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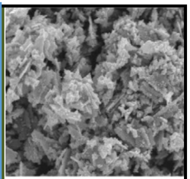

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Effect of Gamma Irradiation and Salt on the Physical Properties and Microbiological Quality of Turmeric Paste (*Curcuma longa*)

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ABSTRACT

Turmeric paste is prized for its color, aroma, and antioxidant properties, serving as a key ingredient in both culinary and traditional medicinal practices. The surge in spice consumption reflects growing consumer awareness of healthy lifestyles and the need for natural preservatives in processed foods. However, the paste's high water content poses challenges for storage stability, necessitating safe preservation methods without chemical additives. Salt addition, a traditional preservative, raises concerns about excessive sodium intake. Spice irradiation emerges as a recognized preservation technique, reducing losses, enhancing shelf life, and ensuring microbiological safety. This study aims to evaluate the storage stability of turmeric paste treated with irradiation (4, 6, and 8 kGy) and salt (10, 20, and 30%) under varying temperatures (4-6°C and 25-27°C) over 30 days. Results indicate minimal differences in water content, pH, color, and curcumin levels between irradiated and salt-treated paste. Salt-treated paste exhibits superior microbiological quality, suggesting it provides better storage stability compared to irradiation. However, considering health concerns related to high salt intake, a formulation combining 20% salt with 8 kGy irradiation stored at chiller temperature is recommended for optimal storage quality.

INTRODUCTION

Turmeric paste, derived from *Curcuma longa*, holds significance as a tropical spice renowned for its color, aroma, and antioxidant properties, commonly used in traditional medicine and culinary applications [1]. With the rising demand for processed foods due to lifestyle changes, turmeric consumption has surged as a natural preservative [2]. However, its high water content renders it unsuitable for long-term storage, necessitating reliable preservation methods [3]. Chemical preservatives are undesirable due to consumer concerns about food safety. Irradiation emerges as a recognized preservation technique for spices, minimizing post-harvest losses, maintaining hygiene, and facilitating trade. Studies have shown that an irradiation dosage of 5kGy effectively controls microbial load and extends the shelf life of turmeric paste to six months [1]. Such treatments enhance microbiological safety and physical properties, ensuring better storage stability [3]. Given turmeric paste's importance in international trade, maintaining its stability during transportation and storage is crucial. This study evaluates the effect of by irradiation and salt treatment on the microbiological safety and physical properties of turmeric paste.

MATERIALS AND METHODOLOGY

Materials

Fresh turmeric (*Curcuma longa)* was purchased from Pasar Borong Selangor, Seri Kembangan, Selangor. Peptone broth, ethanol and curcumin standard (98% purity) were purchased from Sigma-Aldrich.

Sample Preparation
The fresh turmeric was thoroughly cleaned before being finely ground into a paste using a high-duty blender. After incorporating salt, the turmeric paste was carefully packed into a polyethylene container and stored at a chiller temperature (4-6°C) for further analysis. The salt concentration and irradiation dosage formula prepared for this experiment is shown in **Table 1**.

Table 1. Salt concentration and irradiation dosage employed in the experiment.

Salt/ Irradiation	Control (No)	10% (A)	20% (B)	30% (C)
Control	Control	Co A	Co B	Co C
4 kGy	4 No	4 A	4 B	4 C
6 kGy	6 No	6 A	6 B	6 C
8 kGy	8 No	8 A	8 B	8 C

Sample treatment by gamma irradiation
Gamma irradiation treatment was carried out using a cobalt-60 irradiator. Samples were placed alongside the dosimeter in a static mode during treatment. Four different dosages were applied: control (0 kGy), 4 kGy, 6 kGy, and 8 kGy.

Analytical Method for Determining Moisture Content, Water Activity, pH, and Colour
The analysis was conducted to determine moisture content, water activity, pH, and color. Moisture content was measured using A&D's MX/MF-50 moisture analyzer (AOAC, 2000). For water activity (aW), an AwTherm Water Activity Meter (Rotronic USA) was utilized, following the method of Saberi et al. [4]. The pH value was measured with a bench-top pH/MV meter (PL-700PC, Uni Dex). Color parameters (L*, a*, b*) were assessed using the Color Meter CIELab (PCE-TCD 100, PCE Instruments, UK) in accordance with the procedure outlined by Madhusankha et al. [5].

