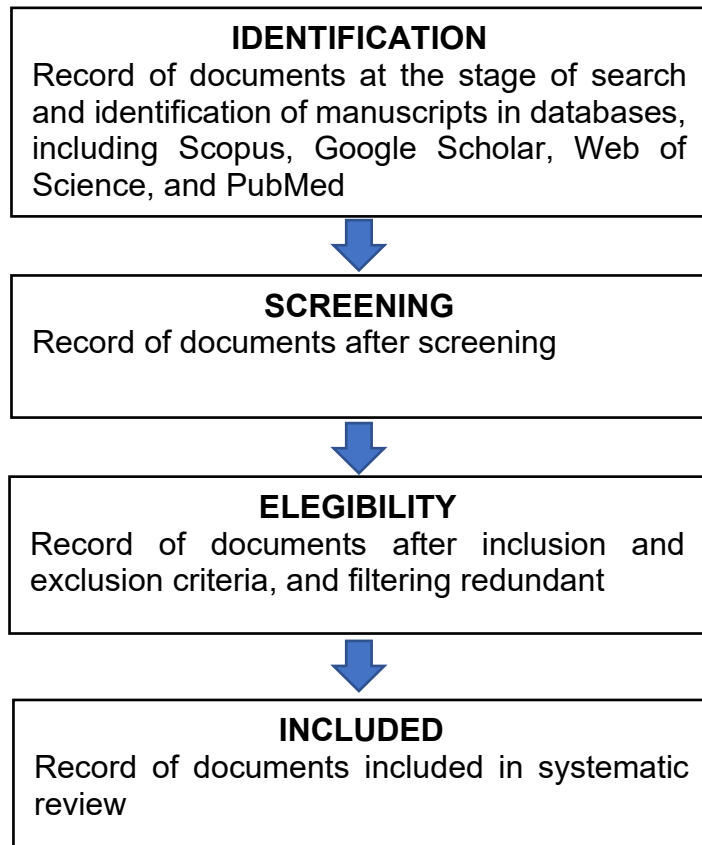


Figure 1. Flowchart describing the systematic review of literature.

Inclusion criteria

The selection of manuscripts at each stage was based on specific criteria carefully selected to align with the scope of this review. The requirements documents had to meet were original research manuscripts, gamma irradiation, and an emphasis on evaluating the antimicrobial activity of mango (against bacteria, including total bacterial count, pathogenic bacteria, yeast, molds, and pathogenic fungal agents), as well as the shelf life of mango.

Exclusion criteria

Manuscripts were excluded from the analysis based on the following criteria: reviews manuscripts, pre-print manuscripts, manuscripts focused on other fruits and produce different from mango, manuscripts focused on only sensory and nutritional properties, as well as manuscripts lacking methodological details, combinations of irradiation sources, and finally manuscripts focused on only the stimulation of antioxidant activity of compounds present in mango.

Evaluation of the manuscripts

According to the PRISMA instructions and guidelines, each manuscript was reviewed and evaluated individually. At the first step, the initial evaluation consisted of reading each abstract to identify the primary focus of the manuscript and determining whether the inclusion and exclusion criteria were met. Further, full reading was performed on each manuscript separately to identify all items related to the purpose of the present study, including the mango cultivar, microorganisms evaluated, doses of gamma irradiation, the time of the shelf-life study, sample number, and the results obtained.

Data extraction

From the selected documents according to the exclusion and inclusion criteria, relevant and sought-after data were collected and organized by the authors,

including irradiation doses, microorganisms studied, results of antimicrobial activity, and the shelf life of mango fruit and/or mango products.

Results and discussion

Descriptive Results

As a result of the systematic search, 147 documents were *identified* during the first stage. From these, the *screening stage* left only 37 documents after removing duplicate and ineligible records. Finally, in the *eligibility stage*, a total of 11 manuscripts that met the specified inclusion/exclusion criteria were identified and included in the systematic review on the applications of gamma irradiation for microbial control in mango. The results were then collected and organized based on the application purpose.

Antimicrobial activity of gamma irradiation

The systematic review of gamma irradiation applications in Mango, focusing on antimicrobial activity, reports the use of gamma irradiation on 17 varieties, including Alphonso, Kent, Keitt, Tommy Atkins, Banginapalli, Mulgoa, Neelam, Raspuri, and Katimon (Table 1). Concerning the use of different doses, generally contemplated as low doses of gamma irradiation, systematic review identified the evaluation of 0, 0.25, 0.35, 0.45, 0.50, 0.75, 1.0, 1.25, 1.50, 2.0, 2.50, 3.0, and 5 kGy for the control of mesophilic aerobic bacteria, as well as for the control of yeasts and molds, either in mango fruit or mango products. From the 11 manuscripts, 4 suggested the use of 1.5 kGy as the best result (Chatha et al., 2019a; Chatha et al., 2019b; Jabin et al., 2023a; Jabin et al., 2023b), while Abdullah et al (2017) suggested the use of 1.25

kGy and Naresh et al. (2015b) the use of 5.0 kGy, being the latest the highest dose used among the different studies, resulting in undetectable bacterial growth, as well as yeast and molds in mango juice (Table 2).

Table 1. Manuscripts identified and included for the study of antibacterial activity of gamma irradiation in Mango.

