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Effects of Gamma Irradiation on Microbial, Chemical, and Organoleptic Characteristics of Ostrich Meat during Refrigeration

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ABSTRACT

Nowadays, there is a growing need to explore methods for increasing the shelf life of food. In the food industry, severe food security industrial techniques are employed, including canning, pasteurization, smoking, salting, freezing, heating, vacuum sealing, the use of chemical materials, and irradiation. This study focuses on the effects of gamma irradiation on changes in the chemical, biological, and organoleptic properties of ostrich meat. Fifteen male ostriches, aged between 10 and 14 months, underwent evaluation. Initially, the ostriches were slaughtered, and their meat) from thigh (was subjected to different irradiation doses (0, 2, 4, 6 KGY) at intervals of0, 5, 10, and 15 days. The various meat groups were then stored at 4°C.In this study, ostrich meat samples were divided into two groups: one group received no irradiation (0 kg) and the other received irradiation at doses of2, 4, and 6 kg. These samples were then stored in a refrigerator for15 days, and microbial, chemical, and organoleptic tests were conducted. The results of our investigation indicate that the 4 kg irradiation dose effectively reduced the counts of mesophilic bacteria, coliform bacteria, Staphylococcus aureus, and psychrophilic bacteria, while also eliminating Salmonella spp and E. coli spp. Additionally, it led to a reduction in Total Volatile Nitrogen (TVN) and prevented adverse organoleptic changes, including alterations in odor and color, over the 15-day refrigerated storage period. The irradiated groups also demonstrated a remarkable reduction and elimination of Staphylococcus aureus, *E. coli spp*, and *Salmonella spp* bacteria during refrigerated storage, with significant differences from the control group. Additionally, Total Volatile Nitrogen (TVN) in the control group exhibited a significant increase onthe15th day compared to the other groups. To sum up, irradiation proves to be a viable method for preserving various foods, especially meats like ostrich, and is highly recommended to safeguard against food spoilage and contamination.

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Introduction

Ostrich meat is characterized by its low cholesterol content and high levels of unsaturated fatty acids, making it a rich source of iron. Furthermore, ostrich meat does not carry the same health risks associated with other red meats like beef and lamb, which can harbor dangerous diseases that may affect human consumers.(1,2). As a result, ostrich meat is a suitable choice for a variety of individuals, including heart patients, athletes, pregnant women, children, and the elderly.(3,4)

Ostrich meat, classified as a type of red meat(5) , emerges as a compelling alternative. Beyond its protein content, ostrich meat boasts distinct attributes. It stands out with its low cholesterol levels and high unsaturated fatty acids, while also being rich in iron. Significantly, ostrich meat is devoid of the health concerns commonly associated with other red meats(6,7).

In contemporary times, the preservation of food has become imperative, given the modern lifestyle's reliance on processed and shelf-stable food resources. While the preservation of food is essential, it should not compromise the nutritional integrity of these food supplies. Within the food safety industry, an array of methods exists, encompassing canning, pasteurization, smoking, salting, freezing,

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heating, vacuum sealing, chemical additives, and irradiation.(8,9,10)

Among these, food irradiation has been introduced as a long-term preservation technique, boasting benefits such as reduced chemical usage, enhanced safety, and the significant reduction of microbial loads(11,12). Numerous studies have confirmed the technique's safety in terms of toxicology and nutritional analyses, indicating minimal changes to essential nutrients. Notably, proteins, carbohydrates, and fats remain largely unaffected, as do vital nutrients like calcium, and potassium(13,14,15).

The utilization of food radiation, including gamma rays, X-rays, or electrons, has become recognized as an effective method for pathogen eradication and the prevention of their reproduction. Among these radiation types, gamma radiation, emitted by nuclei of elements like Cs137 and Co60, holds particular importance in food preservation. It distinguishes itself through its high penetrating power, offering superior results compared to beta rays(16,17,18).

