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The Effect of Gamma Irradiation as A Food Preservation Technology on The Shelf Life and Quality of Fresh-cut Watermelon

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Abstract

Several methods for preserving food, particularly fresh fruit, aim to extend shelf life without compromising nutritional value. Food preservation technology utilizing irradiation techniques ensures food safety and stability by eliminating microbes and microorganisms while preserving nutrients. This study investigates the food preservation process using gamma irradiation, analyzes the physical changes in irradiated food over time, and examines the effects of varying gamma irradiation doses on the weight loss and shelf life of fresh-cut watermelon. The research method involves gamma irradiation at doses of 1, 1.5, 2, 2.5, and 3 kGy. Findings indicate that gamma irradiation at these doses affects the weight loss of fresh-cut watermelon. The highest weight loss, approximately 87.36%, was observed at a dose of 3 kGy, indicating significant cellular and membrane damage. Furthermore, high-dose irradiation leads to nutrient degradation and accelerates water loss, resulting in physical changes in fresh-cut watermelon, such as increased softness, wateriness, and odor.

Keywords: Food irradiation, Food preservation, Watermelon.

1 Introduction

Red watermelon (Citrullus lanatus) is a fruit rich in water content (up to 90%) and is commonly served as fresh-cut pieces. Fresh-cut watermelon is more susceptible to damage and spoilage compared to whole watermelon. Naturally, fruits undergo a ripening process due to ethylene oxide over time, leading to food spoilage. This ripening process is accelerated by bacteria and microorganisms present around the fruit, as well as by temperature and oxygen[1]. Additionally, damage to the fruit results in quality degradation due to ongoing metabolic processes and physical and biological treatments[2]. The cells of the watermelon can be damaged during the cutting process[3].

The spoilage of fresh-cut watermelon can be slowed down by storing it at a cool temperature around 4°C and using plastic wrapping to suppress microbial growth and prevent contamination[3]–[5]. Additionally, UV irradiation can also delay the spoilage process of fresh-cut watermelon[6], [7]. Nevertheless, ensuring food safety and stability through the elimination of microbes remains crucial, and various methods are continuously being researched. One such method is food irradiation. This technique aims to eliminate spoilage-causing microbes and microorganisms by damaging their cell membranes, enzymes, or DNA, thereby extending the shelf life and maintaining the nutritional quality of the food[4].

Compared to UV irradiation, gamma irradiation, using sources such as cobalt-60 or Cs-137, is now emphasized for food preservation. Cobalt-60 is commonly used in food irradiation[8]. The radiation dose in food irradiation is adjusted based on its effectiveness, with preservation doses ranging from 1 kGy to 10 kGy[9], [10].

The irradiation process is often referred to as "cold pasteurization" because it can kill bacteria without using heat[11]. During the irradiation preservation process, no heating occurs, thus preserving the freshness and physical state of the food. Spoilage agents such as bacteria and insects are eliminated from the food and its packaging, preventing recontamination. This method is particularly beneficial in maintaining hygiene in areas where food is handled or processed, such as in tropical conditions[12], [13].

In the radiation preservation process, most of the radiation passes through the food without being absorbed. A small fraction of the radiation targets spoilage microorganisms and bacteria. These organisms are destroyed by electrons breaking the bonds in their DNA, leading to DNA damage, which disables their ability to grow and reproduce[14]. DNA Bond Disruption is shown in Fig. 1.

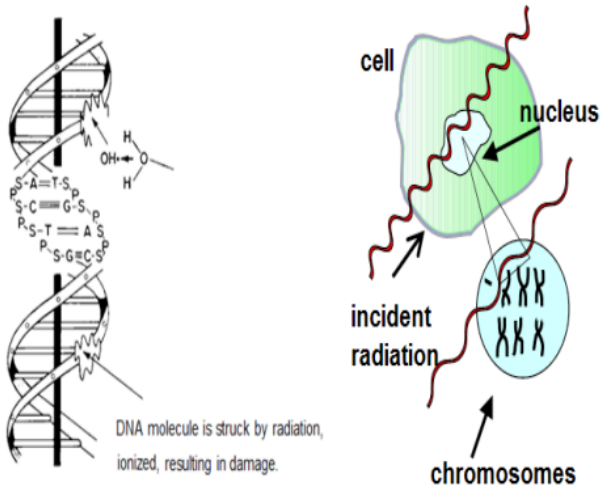

Figure 1. DNA Bond Disruption
(Source: Health Physics Society, The Effect of Radiation on Living Things)

Fruit ripeness can be measured by weight loss. During ripening, physical and chemical changes occur in the fruit, including alterations in texture, color, and weight loss. Weight loss in fruit can be influenced by varying doses of gamma radiation[15]. Gamma irradiation slows down the respiration process. As respiration progresses, O_2 intake decreases while CO_2 output increases. Respiration converts sugars into carbon dioxide and water[16].