Authors	Doses (kgy)	Microorganism	Product	Cultivar	Initial concentration	Final concentration
Naresh et al. (2015 ^a)	0	Total bacteria count	Mango juice	Alphonso	7.2x10 ⁵ CFU/mL	7.2x10 ⁵ CFU/mL
				Banginapalli	6.5x10 ⁵ CFU/mL	6.5x10 ⁵ CFU/mL
				Mulgoa	5.3x10 ⁴ CFU/mL	5.3x10 ⁴ CFU/mL
				Neelam	4.7x10 ⁴ CFU/mL	4.7x10 ⁴ CFU/mL
				Raspuri	6.1x10 ⁵ CFU/mL	6.1x10 ⁵ CFU/mL
				Rumani	7.4x10 ⁴ CFU/mL	7.4x10 ⁴ CFU/mL
				Sindhura	6.3x10 ⁵ CFU/mL	6.3x10 ⁵ CFU/mL
				Totapuri	7.6x10 ⁴ CFU/mL	7.6x10 ⁴ CFU/mL
				0.5	Total bacteria count	Mango juice
	Banginapalli	6.5x10 ⁵ CFU/mL	2.6x10 ³ CFU/mL			
	Mulgoa	5.3x10 ⁴ CFU/mL	2.9x10 ² CFU/mL			
	Neelam	4.7x10 ⁴ CFU/mL	3.5x10 ² CFU/mL			
	Raspuri	6.1x10 ⁵ CFU/mL	2.4x10 ³ CFU/mL			
	Rumani	7.4x10 ⁴ CFU/mL	4.2x10 ² CFU/mL			
	Sindhura	6.3x10 ⁵ CFU/mL	2.3x10 ³ CFU/mL			
	Totapuri	7.6x10 ⁴ CFU/mL	4.4x10 ² CFU/mL			
	1	Total bacteria count	Mango juice			
				Banginapalli	6.5x10 ⁵ CFU/mL	1.8x10 ⁶ CFU/mL
				Mulgoa	5.3x10 ⁴ CFU/mL	1.3x10 ¹ CFU/mL
				Neelam	4.7x10 ⁴ CFU/mL	1.1x10 ¹ CFU/mL
				Raspuri	6.1x10 ⁵ CFU/mL	1.6x10 ¹ CFU/mL
				Rumani	7.4x10 ⁴ CFU/mL	2.1x10 ¹ CFU/mL
				Sindhura	6.3x10 ⁵ CFU/mL	1.7x10 ¹ CFU/mL
				Totapuri	7.6x10 ⁴ CFU/mL	2.3x10 ¹ CFU/mL
3				Total bacteria count	Mango juice	Alphonso
	Banginapalli	6.5x10 ⁵ CFU/mL	No detected			
	Mulgoa	5.3x10 ⁴ CFU/mL	No detected			
	Neelam	4.7x10 ⁴ CFU/mL	No detected			
	Raspuri	6.1x10 ⁵ CFU/mL	No detected			
	Rumani	7.4x10 ⁴ CFU/mL	No detected			
	Sindhura	6.3x10 ⁵ CFU/mL	No detected			
	Totapuri	7.6x10 ⁴ CFU/mL	No detected			
	Naresh et al. (2015 ^b)	0	Total aerobic bacteria			Fresh Mango juice
1		Total aerobic bacteria	Fresh Mango juice	Banginapalli	4.2x10 ⁴ CFU/mL	3.4x10 ³ CFU/mL
3		Total aerobic bacteria	Fresh Mango juice	Banginapalli	4.2x10 ⁴ CFU/mL	2.6x10 ¹ CFU/mL
5		Total aerobic bacteria	Fresh Mango juice	Banginapalli	4.2x10 ⁴ CFU/mL	No detected
0		Total aerobic bacteria	Stored Mango juice	Banginapalli	6.5x10 ⁵ CFU/mL	6.5x10 ⁵ CFU/mL
1		Total aerobic bacteria	Stored Mango juice	Banginapalli	6.5x10 ⁵ CFU/mL	2.3x10 ² CFU/mL
3		Total aerobic bacteria	Stored Mango juice	Banginapalli	6.5x10 ⁵ CFU/mL	1.1x10 ¹ CFU/mL