This study aims to explore the impact of gamma irradiation on ostrich meat, focusing on changes in microbial bacteria levels *(e.g., coliform spp, E. colispp, Staphylococcus aureus spp, Salmonellaspp)*, psychrophilic microorganisms, the total count of aerobic mesophilic bacteria, and chemical parameters such as total volatile nitrogen (TVN). Additionally, the study will assess the organoleptic characteristics of irradiated ostrich meat.

Materials & Methods

Sampling

This study was conducted at the Golbarg Tuba farm located in Saveh province, Iran. Fifteen ostriches, all male and aged between 10 to 14 months, were slaughtered in a slaughter house. lateral thigh muscle samples were collected using a sterile scalpel. Subsequently, ostrich meat samples were divided into two groups: one group received no irradiation (0 KGY) and the other received irradiation at doses of 2,4, and 6 KGY (each sample was divided into 16 foil-wrapped portions) and stored at refrigerator temperature. Samples were sent alongside ice to the Nuclear Agricultural Research Institute, where they were irradiated under doses of 0, 2, 4, and 6 KGY at intervals of 0, 5, 10, and 15 days. The different groups were then stored at 4°C, and their organoleptic, chemical, and microbial properties were evaluated on these respective days.

Microbial Indices

In this experiment, microbial indices were assessed, including the *Total Bacterial Count*, *Coliform* count, *E.coli* and *Salmonella* identification, *Staphylococcus aureus*, and *Psychrophilic bacteria* enumeration. *Nutrient agar*(NA) media were employed for the ***Total Bacterial Count***, **(37°C/1-2days)** (19), while *Violet Red Bile Agar* (VRBA) medium was used for the cultivation of ***Total Coliform*** (20). Also standard media containing *Brilliant Green Bile (2%) Lactose Broth*(BGB) was used for enumeration by Most Probable Number(MPN) method **(37°C/1-2days)** (21). For diagnosing E. coli, indole testing using Peptone Water and BGB was conducted, employing Kovac's reagents (44°C/1-2 days) (23). The identification and enumeration of ***Staphylococcus aureus*** were carried out using *Baird Parker Agar* medium and a 1% solution of potassium telluride**(37°C/1-2 days)**. The detection of ***Psychrophilic bacteria*** was performed using *King Agar* medium **(1-4°C/7-10days)(**24).For detection of ***Salmonella*** used *Lactose Broth*,*Selinate*,*Salmonella-Shigella Agar*,*Triple Sugar Agar* ,*Lysine Iron Agar* and *Urea* cultures ,respectively. **(37°C/1-2days)**

Total Volatile Nitrogen (TVN)

The assessment of TVN was conducted within the groups (25). In each experimental unit, 10 grams of ostrich meat were chopped and mixed with 50 ml of distilled water. Subsequently, 2 grams of magnesium oxide were transferred to a flask containing 250 ml of distilled water. A receiving dish contained 25 ml of boric acid (2%) and a few drops of tochirol reagents. The distillation flask and its contents were heated to boiling for 10 minutes. The distillation process continued for 25 minutes, and the distilled solution was finally titrated with normal hydrochloric acid (0.1N). Using the equation provided, the amount in milligrams was calculated, with each cm^3 of normal hydrochloric acid (0.1N) being equivalent to 1.4 mg TVN.

Organoleptic Tests

To assess the color and smell of the samples, organoleptic tests were conducted after exposure and at 0, 5, 10, and 15 days of storage in the refrigerator. Color was judged by five judges under natural light, each with normal eyesight, and smell was evaluated using a cooking test. Five grams of meat samples were boiled on a direct flame in an Erlenmeyer flask containing distilled water, and the smell was assessed. Color measurements were performed prior to smell measurements. Scores for organoleptic factors were calculated, with three score categories including 'excellent,' 'good,' and 'poor' corresponding to grades of 2, 1, and 0, respectively (26).

