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Quality Evaluation of Sliced and Pizza Cheeses Treated by Gamma and Electron Beam Irradiation

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ABSTRACT : This study was conducted to evaluate and compare the quality changes of commercial sliced and pizza cheeses processed by gamma and electron beam irradiation. The L*-value of sliced and pizza cheeses decreased and the a*-value decreased only in pizza cheese by both irradiation sources. There was no change in pH. There was no difference in 2-thiobarbituric acid reactive substances (TBARS) value between non-irradiated and irradiated samples at a dose of 3 kGy or less ($p<0.05$). However, both irradiation sources resulted in increased TBARS value in sliced and pizza cheeses at 5 kGy. Sensory evaluation revealed that irradiation influenced odor, taste and overall acceptability of both cheeses and may cause the limitation of consumers' acceptance for irradiated cheese products. Results indicate that both gamma and electron beam irradiations with less than 3 kGy may not influence significantly the physicochemical quality of sliced and pizza cheeses. However, to meet a market requirement, a method to overcome the sensory deterioration of cheeses should be developed and applied. (**Key Words :** Sliced and Pizza Cheeses, Quality, Gamma Irradiation, Electron Beam Irradiation)

INTRODUCTION

In dairy industry, cheese is one of the major manufactured goods and has become a predominant consumer product for large segments of the population (IDFA, 2004). The cheese consumption of Korea has increased rapidly since 1990s (Kim et al., 2007b). However, hygienic quality of cheese products can be sometimes threatened by the growth of food-borne pathogens such as *Listeria monocytogenes*, *Staphylococcus aureus*, and *Escherichia coli* due to inadequate management of the storage temperature (Thayer et al., 1998; Kaan Tekinsen and Özdemir, 2006; Jo et al., 2007). Infants, children, and immunosuppressed patients, especially, are very likely to acquire food borne disease (Kanbakna et al., 2004).

Irradiation technology is effective in reducing microorganisms and viruses, and is known as a good method for inactivating pathogens in food materials. Use of ionizing radiation has been gradually increasing worldwide (WHO, 1999). Sources of ionizing radiation that can be used for food sanitation are gamma ray, electron beam and X-ray (WHO, 1988). A major characteristic of gamma irradiation is its high penetrating power, which facilitates its use in treatment of bulk items. On the other hand, this penetration power is a major limitation of electron beams for food use although it has some advantages over gamma ray. With electron beam irradiation, the maximum thickness of the products is about 8 cm when it is used as the energy of 10 MeV with both-sides treatment (Miller, 2005).

Irradiation of dairy product, however, has been generally considered to be unfeasible as the high fat content in these products can lead to development of the undesirable off-flavors after irradiation (Urbain, 1986). Therefore, very few references can be found about dairy products under irradiation. Adeil Pietranera et al. (2003) reported that 4 kGy-irradiated chocolate ice creams presented a very unpleasant taste, mostly rancid or burnt-like. Kim et al. (2008a) also indicated that gamma irradiation caused unfavorable changes in flavor and taste of vanilla ice cream at doses above 3 kGy. Direct and indirect effect of irradiation process increased oxidative deterioration of cheeses (Dipuo Seisa et al., 2004). However, low dose irradiation did not affect the proximate

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compositions of various cheese products (Duipuo Seisa et al., 2004; Konteles et al., 2009) and color, pH, lactose and lactic acid content of plain yogurt (Kim et al., 2008b). Furthermore, Kim et al. (2007a) demonstrated that the addition of mint or citrus flavor in the manufacturing ice cream with irradiation less than 3 kGy may enhance the safety and maintain proper sensory quality for sensitive consumer.

Kim et al. (2010) reported that irradiation of 1 kGy for sliced cheese and 3 kGy for pizza cheese were sufficient to lower the total aerobic bacteria to undetectable level. Inoculation test of pathogens including *L. monocytogenes* and *S. aureus* showed that gamma irradiation was more effective than electron beam at the same absorbed dose, and D_{10} values ranged from 0.84 to 0.93 kGy for *L. monocytogenes* and from 0.60 to 0.63 kGy for *S. aureus* (Kim et al., 2010).

As described, a low dose irradiation can improve the microbial quality significantly and reduce the risk of contamination of cheese products by the food-borne pathogens which can potentially occur during processing, however, the quality changes of such irradiated cheese products has not been well documented. Therefore, the objective of this study was to evaluate and compare the quality changes of commercial sliced and pizza cheeses after gamma and electron beam irradiation.