Kondapalli et al. (2014)	5	Total aerobic bacteria	Stored Mango juice	Banginapalli	6.5x10 ⁵ CFU/mL	No detected
	0	Total plate count	Mango wine	Alphonso	2.8x10 ⁴ CFU/mL	2.8x10 ⁴ CFU/mL
				Banginapalli	2.6x10 ⁴ CFU/mL	2.6x10 ⁴ CFU/mL
				Mulgoa	4.2x10 ⁵ CFU/mL	4.2x10 ⁵ CFU/mL
				Neelam	3.8x10 ⁵ CFU/mL	3.8x10 ⁵ CFU/mL
				Raspuri	4x10 ⁵ CFU/mL	4.0x10 ⁵ CFU/mL
				Rumani	2.9x10 ⁴ CFU/mL	2.9x10 ⁴ CFU/mL
				Sindhura	3.1x10 ⁴ CFU/mL	3.1x10 ⁴ CFU/mL
				Totapuri	3.4x10 ⁵ CFU/mL	3.4x10 ⁵ CFU/mL
	0.5	Total plate count	Mango wine	Alphonso	2.8x10 ⁴ CFU/mL	2.2x10 ⁵ CFU/mL
			Banginapalli	2.6x10 ⁴ CFU/mL	2.1x10 ² CFU/mL	
			Mulgoa	4.2x10 ⁵ CFU/mL	3.4x10 ³ CFU/mL	
			Neelam	3.8x10 ⁵ CFU/mL	2.9x10 ³ CFU/mL	
			Raspuri	4x10 ⁵ CFU/mL	3.2x10 ³ CFU/mL	
			Rumani	2.9x10 ⁴ CFU/mL	2.3x10 ² CFU/mL	
			Sindhura	3.1x10 ⁴ CFU/mL	2.9x10 ² CFU/mL	
			Totapuri	3.4x10 ⁵ CFU/mL	2.7x10 ³ CFU/mL	
1	Total plate count	Mango wine	Alphonso	2.8x10 ⁴ CFU/mL	1.9x10 ¹ CFU/mL	
			Banginapalli	2.6x10 ⁴ CFU/mL	1.2x10 ¹ CFU/mL	
			Mulgoa	4.2x10 ⁵ CFU/mL	1.6x10 ² CFU/mL	
			Neelam	3.8x10 ⁵ CFU/mL	1.3.x10 ² CFU/mL	
			Raspuri	4x10 ⁵ CFU/mL	1.7x10 ² CFU/mL	
			Rumani	2.9x10 ⁴ CFU/mL	2.1x10 ¹ CFU/mL	
			Sindhura	3.1x10 ⁴ CFU/mL	2.8x10 ¹ CFU/mL	
			Totapuri	3.4x10 ⁵ CFU/mL	2.5x10 ⁵ CFU/mL	
Jabin et al. (2023a)	3	Total plate count	Mango wine	Alphonso	2.8x10 ⁴ CFU/mL	No detected
				Banginapalli	2.6x10 ⁴ CFU/mL	No detected
				Mulgoa	4.2x10 ⁵ CFU/mL	No detected
				Neelam	3.8x10 ⁵ CFU/mL	No detected
				Raspuri	4x10 ⁵ CFU/mL	No detected
				Rumani	2.9x10 ⁴ CFU/mL	No detected
				Sindhura	3.1x10 ⁴ CFU/mL	No detected
				Totapuri	3.4x10 ⁵ CFU/mL	No detected
	0	Total microbial count	Mango peels	Amrapalli	6.8x10 ⁵ CFU/mL	7.9x10 ⁸ CFU/mL
	0.5	Total microbial count	Mango peels	BARI-11	6.4x10 ⁴ CFU/mL	6.9x10 ⁹ CFU/mL
1	Total microbial count	Mango peels	Amrapalli	6.8x10 ⁵ CFU/mL	4.1x10 ³ CFU/mL	
			BARI-11	6.4x10 ⁴ CFU/mL	3.8x10 ³ CFU/mL	
1.5	Total microbial count	Mango peels	Amrapalli	6.8x10 ⁵ CFU/mL	3.8x10 ³ CFU/mL	
			BARI-11	6.4x10 ⁴ CFU/mL	3.5x10 ² CFU/mL	
2	Total microbial count	Mango peels	Amrapalli	6.8x10 ⁵ CFU/mL	2.1x10 ² CFU/mL	
			BARI-11	6.4x10 ⁴ CFU/mL	2.8x10 ² CFU/mL	
Jabin et al. (2023b)	0	Total microbial count	Mango peels	Amrapalli	6.8x10 ⁵ CFU/mL	1.4x10 ² CFU/mL
				BARI-11	6.4x10 ⁴ CFU/mL	1.5x10 ² CFU/mL
	0	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	7.3x10 ⁷ CFU/mL
	0.5	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	3.4x10 ³ CFU/mL
	1	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	2.8x10 ² CFU/mL
1.5	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	2.1x10 ² CFU/mL	
2	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	1.9x10 ² CFU/mL	
Gasu et al. (2012)	0	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	3.55 Log ₁₀ CFU/10g
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	3.43 Log ₁₀ CFU/10g
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	3.10 Log ₁₀ CFU/10g
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	3.13 Log ₁₀ CFU/10g
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	1.20 Log ₁₀ CFU/10g
	0	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	3.53 Log ₁₀ CFU/10g
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	3.45 Log ₁₀ CFU/10g

Chatha et al. (2019a)	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	3.43 Log ₁₀ CFU/10g
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	3.37 Log ₁₀ CFU/10g
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	2.45 Log ₁₀ CFU/10g
	0	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	4.7 Log ₁₀ CFU/10g
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	4.3 Log ₁₀ CFU/10g
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	4.3 Log ₁₀ CFU/10g
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	3.5 Log ₁₀ CFU/10g
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	3.25 Log ₁₀ CFU/10g
	0	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	4.83 Log ₁₀ CFU/10g
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	4.83 Log ₁₀ CFU/10g
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	4.5 Log ₁₀ CFU/10g
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	3.17 Log ₁₀ CFU/10g
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	2.60 Log ₁₀ CFU/10g
	0	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	9.9 Log CFU/g
	0.5	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	4.1 Log CFU/g
1	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	3.4 Log CFU/g	
1.5	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	2.9 Log CFU/g	
Abdullah et al. (2017)	0	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	1.8x10 ⁵ CFU/mL
	0.25	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	>1x10 ⁵ CFU/mL
	0.5	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	>1x10 ⁵ CFU/mL
	1.25	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	>1x10 ⁵ CFU/mL
El-samahy et al. (2000)	0	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	2.6 Log CFU/g
	0.5	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	2.4 Log CFU/g
	0.75	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	2.4 Log CFU/g
	1	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	2.1 Log CFU/g
	1.5	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	1.8 Log CFU/g