Statistical Analysis

For the average comparison of *Total Bacterial Count*, *Coliforms spp*, *Psychrotrophic bacteria*, *Staphylococcus aureus*, and TVN in the experimental units, a two-way ANOVA was used with a 95% confidence level. Organoleptic characteristics were statistically compared using a non-parametric test (Friedman). Data concerning *E. coli and Salmonella spp*bacteria were analyzed using a chi-square test.

Results

Bacterial Counting and Identification

The results revealed a significant decrease in microbial load in all irradiated groups, with noteworthy differences among these groups. Additionally, there was a significant reduction in the *Total Bacterial Count* over the course of 0, 5, 10, and 15 days in all irradiated groups, as compared to the control group (0 KGY), which displayed statistically significant differences ($P < 0.05$) (Table 1).

Table 1. Changes in total count of bacteria (Total count), coliforms and psychrophilic bacteria (Mean log 10 cfu / g ± SE) according to different levels of radiation in the storage time of refrigerated

Changes in total count of bacteria (Total count)				
Storage time (Day)	**Dose of gamma radiation (KGY)**			
	0	**2**	**4**	**6**$^{*\#}$
0	3±36.36$^{\#}$	44.12±0$^{*\#}$	0±6.02$^{*\#}$	0$^{*\#}$
5	4±17.39$^{\#}$	1±90.17$^{*\#}$	0±32.9$^{*\#}$	0$^{*\#}$
10	5±55.38$^{\#}$	3±12.22$^{*\#}$	1±44.18$^{*\#}$	0±17.06$^{*\#}$
15	6±98.28$^{\#}$	4±12.23$^{*\#}$	2±12.16$^{*\#}$	0±76.22$^{*\#}$
Change the number of coliforms				
Storage time (Day)	**Dose of gamma radiation (KGY)**			
	0	**2**	**4**	**6**
0	0±67.15$^{\#}$	0$^{*\#}$	0$^{\#}$	0$^{\#}$
5	1±63.18$^{\#}$	0±5.04$^{*\#}$	0$^{\#}$	0$^{\#}$
10	2±60.16$^{\#}$	0±40.11$^{*\#}$	0±4.04$^{\#}$	0$^{\#}$
15	3.2±62$^{\#}$	1±46.19$^{*\#}$	0±29.09$^{\#}$	0±4.03$^{\#}$
psychrophilic bacteria count				
Storage time (Day)	**Dose of gamma radiation (KGY)**			
	0	**2**	**4**	**6**
0	0±92.11$^{\#}$	0$^{*\#}$	0$^{\#}$	0$^{\#}$
5	1±93.15$^{\#}$	0±24.05$^{*\#}$	0$^{\#}$	0$^{\#}$
10	2±85.13$^{\#}$	0±81.11$^{*\#}$	0±6.03$^{\#}$	0$^{\#}$
15	3±91.17$^{\#}$	1±54.16$^{*\#}$	0±54.09$^{\#}$	0±16.05$^{\#}$
Changes in the number of Staphylococcus aureus				
Storage time (Day)	**Dose of gamma radiation (KGY)**			
	0	**2**	**4**	**6**
0	0±16.11$^{\#}$	0$^{*\#}$	0$^{\#}$	0$^{\#}$
5	1±51.14$^{\#}$	0±5.01$^{*\#}$	0$^{\#}$	0$^{\#}$
10	2±44.15$^{\#}$	0±46.06$^{*\#}$	0±2.01$^{\#}$	0$^{\#}$
15	3±72.13$^{\#}$	1±25.10$^{*\#}$	0±31.08$^{\#}$	0±3.01$^{\#}$

$^{\#}p < 0.05$; The changes that are significantly in comparison to the group of control During different days

$^{*}p < 0.05$; The changes that are significantly in comparison to the group of control to different Gamma irradiation doses

The count of *Coliform spp* bacteria in all irradiated groups experienced a reduction over 5, 10, and 15 days. This reduction was statistically significant when compared to the control group (0 KGY). However, no significant difference was observed between the 4 KGY and

KGY groups. Meanwhile, the control group demonstrated a significant increase in the count of *Total coliforms* (P < 0.05) during refrigerated storage over 0, 5, 10, and 15 days (Table 1)

The *Psychrophilic* bacterial load in all irradiated groups exhibited a significant decrease when compared to the control group during refrigerated storage on days 0, 5, 10, and 15. However, there was no significant differentiation observed between the 4 KGY and 6 KGY groups. In contrast, *Psychrophilic* bacteria significantly increased in the control groups stored in the refrigerator (P < 0.05) (Table 1).