MATERIALS AND METHODS

Sample preparation

Sliced and pizza cheeses produced from the same company were purchased from a local market in Daejeon, Korea. The samples (approximately 10 g) were transferred into a sterilized oxygen-impermeable nylon bags (2 ml O^2/m^2/24 h at 0°C, 0.09 mm thickness; Sunkyung Co. Ltd., Seoul, Korea) with a sterilized spoon in a clean bench. The packs were sealed and transferred to a refrigerator and stored.

Gamma and electron beam irradiation

Packed samples were irradiated in a cobalt-60 gamma irradiator (point source, ACEL, IR-79, MDS Nordion, Ontrario, Canada) at the Korea Atomic Energy Research Institute, Jeongeup, Korea. The source strength was approximately 11.1 PBq with a dose rate of 10 kGy/h. Dosimetry was performed using 5 mm diameter alanine dosimeters (Bruker Instruments, Rheinstetten, Germany), and the free radical signal was measured using a Brucker EMS 104 EPR Analyzer. The dosimeters were calibrated against an international standard set by the International Atomic Energy Agency (Vienna, Austria).

At the same day, the prepared samples were also irradiated in a linear electron beam RF accelerator (Energy 2.5 MeV, beam power 40 kW, EB Tech, Daejeon, Korea) at 10±0.5°C. The beam current was in the range of 0-4.5 mA. Irradiation was performed in the presence of air, 2.5 MeV of energy and a conveyor velocity of 10 m/min. The dose rates were 0.55, 1.5 and 2.5 kGy/s. Cheeses were irradiated to 0.5 cm of thickness for both samples with irradiation sources due to the low penetration power of electron beam. To confirm the target dose, alanine dosimeters attached to the top and bottom surfaces of the sample pack were read using a 104 Electron Paramagnetic Resornance unit (EMS-104, Bruker Instruments Inc., Bullerica, MA). The applied doses in this study were 0, 1, 3 and 5 kGy. After irradiation, the samples stored in a refrigerator set at 4°C for further analysis.

Color measurement

Color of the sample surface was measured by a color difference meter (Spectrophotometer CM-3500d, Minolta Co., Ltd. Osaka, Japan). The numerical value of the color was expressed by the lightness (L*), redness (a*, ±red-green) and yellowness (b*, ±yellow-blue). The Hunter values were monitored by a computerized system by using spectra magic software (version 2.11, Minolta Cyberchrom Inc. Osaka, Japan).

pH

Sample (5 g) and 15 ml of deionized distilled water (DDW) were homogenized for 15 sec. The pH changes of homogenate were measured using a pH meter (Model 520A, Orion Research Inc., Boston, USA).

Lipid oxidation

Lipid oxidation was determined as a 2-thiobarbituric acid reactive substances (TBARS) value. Cheese (5 g) and 15 ml of DDW were homogenized with 50 μl BHA (7.2%) for 15 sec. Two milliliter of the homogenate was transferred to a disposable test tube and then four milliliter of thiobarbituric acid (TBA)/trichloroacetic acid (TCA) (20 mM TBA in 15% TCA) solution was added. The mixture was blended and incubated in a boiling water bath for 15 min. The sample was cooled in cold water for 10 min, and then centrifuged for 15 min at 2,500×*g* at 4°C. Absorbance was measured at 532 nm and the lipid oxidation was reported as mg malondialdehyde/kg sample.

Sensory evaluation

Trained panelists (n = 10) were used to evaluate sensory properties of the irradiated and non-irradiated sliced and pizza cheeses. The sensory parameters were color, odor, taste, overall acceptability, and irradiation off- odor. A 7 point hedonic scale was provided to the panelists as follows; like very much (7), like moderately (6), like slightly (5), neither like nor dislike (4), dislike slightly (3), dislike moderately (2), and dislike very much (1). For irradiation off-odor no off-odor (1) and very strong off-odor (7) were provided. The results were averaged and statistically compared.

Statistical analysis

The data were analyzed by the Statistical Package for the Social Science (SPSS, 1997) program. Differences among the mean values were obtained by Duncan's multiple comparison tests at $p<0.05$.