Curcumin Detection in turmeric sample
Samples (5g) were mixed with 50 ml of ethanol and filtered through Whatman Qualitative Filter Paper, 45 mm in diameter. Each sample was then diluted at a 1:10 ratio before absorbance readings were taken. Absorbance readings were measured in triplicate using a spectrophotometer (Libra S35/35PC UV/Visible) at 425 nm. The absorbance values were substituted into the linear equation derived from the curcumin standard curve (98% purity) to determine the curcumin concentration in µg/mL. The curcumin standard curve was generated by preparing solutions with concentrations ranging from 1 to 6 µg/mL from the stock.

Microbiological quality of turmeric paste
For evaluating the microbiological safety of turmeric paste, total plate count and yeast and mould growth were assessed using PCA and PDA agars. Initially, 25 g of samples were mixed with 225 mL saline solution and homogenized for 2 minutes. Serial dilution was performed up to 10^{-3} dilutions, and 0.1 mL from each dilution was spread on agar plates. Incubation at 35°C for 3 days for total plate count and 5 days for yeast and mold was followed. Post-incubation, colony counting was conducted to determine colony forming units per gram (CFU/g).

Statistical Analysis
Two-way ANOVA and Tukey's test ($P < 0.05$) were performed using Minitab 18.0. Results are expressed in means ± SD from triplicate analyses.

RESULTS AND DISCUSSION

Moisture content and water activity
The moisture content, as shown in **Table 2**, indicates no significant difference due to both irradiation treatment and salt addition. The addition of salt typically prompts water extraction from food via osmosis [6]. However, in this case, there is no notable variation in moisture content despite increasing salt concentration. This phenomenon suggests that water might be drawn out of the turmeric membrane cells to balance the salt concentration gradient outside the membrane to achieve equilibrium [7]. Table 2 illustrates water activity, showing no significant change from irradiation treatment but notable differences with salt addition. Changes in water content can cause food degradation, with water activity being critical. Salt reduces water activity by binding sodium and chloride ions with water molecules, reducing free water. This reduction induces osmotic shock in microorganism cells, preserving the food product [8-9].

pH and colour of turmeric paste
Table 3 displays pH values of turmeric paste, unaffected by irradiation or salt addition. Irradiation, termed cold pasteurization, preserves pH through ionization [10]. Bolyston [11] observed minimal pH changes with low-dosage irradiation in fruits. In contrast, heat treatment deactivates oxidative enzymes, leading to browning, while oxygen presence causes pigment oxidation. Irradiation, devoid of heat or oxygen, minimizes color changes [11]. **Table 4** indicates consistent color in irradiated and salt-treated turmeric paste, with minimal alteration.

Table 3. Effect of irradiation and salt treatment on pH value of turmeric paste.

Salt (%)	Irradiation Dosage (kGy)			
	0	4	6	8
0	7.47±0.06^{Aa}	7.52±0.17^{Aa}	7.40±0.07^{Aa}	7.38±0.10^{Aa}
10	7.40±0.08^{Aa}	7.40±0.07^{Aa}	7.37±0.04^{Aa}	7.36±0.12^{Aa}
20	7.39±0.04^{Aa}	7.39±0.07^{Aa}	7.29±0.09^{Aa}	7.26±0.03^{Aa}
30	7.36±0.04^{Aa}	7.30±0.02^{Aa}	7.29±0.02^{Aa}	7.34±0.04^{Aa}

* The mean ± SD values with different superscripts within a row (uppercase) and column (lowercase) in each group are significantly different ($p < 0.05$).

Table 2. Effect of irradiation and salt treatment on moisture content and water activity of turmeric paste.