Also.the results indicated a reduction in *Staphylococcus aureus* in the irradiated groups during refrigerator storage on days 0, 5, 10, and 15, as compared to the control group. There was no significant difference in *S. aureus* reduction between the 4 KGY and 6 KGY groups. However, this bacterium significantly increased in different irradiated groups during refrigerated storage (P < 0.05) (Table 1).

The irradiated groups demonstrated a significant reduction and elimination of *E.coli spp* and *Salmonella spp* bacteria during refrigerator storage on days 0, 5, 10, and 15, in comparison to the control group (P < 0.05) (Table 2).

Table 2. The presence of *E.Coli* bacteria at ostrich meat according to different doses of radiation over a Storage time of refrigerated

***E.Coli* bacteria**								
Storage time (Day)	**Dose of gamma radiation (KGY)**							
	0		**2**		**4**		**6**	
	+	-	+	-	+	-	+	-
0	9$^{\#}$	6	1$^{\#}$	14	0$^{\#}$	15	0$^{\#}$	15
5	9$^{\#}$	6	0$^{\#}$	15	0$^{\#}$	15	0$^{\#}$	15
10	9$^{\#}$	6	0$^{\#}$	15	0$^{\#}$	15	0$^{\#}$	15
15	9$^{\#}$	6	0$^{\#}$	15	0$^{\#}$	15	0$^{\#}$	15
the presence of Salmonella								
Storage time (Day)	**Dose of gamma radiation (KGY)**							
	0		**2**		**4**		**6**	
0	+	-	+	-	+	-	+	-
5	6$^{\#}$	9	1$^{\#}$	14	6$^{\#}$	9	1$^{\#}$	14
10	6$^{\#}$	9	0$^{\#}$	15	6$^{\#}$	9	0$^{\#}$	15
15	6$^{\#}$	9	0$^{\#}$	15	6$^{\#}$	9	0$^{\#}$	15
0	6$^{\#}$	9	0$^{\#}$	15	6$^{\#}$	9	0$^{\#}$	15

$^{\#}$p < 0.05; The changes that are significantly in comparison to the group of control During different days

Total Volatile Nitrogen (TVN) Evaluation

On the 15th day, the control group exhibited a significant increase in TVN compared to the other groups. In contrast, the application of irradiation at doses of 2, 4, and 6 KGY led to a significant decrease in TVN in comparison with the control group (Table 3).

Table 3. TVN changes at radiation levels at ostrich meat according to storage time of refrigerated

Storage time (Day)	**Dose of gamma radiation (KGY)**			
	0	**2**	**4**	**6**
0	26.2±48.01	23.1±13.30*	21±10.55*	21.1±83.22*
5	32.2±92.73	22.1±60.22*	24±30.95*	23±53.91*
10	54.4±73.23$^{\#}$	28.1±44.91$^{*\#}$	23±2.7$^{*\#}$	23.1±48.33$^{*\#}$
15	68.6±46.63$^{\#}$	36.5±64.30$^{*\#}$	2±25.11$^{*\#}$	22±87.99$^{*\#}$

$^{\#}$p < 0.05; The changes that are significantly in comparison to the group of control During different days

*p < 0.05; The changes that are significantly in comparison to the group of control to different Gamma irradiation doses

Organoleptic Tests

The color of both irradiated and non-irradiated ostrich meat samples showed a significant decrease during the storage period in the refrigerator (0, 5, 10, and 15 days). However, it is noteworthy that irradiation did not produce a significant difference in meat color when compared to the non-irradiated group (control) (P<0.05) (Table 4) .