During respiration, complex compounds within the cells are broken down into simpler molecules such as carbohydrates and volatile water (free water). This continuous respiration process leads to increasing weight loss over time. Weight loss also results from water loss through evaporation (free water) and carbon loss due to respiration during storage[17], [18]. Weight loss is calculated using the following equation:

$$\%\, weight\ loss = \frac{W_0 - W_t}{W_0}\ x\ 100\% \quad (1)$$

where W_0 = mass of the watermelon sample before irradiation (grams); W_t = mass of the watermelon sample after irradiation (grams).

This study investigates the food preservation process using gamma irradiation facilities, analyzes physical changes in irradiated food over time, and examines the effects of varying gamma irradiation doses on weight loss and shelf life of fresh-cut watermelon.

2 Material and Methods

This study used local red watermelon samples cut into 2 cm x 2 cm x 2 cm cubes, categorized into six groups based on the gamma irradiation doses received. The fresh-cut watermelon was packaged with clip-on plastic bags labeled with mass and sample identity. Irradiation was performed using a Co-60 source with a dose rate of 2493 Gy/hour on March 6, 2024, at the Gamma Irradiator Type I, Observognis Yogyakarta. The irradiation doses applied were 0 kGy (control), 1 kGy, 1.5 kGy, 2 kGy, 2.5 kGy, and 3 kGy. After irradiation, samples were stored at room temperature in sealed plastic bags. Physical changes and weight loss of the watermelon were monitored and compared with the control.

3 Results and Discussions

Gamma radiation technology aims to eliminate spoilage microbes and microorganisms through DNA damage. Preservation of fresh-cut watermelon with radiation is designed for energy efficiency and ease of control. Gamma rays provide effective penetration without altering the temperature of the watermelon, thus preserving its nutrients and vitamins. Radiation technology requires dose optimization to be effective for its purpose. Incorrect doses can result in undesired cellular damage. In this preservation study, doses ranging from 1 kGy to 3 kGy were used, as shown in Table 1.

Table 1. Mass of fresh-cut watermelon and percent weight loss

Radiation Dose (kGy)	Mass of Fresh-cut Watermelon and %Weight Loss (%WL)										
	D-0	D-1	%WL D-1	D-4	%WL D-4	D-6	%WL D-6	D-8	%WL D-8	D-13	%WL D-13
0	6,80	6,78	0,41	6,59	3,15	6,27	7,81	6,06	10,92	5,97	12,29
1	8,09	8,09	0,00	7,81	3,48	7,56	6,59	7,12	12,00	6,31	22,00
1,5	7,64	7,65	-0,03	7,40	3,15	7,06	7,60	3,11	59,33	2,58	66,21
2	9,18	9,18	0,02	9,08	1,07	7,99	13,00	7,29	20,54	7,17	21,94
2,5	7,78	7,78	-0,06	7,66	1,49	7,40	4,85	7,13	8,30	6,97	10,30
3	8,77	8,76	0,02	8,63	1,55	8,31	5,18	2,38	72,82	2,33	73,44