	Moisture content				Water activity			
Salt (%)	Irradiation Dosage (kGy)				Irradiation Dosage (kGy)			
	0	4	6	8	0	4	6	8
0	78.96±0.61^{Aa}	79.48±0.66^{Aa}	80.05±1.23^{Aa}	79.85±0.93^{Aa}	0.94±0.03^{Aa}	0.93±0.03^{Aa}	0.93±0.02^{Aa}	0.94±0.00^{Aa}
10	80.37±0.83^{Aa}	80.62±1.07^{Aa}	81.18±2.03^{Aa}	80.54±0.95^{Aa}	0.77±0.02^{Ba}	0.75±0.03^{Ba}	0.75±0.04^{Ba}	0.71±0.01^{Ba}
20	81.45±0.46^{Aa}	81.67±1.13^{Aa}	80.53±1.03^{Aa}	81.34±1.12^{Aa}	0.59±0.04^{Ca}	0.54±0.01^{Ca}	0.57±0.02^{Ca}	0.54±0.01^{Ca}
30	82.00±1.72^{Aa}	81.76±1.16^{Aa}	81.45±0.45^{Aa}	82.70±0.92^{Aa}	0.43±0.01^{Da}	0.42±0.01^{Da}	0.42±0.01^{Da}	0.44±0.01^{Da}

* The mean ± SD values with different superscripts within a row (uppercase) and column (lowercase) in each group are significantly different ($p < 0.05$).

Table 4. Effect of irradiation and salt treatment on colour of turmeric paste.

Salt (%)		Irradiation Dosage (kGy)			
		0	4	6	8
0	L	43.4±0.47^{Aa}	43.0±0.62^{Aa}	43.0±0.78^{Aa}	43.3±0.51^{Aa}
	a	15.1±1.07^{Aa}	14.9±0.87^{Aa}	14.8±0.42^{Aa}	15.3±0.40^{Aa}
	b	24.7±1.17^{Aa}	25.1±0.15^{Aa}	24.8±0.10^{Aa}	24.8±0.42^{Aa}
10	L	42.8±0.38^{Aa}	43.5±0.25^{Aa}	43.1±0.68^{Aa}	43.2±0.21^{Aa}
	a	14.7±0.45^{Aa}	15.1±0.44^{Aa}	14.5±0.35^{Aa}	14.4±0.21^{Aa}
	b	24.7±0.15^{Aa}	24.7±0.21^{Aa}	24.9±0.57^{Aa}	25.3±0.45^{Aa}
20	L	43.1±0.47^{Aa}	42.8±0.30^{Aa}	42.9±0.20^{Aa}	43.1±0.45^{Aa}
	a	15.1±0.20^{Aa}	14.8±0.32^{Aa}	15.3±0.40^{Aa}	15.1±0.51^{Aa}
	b	25.6±0.21^{Aa}	24.1±0.20^{Aa}	24.6±0.42^{Aa}	24.9±0.40^{Aa}
30	L	43.9±1.50^{Aa}	42.8±0.12^{Aa}	43.7±1.43^{Aa}	42.2±0.31^{Aa}
	a	15.5±0.21^{Aa}	15.1±0.74^{Aa}	14.5±0.21^{Aa}	14.6±0.31^{Aa}
	b	25.3±0.35^{Aa}	25.8±0.23^{Aa}	25.3±0.55^{Aa}	24.7±0.32^{Aa}

* The mean ± SD values with different superscripts within a row (uppercase) and column (lowercase) in each group are significantly different ($p < 0.05$).

Curcumin level

Curcumin, the active ingredient in turmeric responsible for its bright golden color and renowned for its antioxidant and antifungal properties, typically constitutes approximately 2-5% of turmeric by weight. **Table 5** shows curcumin content unaffected by irradiation or salt, indicating no change in turmeric paste. This aligns with findings by Toda [12], where irradiation at 10 kGy did not impact curcumin, suggesting safe food preservation without affecting curcumin levels.

Table 5. Effect of irradiation and salt treatment on curcumin (µg/mL).

Salt (%)	Irradiation Dosage (kGy)			
	0	4	6	8
0	0.86 ±0.001^{Aa}	0.87±0.009^{Aa}	0.85±0.006^{Aa}	0.88±0.006^{Aa}
10	0.89±0.011^{Aa}	0.88±0.002^{Aa}	0.84±0.008^{Aa}	0.90±0.001^{Aa}
20	0.90±0.003^{Aa}	0.88±0.006^{Aa}	0.88±0.011^{Aa}	0.87±0.001^{Aa}
30	0.90±0.001^{Aa}	0.87±0.009^{Aa}	0.89±0.006^{Aa}	0.86±0.008^{Aa}

* The mean ± SD values with different superscripts within a row (uppercase) and column (lowercase) in each group are significantly different ($p < 0.05$).