Also, the smell in all experimental groups during refrigerated storage (0, 5, 10, and 15 days) was significantly reduced. These results suggested that irradiation had no significant effect on the smell of the meat (P < 0.05) (Table 4).

Table 4. Ostrich meat organoleptic indicators (color and smell) evaluation based on various quantities of radiation in the storage time of refrigerated

meat color				
Storage time	**Dose of gamma radiation (KGY)**			
(Day)	**0**	**2**	**4**	**6**
0	2±98.02[#]	2±76.04[#]	2±64.08[#]	2±68.04[#]
5	2±48.10[#]	2±33.10[#]	2±30.08[#]	2±21.11[#]
10	2±3.13[#]	1±88.16[#]	1±88.12[#]	0±2.08[#]
15	1±25.11[#]	1±70.11[#]	1±90.12[#]	1±90.17[#]
smell of ostrich meat				
Storage time	**Dose of gamma radiation (kilo Gray)**			
(Day)	**0**	**2**	**4**	**6**
0	2±96.03[#]	2±79.05[#]	2±66.04[#]	2±62.06[#]
5	2±46.07[#]	2±28.08[#]	2±3.09[#]	2±14.12[#]
10	1±92.06[#]	2±11.12[#]	1±88.11[#]	1±86.14[#]
15	1±4.11[#]	1±60.12[#]	1±90.10[#]	1±86.12[#]

[#] $p < 0.05$; The changes that are significantly in comparison to the group of control During different days

[*] $p < 0.05$; The changes that are significantly in comparison to the group of control to different Gamma irradiation doses

Discussion

This study highlights the potential of gamma-ray irradiation, often referred to as cold pasteurization, to reduce hazardous microorganisms in food while minimally affecting sensory and nutritional properties (27). It's important to note that while irradiation damages most microorganisms, it doesn't necessarily eliminate all of them. Hence, complementary methods like refrigeration and cooking should accompany irradiation to ensure optimal food safety (28). Combining irradiation with refrigeration has shown more substantial benefits for food safety and health compared to irradiation alone (29).

In this study, the control group showed a significant increase in *Coliform* bacteria at 0, 5, 10, and 15 days. Irradiation had no significant effect on reducing *Coliforms spp* in the control group compared to all irradiated groups. However, between the irradiated groups of 2, 4, and 6 KGY, a statistically significant difference was observed. It appears that the 4 KGY dose is particularly effective in reducing *Coliform* bacteria.Various irradiation doses (2 KGY, 4 KGY, and 6 KGY) had a significant impact on reducing the growth of *Salmonella* and *E. coli* in the present study. This aligns with Viana CM's findings in 1993, where doses between 3-5 KGY led to the inactivation of non-spore-forming bacteria in various meat types (33).

Total Bacterial counts increased significantly during storage at refrigerator temperatures on days 0, 5, 10, and 15 in different groups. This underscores the ability of irradiation to reduce bacterial counts, aligning with Mahrour et al.'s findings in 2003, which demonstrated that *Total Bacterial Counts* decreased with increasing radiation doses (34). Other studies, including that of Williams, RM in 2003, found that irradiated meats had significantly fewer bacteria compared to their non-irradiated counterparts (35). In some instances, irradiation effectively reduced *Total Bacterial Counts* in beef at doses of 1, 2, and 3 KGY (28).

Although the benefits of irradiation for various meats have been documented, limited research has explored its impact on ostrich meat shelf life. One study published in 2012 found that air-packaged ostrich meat irradiated at 1.0 KGY remained acceptable under refrigerated storage for 9 days, in contrast to 7 and 5 days for non-irradiated and samples irradiated at 3.0 KGY, respectively (18).