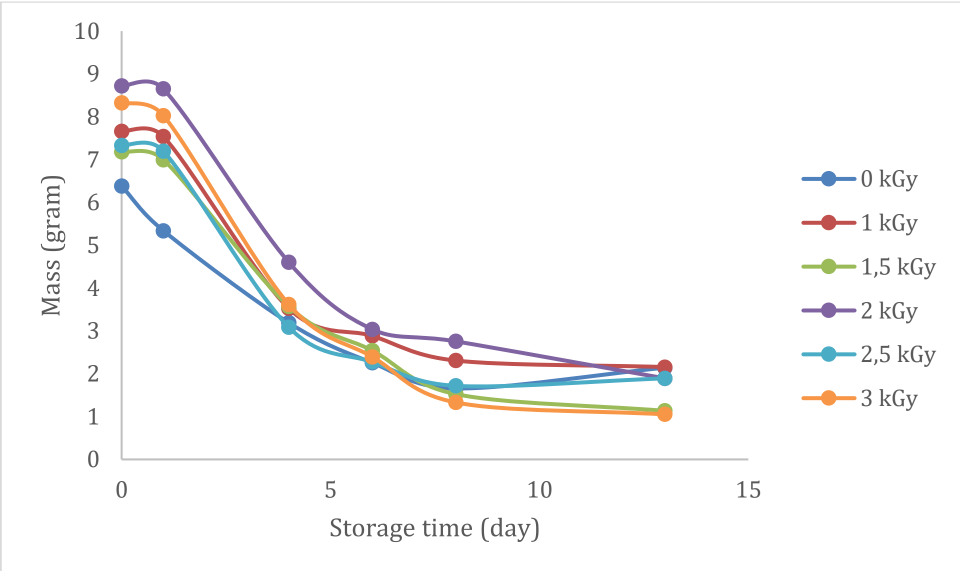

Figure 2. Depicts the correlation between storage time and mass loss in fresh-cut watermelon

Fresh-cut watermelon exhibited a trend of decreasing mass over time following gamma irradiation, as depicted in Fig. 2. Initially, the mass remained relatively stable or decreased slowly. However, over time, the mass loss became more significant. For example, at an irradiation dose of 2 kGy, the watermelon mass on day 8 was 2.756 grams, decreasing to 1.894 grams by day 13. This indicates a significant weight reduction over that period. This loss is attributed to the continuous respiration process, leading to increased mass reduction over time. Additionally, mass reduction is due to water loss from evaporation (free water) and carbon loss from respiration during storage. Monitoring watermelon mass changes helps evaluate the quality of the food after gamma irradiation, aiding in determining food safety and shelf life.

In cases of watermelon slices irradiated at different doses, higher irradiation doses resulted in higher weight loss percentages, as shown in Fig. 3. This is due to radiolysis effects caused by radiation exposure, which can alter the molecular structure of the food, including cellular and nutritional damage, affecting weight loss. High doses not only damage microbial DNA but also the structure of the watermelon itself. Additionally, the cutting process damages the cell walls of the watermelon, leading to accelerated ripening.

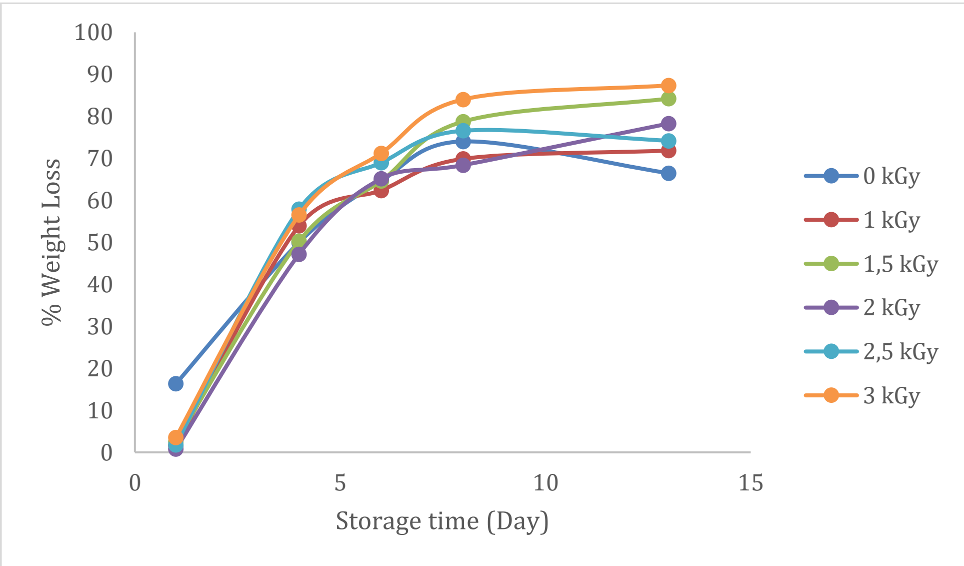

Figure 3. Depicts the correlation between storage time and percentage weight loss