Plate count of turmeric paste

Tables 6 to 8 detail the monitoring of total plate counts over 30 days at room temperature (25-27°C) and chiller temperature (4-6°C). At room temperature, samples with 20% and 30% salt concentrations across all irradiation dosages showed no significant microbial growth by day 30. However, the sample with 20% salt concentration without irradiation treatment exhibited microbial counts (2.1×10^{2} CFU/g and 2.3×10^{2} CFU/g, respectively), below the standard limit stated in Food Regulation 39 Fifteenth Schedule, indicating safety for consumption despite observed growth.

Table 6. Mean count of total plate count (TPC) detected in turmeric paste after irradiation and storage at room temperature (25-27°C) for 30 days.

	0 kGy				4 kGy				6 kGy				8 kGy			
Irradiation/ Time	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30%
Day 0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 5	$1.1\times10^{2}\pm0.67$	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 7	TNTC	$5.3\times10^{2}\pm0.64$	<1	<1	TNTC	$6.5\times10^{2}\pm0.53$	<1	<1	5.7±0.69	<1	<1	<1	$2.6\times10^{1}\pm0.58$	$2.0\times10^{2}\pm0.52$	<1	<1
Day 14	Spoilt	TNTC	<1	<1	Spoilt	TNTC	<1	<1	Spoilt	$1.3\times10^{2}\pm0.61$	<1	<1	Spoilt	$3.0\times10^{2}\pm0.43$	<1	<1
Day 30	Spoilt	Spoilt	$2.1\times10^{2}\pm0.56$	<1	Spoilt	Spoilt	<1	<1	Spoilt	Spoilt	<1	<1	Spoilt	Spoilt	<1	<1

* The units are in CFU/g.

Table 7. Mean count of yeast and mould (Y&M) detected in turmeric paste after irradiation and storage at room temperature (25-27°C) for 30 days.

	0 kGy				4 kGy				6 kGy				8 kGy			
Irradiation/ Time	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30 %	0%	10%	20%	30%
Day 0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 5	$1.4\times10^{2}\pm0.5$	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 7	TNTC	$3.8\times10^{2}\pm0.52$	<1	<1	TNTC	$6.3\times10^{2}\pm0.46$	<1	<1	5±0.48	$3.7\times10^{2}\pm0.42$	<1	<1	$3.3\times10^{1}\pm0.75$	<1	<1	<1
Day 14	Spoilt	TNTC	$1.2\times10^{2}\pm0.53$	<1	Spoilt	TNTC	<1	<1	Spoilt	$3.4\times10^{2}\pm0.58$	<1	<1	Spoilt	$2.6\times10^{2}\pm0.49$	<1	<1
Day 30	Spoilt	Spoilt	$2.3\times10^{2}\pm0.44$	<1	Spoilt	Spoilt	<1	<1	Spoilt	Spoilt	<1	<1	Spoilt	Spoilt	<1	<1

* The units are in CFU/g

Table 8. Mean count of total plate count (TPC) and yeast and mould (Y&M) detected in turmeric paste after irradiation and storage at 4-6°C for 30 days.

		0 kGy				4 kGy				6 kGy				8 kGy			
Irradiation/ Time	Type	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30%	0%	10%	20%	30%
Day 0	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 1	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 3	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 5	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 7	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 14	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Day 30	TPC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Y&M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

* The units are in CFU/g.

Conversely, samples with 0% and 10% salt concentrations spoiled by day 30. Chiller-stored samples showed no significant microbial growth, indicating superior microbiological quality with higher salt concentrations and irradiation dosages. Notably, chiller storage prolonged shelf life compared to room temperature. Studies by Dhanya [3] and Yamaoki and Kimura [13] support irradiation's effectiveness in extending turmeric's shelf life by reducing microbial contamination, highlighting its potential in enhancing storage stability.

CONCLUSION

In conclusion, the optimal formulation and treatment for turmeric paste involves a 20% salt concentration combined with an 8 kGy irradiation dosage, stored at chiller temperature. This combination ensures better storage quality and stability without compromising the main active ingredient, curcumin. The irradiation method effectively reduces microbial load without altering the physical properties of the turmeric paste. Overall, the integration of salt addition and irradiation treatment at low temperature enhances the storage and shelf-life quality of turmeric paste, making it a promising approach for food preservation.

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