Food irradiation is a technology known for controlling spoilage bacteria and reducing foodborne pathogens such as *Salmonella* (36). The application of irradiation by doses of 1-3 KGY has been shown to be remarkably effective in reducing the presence of foodborne pathogens like *Salmonella*, *Toxoplasma*, *Cryptosporidium*, *Listeria*, and *E. coli* in meat, poultry, and fish (37). For instance, Thayer et al. in 1997 reported that doses of 1.5 and 3 KGY at 5°C effectively reduced various bacteria types in ostrich meat, including *Salmonella* and *Staphylococcus aureus* (30), aligning with the results of the present study. Similarly, Javanmard et al. in 2005 found that irradiation doses of 0.75, 3, and 5 KGY resulted in decreased *Total Bacterial Counts* in frozen chicken meat, with the 5 KGY dose effectively halting the growth of bacteria such as *Salmonella* *spp*, *E. coli spp*, *Coliforms spp*, and *Total Bacterial Counts* during nine months (38).

Numerous studies have highlighted the effectiveness of gamma irradiation in eliminating harmful microorganisms in various food products. For instance, frozen poultry carcasses treated with 2.5 KGY irradiation have shown efficacy in destroying *Salmonella* (41, 42). D values, a measure of the radiation dose required to inactivate specific bacterial species, have been determined for different types of Salmonella. For instance, *Salmonella typhimurium* is effectively inactivated with a 0.5 KGY dose (43), while *Salmonella enteritidis* in chicken meat requires a dose of 0.37 KGY (44). In some studies, it was observed that a 6 KGY dose under refrigeration conditions prevented the growth of *Salmonella typhimurium* for up to 28 days (45). *E. coli* has also been found to be effectively inactivated after 4 KGY irradiation in fish extracts (33).

D values for *E. coli* $O_{157}H_7$ have been established, with studies indicating that doses as low as 0.27 KGY at -5°C and 0.42 KGY at 5°C are effective in eliminating this bacterium (9, 30). The sensitivity of various bacteria to irradiation has been studied, with *Campylobacter jejuni*, for example, being particularly sensitive to low-dose irradiation, effectively destroyed at a 1 KGY dose (43). In another study, it was reported that using 2 KGY of radiation reduced *Total Bacterial Counts* by 3 logs, while 4 KGY reduced counts by 6 logs, and no *E. coli* growth was observed at 8 KGY (45).

In our study, the mean logarithmic transformation of *Staphylococcus aureus* and *Psychrophilic bacteria* increased significantly in the control group during storage at 0, 5, 10, and 15 days. Irradiation with doses of 2, 4, and 6 KGY significantly reduced the numbers of *Staphylococcus aureus* and *Psychrophilic bacteria* compared to the control group. The difference between the 2 and 4 KGY irradiated groups versus the 4 and 6 kGy groups was statistically significant, consistent with other research findings.

Studies have proposed various doses of irradiation for specific bacteria. Kilinger et al. (1986) suggested a 5.4 KGY dose for reducing *Salmonella* by 2 logs and a 7 KGY dose for decontaminating poultry carcasses with *Staphylococcus aureus* and *coliforms* (30). Farkas, J (1998) indicated that irradiation at a dose of 7.2 KGY reduced foodborne bacterial pathogens, including *Salmonella*, *Staphylococcus aureus*, *Campylobacter*, *Listeria monocytogenes*, and *E. coli* $O_{157}H_7$ (46). According to the World Health Organization's technical report in 1999, relatively resistant bacteria, including *Staphylococcus aureus*, could withstand doses of 0.0-4.8 KGY irradiation, along with various species of *Salmonella*, *Listeria monocytogenes*, *Clostridium perfringens*, and *Moraxella phenylpyruvia* growing forms (28).