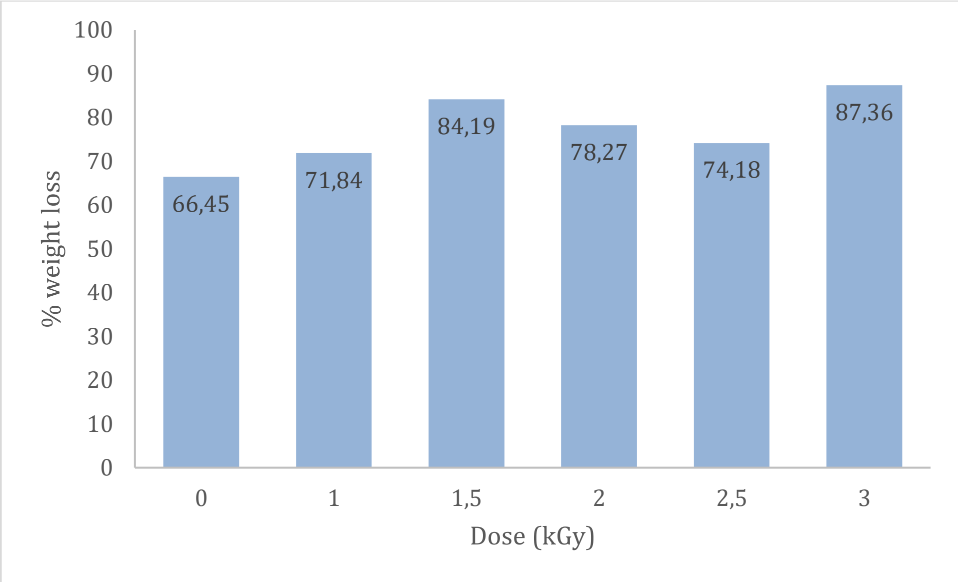

Figure 4. Illustrates the relationship between radiation dose and average weight loss

Fig. 4 illustrates the impact of irradiation dose on watermelon mass changes over time. Higher irradiation doses tend to cause faster mass loss compared to lower doses. Lower doses result in slower mass loss, suggesting they may be sufficient to inhibit microorganism growth without causing significant structural damage to the watermelon. At 0 kGy, the average weight loss was the lowest (66.45%), indicating that without radiation, the watermelon structure remained relatively intact but was more susceptible to microorganism growth. Conversely, at 3 kGy, the highest weight loss percentage (87.36%) was observed, indicating significant cellular damage and water loss. The average weight loss increased with higher radiation doses, consistent with the theory that higher doses cause more damage to cell walls and membranes, leading to greater water and nutrient loss.

Changes in watermelon mass depicted in the graphs provide insight into the effectiveness of specific irradiation doses in slowing food degradation. In addition to irradiation dose, storage time also influences the mass change of food post-irradiation. Longer storage time increases the likelihood of weight loss in the food. The data show that the percentage of weight loss in watermelon tends to increase over time after irradiation.

Figure 5. Fresh-cut watermelon on day 1 (left) and fresh-cut watermelon on day 13 (right)

Increased irradiation doses result in worsening physical and chemical changes in fresh-cut watermelon. The watermelon becomes soft, watery, and odorous due to damage to cell walls and nutrient degradation, as seen in Fig. 5. These changes lead to increased mass loss, reflected in high weight loss percentages after irradiation. Gamma irradiation induces radiolysis, where gamma rays interact with the water molecules in the fresh-cut watermelon at excessively high doses. Radiolysis generates free radicals that damage cell structures and organic molecules. This damage includes nutrient degradation, cell wall and membrane damage, and accelerated water loss. These negative effects arise from excessively high doses, necessitating optimal doses to target only microbes and microorganisms. Based on this study, the optimal dose for preserving fresh-cut watermelon is at lower doses around 1 kGy or lower.

4 Conclusions

Based on the data presented in this study on the preservation of fresh-cut watermelon using gamma irradiation, the following conclusions can be drawn:

1. Gamma irradiation can be utilized as a food preservation method to extend shelf life and maintain food quality when applied at optimal doses.

2. The dose of gamma radiation significantly affects the weight loss of food products. Higher doses result in an increased percentage of weight loss in watermelon.

Prolonged storage time after irradiation leads to greater mass loss. The graph depicting the relationship between storage time and mass of watermelon illustrates a consistent trend of mass reduction over time, which can be utilized as a monitoring tool for product quality.

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