The presence of bacterial and fungal agents in foods can be correlated with the quality of the production process, which may contribute to spoilage and shorten the shelf life of processed and minimally processed foods, fruits, and vegetables. These are referred to as indicator microorganisms; among them are Lactic Acid Bacteria, *Enterobacteriaceae*, Yeast and Molds, and mesophilic aerobic bacteria. Their presence is also an indication of contamination processes in the production chain and the supply chain (Erkmen and Bozoglu, 2016; Zoelner, 2016; Alegbeleye et al., 2022; Barth et al. 2009). In this regard, the use of microbial indicators is an ally in the food industry, either to determine the general and microbiological quality of the commodity or to evaluate the effectiveness of the good manufacturing practices followed.

When evaluating gamma irradiation for microbial decontamination in mango (*Mangifera indica* L.) juice, Naresh et al. (2015b) achieved significant reductions in the microbial load with doses ranging from 1 to 5.0 kGy. In that study, the results for total aerobic bacteria, yeast, and molds showed a substantial decrease as the gamma irradiation dose increased, with a dose of 5.0 kGy resulting in non-detectable growth for all three microbial groups. These authors suggest using gamma irradiation to assess the microbial quality and improve the quality of mango juice, with no significant changes in sensorial attributes. Jabin et al. (2023b) evaluated the impact of gamma irradiation on fresh whole mango, using different doses, indicating that 1.5 kGy yielded a favorable extension of the mango's shelf life, achieving reduction of the total count of bacteria after two weeks following irradiation treatment, demonstrating that the total microbial count was 2.1×10^2 CFU/mL and 4.1×10^2

CFU/mL at the first and second weeks after the irradiation process, respectively. Similarly, Chatha et al. (2019b) concur that the application of gamma irradiation enhances the shelf life and maintains the microbiological quality of mangoes.

Comparably, Naresh et al. (2015a) suggested that gamma irradiation in mango juice contributes to microbial reduction, thereby maintaining the bright color and quality of the mango juice. However, it is essential to consider that the results of antimicrobial activity of gamma irradiation vary among cultivars in the different studies (Table 1), which suggests differences in the characteristics of the mango peels in each cultivar, as well as the composition of each mango produced according to each cultivar, dealing with differences in the antimicrobial activity of gamma irradiation at different doses.

Table 2. Manuscripts identified and included for the study of antifungal and anti-yeast activity of gamma irradiation in Mango.

AUTHORS	DOSES (KGY)	MICROORGANISM	PRODUCT	CULTIVAR	INITIAL CONCENTRATION	FINAL CONCENTRATION
Naresh et al. (2015 ^a)	0	Yeasts and mold count	Mango juice	Alphonso	2.4x10 ³ CFU/mL	2.4x10 ³ CFU/mL
				Banginapalli	2.7x10 ³ CFU/mL	2.7x10 ³ CFU/mL
				Mulgoa	2.1x10 ² CFU/mL	2.1x10 ² CFU/mL
				Neelam	2.6x10 ² CFU/mL	2.6x10 ² CFU/mL
				Raspuri	3.2x10 ² CFU/mL	3.2x10 ² CFU/mL
				Rumani	2.8x10 ² CFU/mL	2.8x10 ² CFU/mL
				Sindhura	2.5x10 ³ CFU/mL	2.5x10 ³ CFU/mL
				Totapuri	3.1x10 ² CFU/mL	3.1x10 ² CFU/mL
				0.5	Yeast and mold count	Mango juice
	Banginapalli	2.7x10 ³ CFU/mL	1.8x10 ² CFU/mL			
	Mulgoa	2.1x10 ² CFU/mL	1.3x10 ¹ CFU/mL			
	Neelam	2.6x10 ² CFU/mL	1.4x10 ¹ CFU/mL			
	Raspuri	3.2x10 ² CFU/mL	1.7x10 ¹ CFU/mL			
	Rumani	2.8x10 ² CFU/mL	1.9x10 ¹ CFU/mL			
	Sindhura	2.5x10 ³ CFU/mL	1.6x10 ² CFU/mL			
	Totapuri	3.1x10 ² CFU/mL	1.8x10 ¹ CFU/mL			
	1	Yeast and mold count	Mango juice			
				Banginapalli	2.7x10 ³ CFU/mL	<10 ¹ CFU/mL
				Mulgoa	2.1x10 ² CFU/mL	No detected