Spoto et al. (2000) showed that a 6 KGY dose inhibited the growth of *Staphylococcus aureus*, *E. col sppi*, and *Salmonella typhimurium* in chicken under refrigeration conditions for up to 28 days (45). Some bacteria have been found to be highly sensitive to low-dose irradiation. For instance, Molins, RA et al. (2001) showed that bacteria such as *Yersinia SPP*, *Campylobacter SPP*, *Arcobacter butzleri*, *Pseudomonas Spp*, *Aeromonus SPP, E. coli* $O_{157}H_7$, and *Bacillus cereus* growing forms were most sensitive to 0.2 KGY irradiation (37).

Additionally, irradiation can lead to the production of volatile compounds responsible for changes in odor. For example, dimethyl trisulfide has been identified as one of the strongest-smelling compounds in irradiated raw chicken meat (49). Some studies have reported fresh and "bloody" smells in irradiated chicken and meat after cooking (50).

In our study, *Total Volatile Nitrogen* (TVN) in ostrich meat showed an increase during refrigerated storage on days 0, 5, 10, and 15 in the control group. Although the difference was statistically significant only between the 10th and 15th days compared to the first day, each irradiated group showed a significant decrease in TVN compared to the control group. While there were no statistical differences between each radiation dose, TVN analysis is a routine method for evaluating meat product quality. Irradiation can induce changes in food, both directly and indirectly, which may result in alterations in flavor and odor. Refrigeration is one of the most effective methods to reduce unfavorable flavor changes induced by irradiation. Some studies have reported popcorn or barbecue taste and smell in irradiated turkey meat, which was not present in non-irradiated samples (51).

Stephan (1998) reported that no off-flavor was observed in irradiated cooked chicken at doses below 3 KGY (52). In our present study, organoleptic tests, specifically assessing color and odor, were conducted at various time points during the 15-day refrigerated storage period following irradiation. The results did not reveal any significant differences in color or odor. Notably, no noticeable changes in odor or color were detected in irradiated ostrich meat exposed to doses of 2, 4, and 6 KGY, even after 15 days of refrigerated storage.

It is important to note that while TVN levels experienced a significant increase on the 15th day of storage, irradiation appeared to have a decreasing effect on this index. However, this difference was not statistically significant. Overall, our study suggests that irradiation had no significant impact on the organoleptic characteristics, including odor and color, of the ostrich meat.

In the study conducted by Heydari and colleagues (2017), ostrich meat was treated with doses of 1.5, 3, and 5 KGY gamma irradiation. The results showed a significant reduction in the levels of nitrogen compounds and an increase in protein content compared to the control group. Additionally, the gamma irradiation treatment significantly reduced the levels of some essential minerals, including iron, in the ostrich meat. Furthermore, the application of gamma irradiation enhanced the safety and quality of the meat, making it more suitable for human consumption.(40)

In Khalida and colleagues' study in 2021, the effects of gamma irradiation and kale leaf powder (KLP) on the microbiological parameters (*Total Bacteria Count* and *Coliforms*) and quality parameters (Hunter color values L*, a*, and b*) of ostrich and chicken meat and meat products were assessed. The results indicated that irradiation, with or without different load compositions, minimized the *Total Bacteria Count* and substantially reduced *Coliformspp* contamination during storage in both types of meat and meat products. Moreover, the nutritional, qualitative, and sensory characteristics of the products were improved with gamma irradiation.(32)

In conclusion, the use of irradiation as a food preservation method, particularly for meat products like ostrich meat, is highly recommended. Irradiation can be regarded as a critical control point in the food supply chain, serving as an additional contamination control measure in the processing of raw animal-derived food products at slaughterhouses, meatpacking centers, and meat processing facilities. The application of irradiation for extending the shelf life of ostrich meat is encouraged, and it has the potential to be one of the most effective methods for ensuring the safety and quality of ostrich meat products.

It is advisable to explore the combined use of irradiation with other preservation techniques to further reduce microbial contamination and eliminate foodborne pathogens in ostrich carcasses. This holistic approach can enhance the overall safety of ostrich meat products. Therefore, it is essential to conduct further research in this area to address health concerns related to ostrich meat supply.

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