RESULTS AND DISCUSSIONS

Color changes

The Hunter color value changes of sliced and pizza cheeses by gamma and electron beam irradiation are shown in Table 1. The L*-values decreased significantly with an increase of irradiation dose in all samples. The a*- and b*-values did not show any differences by irradiation dose in sliced cheese. However, a*- and b*- values of pizza cheese decreased significantly with an increase of irradiation doses. The Hunter color value changes of sliced and pizza cheeses did not show any differences by radiation sources. Hashisaka et al. (1990) reported that cheese was the product most sensitive to lightness (L*-value) as a result of gamma irradiation treatment and irradiated cheese became less yellow and less red. Oh et al. (2005) reported that browning reaction was occurred in sugar-lysine solution by gamma irradiation and this may be one of the reasons for the lower L*-value in irradiated cheeses. In the case of Feta cheeses, the Maillard reaction may occur between milk proteins or amino acids with milk lactose by irradiation (Konteles et al., 2009). Similarly, the L*-values of ice cream and yogurt were decreased browning reaction by gamma irradiation (Kim et al., 2008a; Kim et al., 2008b) and agreed well with the present result.

pH changes

The pH changes of gamma- or electron beam-irradiated sliced and pizza cheeses are shown in Table 2. The ranges of pH were from 6.58 to 6.68 for gamma irradiation and from 6.57 to 6.67 for electron beam irradiation. The pH changes of sliced and pizza cheeses did not show any differences by irradiation dose and radiation sources. Very few references can be found about pH changes of dairy products after irradiation. The pH changes of yogurt and Feta cheese did not show any differences by gamma irradiation (Kim et al., 2008b; Konteles et al., 2009) which is consistent with the results of this study.

Lipid oxidation

The TBARS value was used to investigate the inhibition effect of lipid oxidation by the irradiated sample and the

Table 1. Hunter color values of sliced and pizza cheeses treated by gamma and electron beam irradiation

Sample	Irradiation sources	Irradiation dose (kGy)	Hunter value		
			L	a	b
Sliced cheeses	Gamma ray	0	65.06^{a}	-1.42	0.64
		1	63.71^{a}	-1.42	0.54
		3	61.92^{ab}	-1.33	0.66
		5	57.11^{b}	-1.28	0.96
		SEM[1]	2.21	0.17	0.72
	Electron beam	0	65.12^{a}	-1.42	0.65
		1	63.75^{a}	-1.42	0.53
		3	61.87^{ab}	-1.35	0.61
		5	58.13^{b}	-1.29	0.85
		SEM	2.20	0.16	0.71
Pizza cheeses	Gamma ray	0	64.70^{a}	-1.27^{a}	1.63^{a}
		1	63.25^{ab}	-1.33^{a}	1.20^{a}
		3	60.33^{bc}	-1.40^{ab}	1.09^{a}
		5	57.23^{c}	-1.53^{b}	0.34^{b}
		SEM	1.34	0.06	0.29
	Electron beam	0	64.71^{a}	-1.28^{a}	1.65^{a}
		1	63.23^{ab}	-1.32^{a}	1.21^{a}
		3	60.32^{bc}	-1.41^{ab}	1.08^{a}
		5	57.27^{c}	-1.55^{b}	0.36^{b}
		SEM	1.37	0.06	0.31

[1] Standard errors of the mean (n = 3).

[a-c] Means with the same letter in each sample are not significantly different ($p<0.05$).

Table 2. The pH changes of sliced and pizza cheeses treated by gamma and electron beam irradiation

Irradiation sources	Irradiation dose (kGy)	Sliced cheese	Pizza cheese
Gamma ray	0	6.63	6.58
	1	6.65	6.59
	3	6.67	6.61
	5	6.68	6.61
	SEM[1]	0.03	0.03
Electron beam	0	6.62	6.65
	1	6.67	6.63
	3	6.67	6.60
	5	6.65	6.57
	SEM	0.03	0.10

[1] Standard errors of the mean (n = 3).

result of sliced and pizza cheeses are shown in Figure 1. TBARS values of 5 kGy-irradiated samples were greater than those from the other samples. The TBARS values of sliced and pizza cheeses did not show any differences by radiation sources. Kim et al. (2007b) indicated that TBARS values increased as the increase of irradiation dose, but there was no significant difference between non-irradiated and irradiated (less than 3 kGy) cheddar cheese. This is an indication of oxidation of lipids by the irradiation process by producing OH radicals formed due mainly to water radiolysis (Lee et al., 2005). This increase of lipid oxidation also related with color change since the reaction of lipid oxidation products with amino acids and proteins has been related to browning in many food products, particularly fatty ones (Zamora and Hidalgo, 2005).

