Sjournals
Scientific Journals
Scientific Journal of Animal Science (2012) 1(5) 159-165
ISSN 2322-1704

Contents lists available at Sjournals
Scientific Journal of Animal Science
Journal homepage: www.Sjournals.com

Original article

Chemical and sensory quality changes of ostrich meat treated by gamma irradiation

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ARTICLE INFO

Article history:
Received 06 October 2012
Accepted 20 November 2012
Available online 29 November 2012

Keywords:
Refrigeration
Gamma irradiation
Lipid oxidation
Ostrich meat

ABSTRACT

Effects of gamma irradiation and storage time on the Chemical and Sensory quality of ostrich meat stored at 4˚C were evaluated in this study. Irradiation increased (P<0.05) the intensity of lipid oxidation, irradiation odor and loss of color and sensory quality in aerobic packages. No significant differences in pH value of ostrich meat were observed due to irradiation. Considering the sensory analyses, color and TBA analyses as a whole, air-packaged samples irradiated at 1.0 kGy were acceptable under refrigerated storage for 9 days, compared to 5 and 7 days for air-packaged samples irradiated at 3.0 kGy and nonirradiated air-packaged, respectively.

1. Introduction

Irradiation is known to be the best method for the control of potentially pathogenic microorganisms in meat without affecting its physical state (Gants 1998). Food irradiation is generally defined as the process in which foods are exposed to certain forms of ionizing energy from radioactive sources mainly gamma rays. Cobalt-60 is a highly penetrating source of ionizing radiation used in food either fresh or after processing and packaging. Irradiated foods are not radioactive (Satin 2002). Ostrich meat also contains high amounts of polyunsaturated fatty acids as compared to beef and chicken making it more susceptible to oxidation (Horbanczuk *et al*., 1998; Sales and Oliver-Lyons, 1996). Several studies have been published on physical properties, chemical composition, sensory properties and nutritive values of ostrich meat (Girolami *et al.,* 2003; Paleari *et al.,* 1998; Sales 1996; Sales and Hayes 1996; Sales and Horbanczuk 1998) whereas no data have been published on the preservation and extension

of the shelf-life of fresh Ostrich meat by gamma irradiation. The objective of this study was to investigate the effects of gamma irradiation on lipid oxidation, color changes, and sensory qualities of ostrich meat during refrigerated storage.

2. Materials and methods

2.1. Sample preparation and packaging

Ostrich meat samples from Six ostriches (Struthio camelus var. domesticus) were obtained at a slaughter house (Qazvin, Iran) 1 h after slaughtering and used separately as replications for preparation of samples (three separate replicates). Muscle samples were cut cylindrically (5 cm diameter and 10 cm length). Any visible fat was removed from the muscle tissues. Measurements of pH, color, tensile strength analysis, lipid oxidation, microbial and sensory quality were conducted on meat samples. A Packaging machine model A200, (Henkelman, Netherlands) was used for packing. Meat samples were randomly assigned to packages (sterile polyester polyethylene (PET/Poly) pouches (thickness-62lm)). The samples were packed and sealed aseptically in polyethylene pouches and divided into two sets, one group of ostrich meat was kept as control (nonirradiated) and another group was irradiated with gamma. The packs remained in storage at 4°C for the entire duration of the experiment. Samples were analyzed at 0, 7, 14, 21 days post-slaughter.

2.2. Irradiation

Packaged ostrich meat samples were gamma irradiated at the Atomic Energy Organization of Iran (AEOI, Tehran, Iran) inside a package irradiator (Gamma Cell 220, Nordion Intl. Inc., Ontario, Canada) with a ^{60}Co source at a dose rate of 1.576 kGy/h. The dose rate was established using alanine transfer dosimeter to make sure that the dose reached the target dose.

2.3. pH measurement

pH was measured on each sampling day, one piece of meat from each treatment was homogenized in 20 mL of distilled water for 2 min using the Stomacher Lab-Blender 400 (Seward Medical, London, U.K.). The pH of the meat slurry was measured using a pH meter (Hanna, 211, Mauritius).