Naresh et al. (2015b)	3	Yeast and mold count	Mango juice	Neelam	2.6x10 ² CFU/mL	No detected
				Raspuri	3.2x10 ² CFU/mL	No detected
				Rumani	2.8x10 ² CFU/mL	No detected
				Sindhura	2.5x10 ³ CFU/mL	No detected
				Totapuri	3.1x10 ² CFU/mL	No detected
				Alphonso	2.4x10 ³ CFU/mL	No detected
				Banginapalli	2.7x10 ³ CFU/mL	No detected
				Mulgoa	2.1x10 ² CFU/mL	No detected
				Neelam	2.6x10 ² CFU/mL	No detected
				Raspuri	3.2x10 ² CFU/mL	No detected
				Rumani	2.8x10 ² CFU/mL	No detected
				Sindhura	2.5x10 ³ CFU/mL	No detected
				Totapuri	3.1x10 ² CFU/mL	No detected
				Banginapalli	1.4x10 ² CFU/mL	1.4x10 ² CFU/mL
	0	Yeast and mold	Stored Mango juice	Banginapalli	2.1x10 ² CFU/mL	2.1x10 ² CFU/mL
	1	Yeast and mold	Fresh Mango juice	Banginapalli	1.4x10 ² CFU/mL	1.2x10 ¹ CFU/mL
	3	Yeast and mold	Fresh Mango juice	Banginapalli	1.4x10 ² CFU/mL	No detected
	5	Yeast and mold	Fresh Mango juice	Banginapalli	1.4x10 ² CFU/mL	No detected
	0	Yeast and mold	Stored Mango juice	Banginapalli	2.1x10 ² CFU/mL	2.1x10 ² CFU/mL
	1	Yeast and mold	Stored Mango juice	Banginapalli	2.1x10 ² CFU/mL	<10 ¹ CFU/mL
	3	Yeast and mold	Stored Mango juice	Banginapalli	2.1x10 ² CFU/mL	No detected
	5	Yeast and mold	Stored Mango juice	Banginapalli	2.1x10 ² CFU/mL	No detected
	0	Total fungal count	Mango wine	Alphonso	2.2x10 ³ CFU/mL	2.2x10 ³ CFU/mL
	0.5			Banginapalli	2.1x10 ³ CFU/mL	2.1x10 ³ CFU/mL
	Mulgoa			1.3x10 ³ CFU/mL	1.3x10 ³ CFU/mL	
	Neelam			1.5x10 ³ CFU/mL	1.5x10 ³ CFU/mL	
	Raspuri			1.4x10 ³ CFU/mL	1.4x10 ³ CFU/mL	
	Romani			1.9x10 ³ CFU/mL	1.9x10 ³ CFU/mL	
Sindhura	1.8x10 ³ CFU/mL			1.8x10 ³ CFU/mL		
Totapuri	1.6x10 ³ CFU/mL			1.6x10 ³ CFU/mL		
Alphonso	2.2x10 ³ CFU/mL			1.9x10 ² CFU/mL		
Banginapalli	2.1x10 ³ CFU/mL			1.7x10 ² CFU/mL		
Mulgoa	1.3x10 ³ CFU/mL			1.1x10 ² CFU/mL		
Neelam	1.5x10 ³ CFU/mL			1.3x10 ² CFU/mL		
Raspuri	1.4x10 ³ CFU/mL			1.2x10 ² CFU/mL		
Romani	1.9x10 ³ CFU/mL			1.5x10 ² CFU/mL		
Sindhura	1.8x10 ³ CFU/mL	1.6x10 ² CFU/mL				
Totapuri	1.6x10 ³ CFU/mL	1.4x10 ² CFU/mL				
1	Total fungal count	Mango wine	Alphonso	2.2x10 ³ CFU/mL	<10 ¹ CFU/mL	
Banginapalli			2.1x10 ³ CFU/mL	<10 ¹ CFU/mL		
Mulgoa			1.3x10 ³ CFU/mL	No detected		
Neelam			1.5x10 ³ CFU/mL	No detected		
Raspuri			1.4x10 ³ CFU/mL	No detected		
Romani			1.9x10 ³ CFU/mL	<10 ¹ CFU/mL		
Sindhura			1.8x10 ³ CFU/mL	<10 ¹ CFU/mL		
Totapuri			1.6x10 ³ CFU/mL	No detected		
Alphonso			2.2x10 ³ CFU/mL	No detected		
Banginapalli			2.1x10 ³ CFU/mL	No detected		
Mulgoa			1.3x10 ³ CFU/mL	No detected		
Neelam			1.5x10 ³ CFU/mL	No detected		
Raspuri			1.4x10 ³ CFU/mL	No detected		
Romani			1.9x10 ³ CFU/mL	No detected		
Sindhura	1.8x10 ³ CFU/mL	No detected				
Totapuri	1.6x10 ³ CFU/mL	No detected				
3	Total fungal count	Mango wine	Alphonso	2.2x10 ³ CFU/mL	No detected	
Banginapalli			2.1x10 ³ CFU/mL	No detected		
Mulgoa			1.3x10 ³ CFU/mL	No detected		
Neelam			1.5x10 ³ CFU/mL	No detected		
Raspuri			1.4x10 ³ CFU/mL	No detected		
Romani			1.9x10 ³ CFU/mL	No detected		
Sindhura			1.8x10 ³ CFU/mL	No detected		
Totapuri			1.6x10 ³ CFU/mL	No detected		