2.4. Measurement of color values

The color of the raw muscle slices were recorded according to the method described by Honikel (1998) with the use of a Color-guide 45°/0° colorimeter (Cat no: 6805; BYK-Gardner, USA). Muscle slices (1.5–2.0 cm thick) were allowed to ‘‘bloom’’ for 30 min at room temperature (20 °C) prior to color measurements. Color measurements were recorded in triplicate for each sample at randomly selected positions and expressed by the coordinates L*, a* and b* of the CIE Lab colorimetric space (Minolta 1998). Total color difference (DE) was calculated using the following equation: $DE=[(L^*\text{-}L^*_{day\,0})^2 + (a^* - a^*_{day\,0})^2 + (b^* - b^*_{day\,0})^2]^{1/2}$. Five readings per package were recorded for a total of 10 readings per packaging treatment.

2.5. Lipid oxidation

Lipid oxidation was evaluated by the determination of thiobarbituric acid reactive substances (TBARS) using the extraction method described by Witte et al. (1970). Twenty grams of the minced meat were blended with 50 mL of cold solution containing 20% trichloroacetic acid in 2 M phosphoric acid for2 min. The resulting slurry was then transferred into a100 mL volumetric flask. The slurry was diluted to 100 mL with double-distilled water, homogenized by shaking and filtered through Whatman no. 1 filter paper. Five mL of the filtrate was then pipetted into a test tube and 5 mL of fresh chilled 2- thiobarbituric acid (0.005 M in double distilled water) was added. The test tube was shaken well and placed in the dark at room temperature (25°C) for15 h to develop the color reaction. The resulting color was measured in a spectrophotometer at 530 nm to calculate the TBARS value. The results were expressed as mg malonaldehyde/kg meat.

2.6. Sensory evaluation

A sensory test, using a consumer type panel, comprised of 5 staff members from different departments, was employed to detect sensory differences samples within 6 months after storage in freezing condition. Each

untrained panelist received four coded samples. Each member independently evaluated the turkey meat for taste, odor, color and flavor on a 5-point hedonic scale (1: extremely poor, 2: poor, 3: acceptable, 4: good and 5: excellent) (Lavrova and Krilova 1975). Evaluation was performed under cool white fluorescent light in the sensory laboratory. The same meat samples were evaluated over storage times. The shelf life limit was defined as the point when 50% of the panelists rejected the sample.

2.7. Statistical analysis

Data from microbial, chemical and sensory analysis were subjected to an analysis of irradiation doses (0, 1.0 and 3.0 kGy), and storage time (1, 7, 14, and 21 days) by simple and interaction effects using two-way ANOVA. Comparison of means were based on Post Hoc multiple test (Tukey). Data were analyzed using the SAS (1988) statistical package.

3. Results and discussion

3.1. pH

The effect of various levels of gamma irradiation on pH of ostrich is shown in Table 1. One of the parameters responsible for meat quality is its pH. On the average, ostrich meat has been classified as intermediate, *i.e*. of pH from regular (<5.8) to high (>6.2) as measured 24 hours post-slaughter (Sales and Mellett 1996). These values were further confirmed by Otremba *et a*l. (1999) and Majewska *et al.* (2009) and make ostrich meat ideal for processing (Sales and Mellett 1996; Fisher *et al*. 2000) even though its high pH could lead to elevated water-holding capacity (Sales 1994). Initial pH was approximately 6.12. No significant differences in pH value of ostrich meat were observed due to irradiation. The effect of gamma irradiation on the characteristics of ostrich meat has not been previously investigated, but similar observations on other kinds of meat were reported by Mahmoud (1988) who found no significant differences in chemical composition such as moisture content, crude protein, crud fat and ash content of buffalo meat treated with 2.5, 5.0 and 7.5 kGy doses of gamma irradiation. Gamma irradiation up to 4.5 kGy had no effect on the chemical composition of cooked meat components (Rady *et al*. 2005).

Table 1
The pH of packaged ostrich meat affected by radiation dose and storage time at 4 °C.

Storage time	0 kGy	1kGy	3 kGy
Day 0	6.11[a]	6.10[a]	6.08[a]
Day 7	6.07[ab]	6.08[a]	6.07[a]
Day 14	5.92[b]	5.93[b]	5.91[b]
Day 21	5.79[c]	5.83[c]	5.81[c]

[a-c] values in the same column with different superscripts are significantly different (p <0.05).