Gonçalves et al. (2010)	0	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 conidia/mL 0 cm diameter	9 cm diameter
	0.25	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 conidia/mL 0 cm diameter	8 cm diameter
	0.35	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 conidia/mL 0 cm diameter	7.5 cm diameter
	0.45	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 conidia/mL 0 cm diameter	5.5 cm diameter
Chatha et al. (2019b)	0	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	195 isolates
	0.5	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	28 isolates
	1	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	21 isolates
	1.5	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	4 isolates
Abdullah et al. (2017)	0	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	1x10 ⁴ CFU/mL
	0.25	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	1x10 ⁵ CFU/mL
	0.5	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	<1x10 ⁵ CFU/mL
	1.25	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	No detected
El-samahy et al. (2000)	0	Total yeast count	Fresh mango fruit	Zebda	1.9 logCFU/g	4.4 Log CFU/g
	0.5	Total yeast count	Fresh mango fruit	Zebda	1.9 logCFU/g	3.8 Log CFU/g
	0.75	Total yeast count	Fresh mango fruit	Zebda	1.9 logCFU/g	3.6 Log CFU/g
	1	Total yeast count	Fresh mango fruit	Zebda	1.9 logCFU/g	2.4 Log CFU/g
	1.5	Total yeast count	Fresh mango fruit	Zebda	1.9 logCFU/g	2.5 Log CFU/g
El-samahy et al. (2000)	0	Total fungal count	Fresh mango fruit	Zebda	2.3 logCFU/g	4.2 Log CFU/g
	0.5	Total fungal count	Fresh mango fruit	Zebda	2.3 logCFU/g	3.6 Log CFU/g
	0.75	Total fungal count	Fresh mango fruit	Zebda	2.2 logCFU/g	3.2 Log CFU/g
	1	Total fungal count	Fresh mango fruit	Zebda	2 logCFU/g	2.7 Log CFU/g
	1.5	Total fungal count	Fresh mango fruit	Zebda	1.9 logCFU/g	2.4 Log CFU/g

Gamma irradiation in mango, mango produce, and its impact on shelf life

Interestingly, from the 11 documents included in the systematic review, a subgroup of studies was focused on the shelf life of mango fruit and mango products (Table 3), which is an essential aspect of the benefits of gamma irradiation, based on the literature that suggests the extension of shelf life in the irradiated foods. In this regard, Yadav et al. (2014) evaluated doses of gamma irradiation, including 0.2, 0.4, and 0.6 kGy, revealing that 0.2 and 0.4 kGy gamma irradiation had a positive effect on the shelf life of mango fruit, which was extended more than 38 days, delaying ripening and acceptability of Alphonso mango. Regarding Tommy Atkins mangoes, several doses of gamma irradiation (0.24, 0.35, and 0.45 kGy) evaluated against *Fusicoccum parvum* proved that 0.45 kGy did not negatively affect the physicochemical properties of mango fruit and diminished the severity of mango rot caused by *Fusicoccum parvum* (Gonçalves Santos et al., 2010). On the other hand, Chatha et al. 2019(a), evaluated the use of gamma irradiation at doses of 0.5, 1.0, and 1.5 kGy as preventive action for fungal growth in mango (Safaid Chunsa, Kala Chunsa) fruit during 60 days; in this scenario, gamma irradiation at 1.5 kGy per hour showed the best results in antifungal activity, lowering the presence of 13 fungal species (in non-irradiated mangoes) to only four belonging to *Aspergillus*, *Penicillium*, *Cladosporium*, and *Fusarium*, which favors shelf life preventing spoilage due these fungal agents.

Table 3. Application of gamma irradiation in mango and mango products; evaluation of antimicrobial activity, and shelf life.

Authors	Doses (kg)	Microorganism	Product	Cultivar	Initial concentration	Final concentration at shelf life
Jabin et al. (2023a)	0	Total microbial count	Mango peels	Amrapalli BARI-11	6.8x10 ⁵ CFU/mL 6.4x10 ⁴ CFU/mL	7.9x10 ⁸ CFU/mL, at two weeks 6.9x10 ⁸ CFU/mL, at two weeks
	0.5	Total microbial count	Mango peels	Amrapalli BARI-11	6.8x10 ⁵ CFU/mL 6.4x10 ⁴ CFU/mL	3.4x10 ³ CFU/mL, at two weeks 4.1x10 ⁴ CFU/mL, at two weeks
	1	Total microbial count	Mango peels	Amrapalli BARI-11	6.8x10 ⁵ CFU/mL 6.4x10 ⁴ CFU/mL	4.2x10 ³ CFU/mL, at two weeks 5.6x10 ² CFU/mL, at two weeks
	1.5	Total microbial count	Mango peels	Amrapalli BARI-11	6.8x10 ⁵ CFU/mL 6.4x10 ⁴ CFU/mL	3.7x10 ² CFU/mL, at two weeks 3.8x10 ² CFU/mL, at two weeks
	2	Total microbial count	Mango peels	Amrapalli BARI-11	6.8x10 ⁵ CFU/mL 6.4x10 ⁴ CFU/mL	2.1x10 ³ CFU/mL, at two weeks 4.5x10 ³ CFU/mL, at two weeks
Jabin et al. (2023b)	0	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	7.3x10 ⁷ CFU/mL, at two weeks
	0.5	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	4.4x10 ⁴ CFU/mL, at two weeks
	1	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	2.7x10 ³ CFU/mL, at two weeks
	1.5	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	4.1x10 ² CFU/mL, at two weeks
	2	Total microbial count	Mango peels	Katimon	5.3x10 ⁵ CFU/mL	3.6x10 ² CFU/mL, at two weeks
Gonçalves et al. (2017)	0	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 connidia/mL 0 cm diameter	9 cm in diameter, at day 7
	0.25	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 connidia/mL 0 cm diameter	8 cm in diameter, at day 7
	0.35	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 connidia/mL 0 cm diameter	7.5 cm diameter, at day 7
	0.45	<i>Fusicoccum parvum</i>	Mango fruit	Tommy Atkins	16 connidia/mL 0 cm diameter	5.5 cm diameter, at day 7
Gasu et al. (2012)	0	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	2.95 Log ₁₀ CFU/10g, at day 12
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	No detectable at day 12
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	No detectable at day 9
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	No detectable at day 9
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 6°C	3.55 Log ₁₀ CFU/10g	No detectable at day 3
	0	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	3.45 Log ₁₀ CFU/10g, at day 15
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	No detectable at day 12
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	No detectable at day 12