3.2. Lipid oxidation

Effects of irradiation doses on lipid oxidation of ostrich meat during storage were compared (figure 1). With aerobic packaging, irradiated ostrich meat had higher TBARS values than the nonirradiated. The TBARS values of aerobically packaged meat increased with storage and the increase was greater by irradiation. Although lipid oxidation was not directly related to the pink color of irradiated ostrich meat, the high TBARS values in aerobically packaged meat partially explained the low a-values. Lipid oxidation proceeded along with pigment oxidation during aerobically pack- aged storage. Under air packaging conditions, the TBARS values of ostrich meat increased by approximately 5-fold from 0day values to 21 days of storage. After 7 days of storage, the TBARS values meat samples were the highest in air-packaged irradiated, followed by air-packaged nonirradiated. Figure 1 illustrates that prior irradiation causes accelerated lipid oxidation in ostrich meat during subsequent storage. But oxygen exposure is a more important factor than irradiation in catalyzing lipid oxidation of raw meat patties during storage. TBA values for ostrich meat in air-packaged irradiated and nonirratiated at 7 and 14 days of display were more than 3 mg MDA/kg meat, respectively. In MAP meat, the amounts of TBARS formed in the course of storage were far below the critical value of 3 mg/kg at which rancidity is detected (*Wong et al.,* 1995). The TBA values have

been commonly considered as an index of lipid rancidity. Subsequent decomposition of the unstable lipid oxides produces malonaldehyde. Increase of the TBA values during storage is due to the decomposition of the oxidized lipids (Alam *et al*. 2005). Spainer (1992) stated that the amount of heme catalyst (from hemoglobin, myoglobin and cytochrome) and the amount of heme and non-heme iron present in meat tissue was related to lipid oxidation rate. Ostrich meat has high heme iron (Sales and Hayes, 1996) and polyunsaturated fatty acid (Sales *et al.* 1996) contents make ostrich meat susceptible to oxidation. There are many factors such as fat content, pro-oxidant concentrations (e.g. iron), antioxidant types and concentrations (e.g. tocopherol and antioxidant enzymes), and lipid membrane concentrations (e.g. amount of mitochondria) that could be responsible for some of the differences in oxidation rates of different muscles. However, fat content in meat might have played an important role in lipid oxidation of raw meat (Ahn *et al*. 1998).

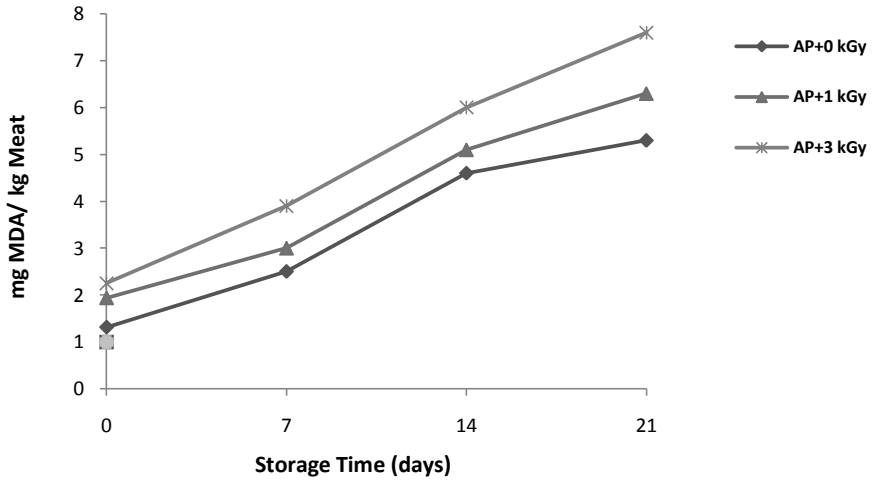

Fig. 1. Changes in Thiobarbituric acid (TBA) value of irradiated and nonirradiated ostrich meat during refrigerated storage. AP: air-packaged.

3.3. Color values

Table 2 presents the influence of irradiation conditions on color L-values of ostrich meat during storage. It includes the three primary (L*, a* and b*) color co-ordinates used in the Hunter system to determine color. Chemical changes in raw meat such as protein denaturation, oxidation, hydrolysis, changes in pH, and enzyme action are also significant factors affecting the color of raw meat (Reid 1999). Initial mean surface L* value of 39.5 was similar to reported by other authors (Navarro et al. 2000) and it decreased during storage in all cases. Generally, the L* value decreased during 21 days of storage in 4°C. These results agree with previous observations (Jouki and Khazaei, 2011). We also observed that L* value differed between packaged-meat samples under air packaging. Although the samples were irradiated the values were reduced in all cases (i.e. meat darkening) and the differences were not a significant. Results for color determination show that irradiation doses of 1.0 and 3 kGy had no effect on the L* values when compared to the non-irradiated controls (Table 2). High L* values indicate samples light (white) in color, whereas low L* values indicate samples dark in color. Although no differences in L* values were found among the treatment groups and controls, differences in a* and b* values were detected. Color a-values of ostrich meat during storage were influenced ($p<0.05$) by irradiation treatment. When irradiation was combined with aerobic conditions, further reduction in a-values was observed in all meat samples during the 21 days of storage. The surface color was grayish brown regardless of irradiation, and the a-values decreased due to color oxidation during storage. Surface +a* value fell down during storage in all cases. The a* values decreased ($P<0.05$) for meat in air packages in the first 7 days of display. The pink color intensity of the inside of ostrich meat was stronger in irradiated meat than the nonirradiated, and the a-value was irradiation dose-dependent. The pink color inside of aerobically packaged meat, however, mostly discolored to brown or yellow regardless of irradiation at 3 weeks because of pigment oxidation. Under vacuum packaging, the increased redness was irradiation dose-dependent, and it was stable during the storage. Results similar to those found in our study have also been

observed in other studies. A study by Byun *et al.* (1999) indicated that irradiation with 3 and 5 kGy caused significant increases in a* values in raw and cooked pork loins. Color b-values of ostrich meat during storage were also influenced ($p < 0.05$) by the irradiation treatments. Irradiation decreased the b-values of aerobic-packaged ostrich meat samples. The color data in ostrich meat with different irradiation indicated that irradiation had a significant ($p < 0.05$) effect on color components (L-, a-, b-values). Color changes of ostrich meat were not directly related to lipid oxidation and the generation of off-flavor in irradiated ostrich meat. Total color difference (DE) indicates the magnitude of difference between locations in the CIE L* a* b* color system (Table 2). Higher DE results indicate a greater relative change in color compared to the meat's original color. The DE value was highest for the ground ostrich meat in air-packaged irradiated followed by that in air-packaged nonirradiated. According to our results, samples of ostrich meat packed in air treatments (≥ 5% O_2) were considered less acceptable. Additionally, red color is best kept in air-packaged for 14 days.

Table 2
Changes of color (L*, a*and b*) of irradiated and nonirradiated Ostrich meat during storage at 4°C.

Color attributes/ time		0 kGy	1 kGy	3 kGy
Lightness (L*)	Day0	39.92^{a}	39.77^{a}	39.76^{a}
	Day7	38.17^{b}	38.05^{b}	37.88^{b}
	Day14	$38.11^{b,w}$	$37.67^{ab,wx}$	$37.43^{bc,wx}$
	Day21	$35.97^{c,w}$	$35.76^{c,wx}$	$35.60^{c,wx}$
Redness (a*)	Day0	16.22^{a}	15.95^{d}	15.80^{a}
	Day7	$15.31^{b,wx}$	$15.02^{c,x}$	$14.12^{b,y}$
	Day14	$14.67^{c,y}$	$13.60^{b,yz}$	$13.26^{c,z}$
	Day21	$11.80^{d,y}$	$11.20^{a,yz}$	$10.91^{d,z}$
Yellowness (b*)	Day0	10.95^{a}	10.95^{a}	10.56^{a}
	Day7	$8.10^{ab,wx}$	$8.11^{b,wx}$	$7.68^{b,x}$
	Day14	$7.27^{b,w}$	$6.90^{c,wx}$	$6.71^{bc,wx}$
	Day21	$5.91^{c,wx}$	$6.14^{c,w}$	$6.01^{c,wx}$
ΔE	Day0	0	0	0
	Day7	3.17	3.44	3.82
	Day14	4.55	5.13	5.16
	Day21	8.01	7.85	7.86

$^{a-d}$ values in the same column with different superscripts are significantly different ($p < 0.05$).
$^{w-z}$ values in the same raw with different superscripts are significantly different ($p < 0.05$). AP (Air packaging).