Chatha et al. (2019a)	2	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	No detectable at day 12
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Kent at 10°C	3.53 Log ₁₀ CFU/10g	No detectable at day 9
	0	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	2.28 Log ₁₀ CFU/10g at day 15
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	No detectable at day 12
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	No detectable at day 9
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	No detectable at day 9
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 6°C	4.7 Log ₁₀ CFU/10g	No detectable at day 9
	0	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	3.20 Log ₁₀ CFU/10g at day 15
	1	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	No detectable at day 12
	1.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	No detectable at day 12
	2	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	No detectable at day 12
	2.5	Total viable cells (Bacteria)	Fresh-cut Mango	Keitt at 10°C	4.83 Log ₁₀ CFU/10g	No detectable at day 6
	0	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	10.2 Log CFU/g at day 14
	0.5	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	4.9 Log CFU/g at day 56
	1	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	3.7 Log CFU/g at day 56
1.5	Total viable cells (Bacteria)	Fresh mango fruit	Kala Chunsa	9.9 Log CFU/g	3.3 Log CFU/g at day 56	
Chatha et al. (2019b)	0	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	195 isolates at day 60
	0.5	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	28 isolates at day 60
	1	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	21 isolates at day 60
	1.5	Fungal load count	Fresh mango fruit	Kala Chunsa	195 isolates	4 isolates at day 60
Abdullah et al. (2017)	0	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	>1x10 ⁵ CFU/mL at day 14
	0.25	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	>1x10 ⁵ CFU/mL at day 21
	0.5	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	>1x10 ⁵ CFU/mL at day 21

Abdullah et al. (2017)	1.25	Total viable bacteria count	Fresh mango fruit	Chaunsa	1.8x10 ⁵ CFU/mL	No detectable at day 21
	0	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	>1x10 ⁴ CFU/mL at day 14
	0.25	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	No detectable at day 21
	0.5	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	<1x10 ⁴ CFU/mL at day 21
EI-samahy et al. (2000)	1.25	Total fungal count	Fresh mango fruit	Chaunsa	1x10 ⁴ CFU/mL	No detected since day 1
	0	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	4.8 Log CFU/mL at day 30
	0.5	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	4.8 Log CFU/g at day 60
	0.75	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	4.6 Log CFU/mL at day 60
EI-samahy et al. (2000)	1	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	3.4 Log CFU/mL at day 60
	1.5	Total bacterial count	Fresh mango fruit	Zebda	3.7 LogCFU/g	3.2 Log CFU/mL at day 60
	0	Total yeast count	Fresh mango fruit	Zebda	1.9 LogCFU/g	4.4 Log CFU/mL at day 30
	0.5	Total yeast count	Fresh mango fruit	Zebda	1.9 LogCFU/g	3.8 Log CFU/g at day 60
EI-samahy et al. (2000)	0.75	Total yeast count	Fresh mango fruit	Zebda	1.9 LogCFU/g	3.6 Log CFU/mL at day 60
	1	Total yeast count	Fresh mango fruit	Zebda	1.9 LogCFU/g	2.4 Log CFU/mL at day 60
	1.5	Total yeast count	Fresh mango fruit	Zebda	1.9 LogCFU/g	2.5 Log CFU/mL at day 60
	0	Total fungal count	Fresh mango fruit	Zebda	2.3 LogCFU/g	4.2 Log CFU/mL at day 30
EI-samahy et al. (2000)	0.5	Total fungal count	Fresh mango fruit	Zebda	2.3 LogCFU/g	3.6 Log CFU/g at day 60
	0.75	Total fungal count	Fresh mango fruit	Zebda	2.2 LogCFU/g	3.2 Log CFU/mL at day 60
	1	Total fungal count	Fresh mango fruit	Zebda	2 LogCFU/g	2.7 Log CFU/mL at day 60
	1.5	Total fungal count	Fresh mango fruit	Zebda	1.9 LogCFU/g	2.4 Log CFU/mL at day 60

The microbicidal activity of gamma irradiation has been positively correlated with the shelf life of mangoes. Jabin et al. (2023b) evaluated the antimicrobial activity of

gamma irradiation at 0.5, 1.0, 1.5, and 2.0 kGy. The use of gamma irradiation improved the texture and firmness while reducing microbial growth from 6.8×10^5 CFU/mL to 2.1×10^2 and 1.4×10^2 CFU/mL using 1.5 and 2.0 kGy, respectively. Interestingly, in the control group, the total count of bacteria increased over time, from 6.8×10^5 CFU/mL in week 1 to 7.9×10^8 CFU/mL during week 2. In contrast, mangoes irradiated with 1.5 kGy showed results of 2.1×10^2 CFU/mL for week 1 and 3.7×10^2 CFU/mL during week 2. These results suggest that surviving bacteria in irradiated mangoes have a limited growth rate during the mango's shelf life.