3.4. Sensory quality

The ostrich meat was also evaluated for changes in surface color, texture, and odor by semi-trained panelists. The sensory attributes of irradiated ostrich meat during storage at 4˚C are shown in figure 4. By the 7 days of the storage time, irradiated air-packaged samples were acceptable (scores >6). The surface of the samples, especially those irradiated air-packaged, was not severely discolored and remained acceptable even after 7 days storage. Storage time effect within treatment indicated that surface discoloration increased ($P<0.05$) especially at day 21 in nonirradiated air-packaged samples and irradiated air-packaged samples. The data suggest that gamma irradiation of air-packaged meat samples protected the surface color. Panelists rejected air packaged samples after 7 days storage at 4°C. At day 21, air packaged ostrich meat samples received lower scores than other samples (about color and texture). The acceptable samples were described as having good appearance or natural odor without any sign of rancidity. The ostrich meat packaged in air quickly lost its qualities (especially odor and texture) during 7 days of storage period. The acceptability results from figure 2 indicated that storage time and radiation doses had significant impacts on panel acceptability. In our present study, irradiation at dose 1 kGy extended the shelf life of air-packaged Ostrich meat about 9 days a compared to the air-packaged samples (7 days) stored at refrigeration temperature. Miyauchi *et al*. (1964) stated that the average sensory score of 6 might be acceptable. On the basis of organoleptic evaluation, it was found that irradiation dose of 1 kGy could extend the shelf life of ostrich meat for 9 days.

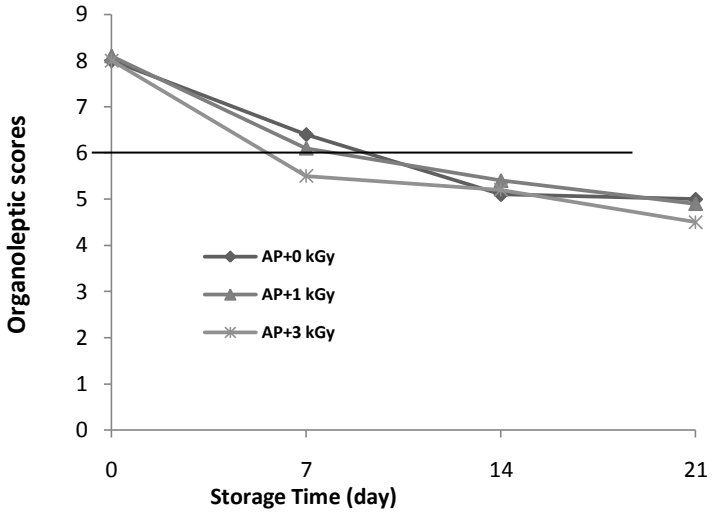

Fig. 4. Organoleptic scores of irradiated ostrich meat during refrigerated storage. AP= Air packaging.

4. Conclusion

Irradiation increased TBARS and off odor in aerobically packaged ostrich meat. Irradiation improved the color of the meat samples. The reduction of the L* parameter for all exposed samples, was not significant ($\alpha = 0.05$). A significant reduction in the a* parameter was observed in femoral musculature for a dose of 3 kGy. Packaging and storage condition of raw meat after irradiation were important factors in lipid oxidation of ostrich meat. The results of this study indicates that lipid oxidation is a major problem in irradiated (1.5 and 3.0 kGy) air-packaged ostrich meat stored at 4°C up to 21 days. Irradiation also caused significant loss of color and sensory quality in aerobic packages. Considering the sensory analyses, color and TBA analyses as a whole, air-packaged samples irradiated at 1.0 kGy were acceptable for 9 days under refrigerated storage.

Acknowledgements

The authors extend their sincere gratitude to Young Researchers Club- Islamic Azad University- Shahr-e-qods Branch, Tehran, I. R. Iran, for having provided all facilities to conduct the above research work.

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