Discussion and opportunities

As a result of the systematic review, specific gaps in the data presented in these analyzed studies were identified, which could lead to new research opportunities. Among studies, the antibacterial and antifungal activity of gamma irradiation in mango and mango products has been commonly evaluated using the natural microbial population, which is generally present in low concentrations and is difficult to identify specifically, as well as the respective levels present on the mango surface and in mango products that can vary highly. Lacking control over the initial microbial load and, conversely, very low concentrations of naturally occurring bacteria on the mango surface or products, it is challenging to accurately estimate the real reduction aptitude of any antimicrobial measure being evaluated.

Another relevant issue identified in the published information is the lack of precise sample size specifications, which were not consistently provided in the studies under consideration. For example, El-Samahy et al. (2000) reported a sample size of 5

mangoes for microbiological analysis; however, the sample size for the irradiation process was not reported. On the other hand, Abdullah et al. (2017) stated that mango samples were divided into two groups, labeled as experimental and control. Still, the actual sample size of each group or the sample size used for microbial analysis was not described. Knowing the extent to which research has been conducted enables us to establish a solid foundation for further experiments and in-depth research, thereby expanding our knowledge on the same topic.

Regarding microorganisms, none of the manuscripts considered here, based on established criteria, have focused their investigation on foodborne pathogenic bacteria. Hence, it is desirable to conduct studies focused on specific pathogens, such as *Salmonella*, *Listeria monocytogenes*, *Staphylococcus aureus*, and pathogenic strains of *Escherichia coli*, which are among the top pathogens transmitted through food, ensuring the use of actual pathogenic bacteria. Regarding this topic, several studies have been conducted using culture media such as MacConkey agar to investigate the presence of enteric bacteria, including coliforms, *E. coli*, and *Salmonella*. However, the results obtained from this methodological approximation remain presumptive and might differ from those when using known concentrations of specific pathogens spiked.

To further evaluate the antimicrobial activity of gamma irradiation, there are some studies using X-ray that could serve to set the basis of experimentation, like the one by Mahmoud (2010), who evaluated the application of X-ray irradiation (0.1, 0.5, 0.75, 1.0, and 1.5 kGy) against inoculated *E. coli* O157:H7, *Listeria monocytogenes*,

Salmonella enterica, and *Shigella flexneri* in Roma tomatoes, achieving total reductions of *E coli* O157:H7 at 1kGy, *Listeria monocytogenes*, *Shigella flexneri*, and *Salmonella enterica* at 1.5 kGy dose. Particularly in mango whole fruits, Mahmoud et al. (2015) evaluated the application of X-ray irradiation against *E. coli* O157:H7, *Listeria monocytogenes*, *Shigella flexneri*, and *Salmonella* on inoculated whole fruits; at a 0.1 kGy dose, reductions of 2.2, 0.8, 1.9, and 3 Log CFU/cm², respectively, were achieved. At 0.5kGy, achieved 2.9, 1.8, 2.1, and 5.2 Log CFU/cm², and at 1.0 kGy achieved reductions of 4.8, 3.4, 4.0, and 5.7 Log CFU/cm² for *E coli* O157:H7, as well as undetectable levels of *Listeria monocytogenes*, *Shigella flexneri*, and *Salmonella* at 1.5 kGy on the surface of the inoculated mangoes.

As a result of this systematic review, the use of gamma irradiation at low doses might be a safe option for decontamination of fruits such as mango, based on its insecticidal and antifungal activity, delaying the ripening process, favoring the firmness of fruits, and extending shelf life (Horton, 1976; Mahto & Das, 2013). Nevertheless, to summarize in relation to the microorganisms to be evaluated in future studies, it is essential to consider designing methodological strategies focused on artificially inoculated samples, to know the specific microbial agent and the respective concentration in mango before the application of gamma irradiation, indicating the total of fruits included in the study, the number of fruits per group of treatments, the sample size for microbiological analysis, replicates, repetitions, as well as the statistical design of the experiments performed.

Conclusion

In conclusion, based on scientific knowledge, the use of gamma irradiation for mango decontamination emerges as a viable strategy due to its antimicrobial activity against bacterial and fungal agents, which also extends the shelf life to up to 60 days while preserving the nutritional and sensory properties of mangoes and mango products. Nevertheless, it is necessary to conduct further studies focused on evaluating gamma irradiation against vegetative cells and microbial communities of specific foodborne pathogens under controlled experimental and real scenarios and variables to assess the actual reduction in pathogenic load and survival during the shelf life of mango. Additionally, it is essential to extend research to other mango cultivars and varieties, thereby ensuring the effectiveness and reliability of the use of gamma irradiation on this important food commodity, while providing consumers with safe mangoes.

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