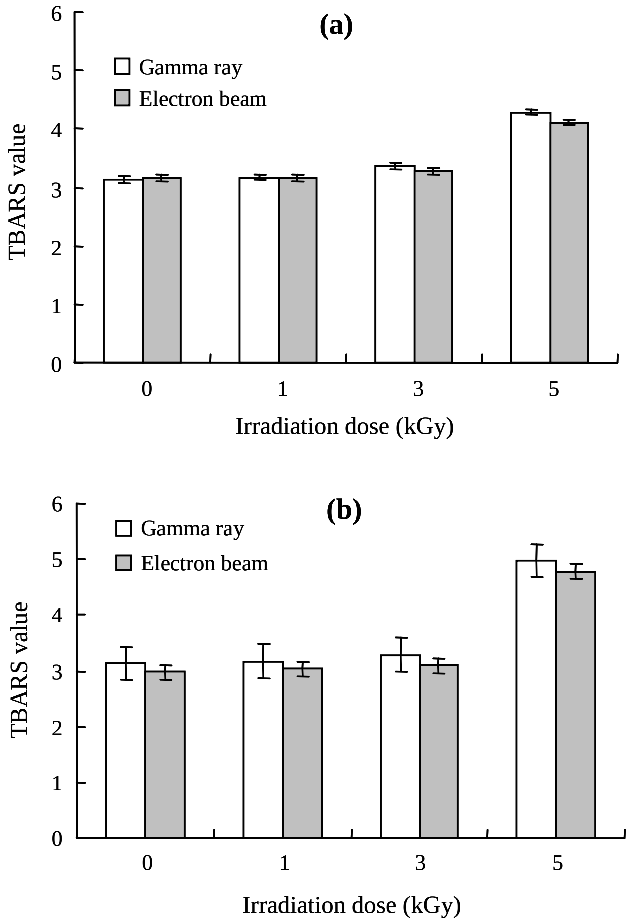

Figure 1. 2-thiobarbituric acid reactive substances of sliced (a) and pizza cheeses (b) treated by gamma and electron beam irradiation.

Sensory evaluation

Table 3 and 4 shows the sensory results of sliced and pizza cheeses treated by gamma and electron beam irradiation. The result indicates that panelists did not see any differences in color in irradiated cheeses. It means that even though instrumental color values, mainly lightness, were changed, it may not be as significant as recognized by

Table 3. Sensory attributes of sliced cheeses treated by gamma and electron beam irradiation

Irradiation dose (kGy)	Color	Odor	Taste	Overall acceptability	Off-odor
Gamma ray					
0	5.80	5.70[a]	6.40[a]	6.30[a]	2.00[c]
1	5.70	4.60[b]	3.50[b]	3.80[b]	3.00[b]
3	5.50	3.90[b]	3.40[b]	3.50[b]	3.90[b]
5	5.50	1.90[c]	2.30[b]	1.60[c]	6.20[a]
SEM[1]	0.36	0.51	0.61	0.54	0.61
Electron beam					
0	5.30	5.90[a]	5.50[a]	5.70[a]	1.50[c]
1	5.10	4.30[b]	4.60[a]	4.50[b]	1.90[c]
3	5.00	2.60[c]	2.50[b]	2.60[c]	4.20[b]
5	5.10	1.80[c]	1.70[b]	1.40[d]	5.90[a]
SEM	0.39	0.43	0.62	0.58	0.59

[1] Standard errors of the mean (n = 3).

[a-c] Means with the same letter in each sample are not significantly different (p<0.05).

Table 4. Sensory attributes of pizza cheeses treated by gamma and electron beam irradiation

Irradiation dose (kGy)	Color	Odor	Taste	Overall acceptability	Off-odor
Gamma ray					
0	5.30	5.90[a]	6.10[a]	6.40[a]	1.00[c]
1	5.40	4.30[b]	3.90[b]	4.10[b]	3.20[b]
3	5.50	3.30[bc]	3.30[bc]	3.40[bc]	3.50[b]
5	4.90	2.40[c]	2.30[c]	2.30[c]	5.70[a]
SEM[1]	0.43	0.55	0.65	0.55	0.65
Electron beam					
0	5.30	6.00[a]	5.50[a]	6.10[a]	1.90[c]
1	5.40	4.30[b]	4.20[b]	4.40[b]	2.50[bc]
3	4.80	2.70[c]	2.80[c]	2.60[c]	3.70[b]
5	4.70	1.90[c]	1.80[c]	1.90[c]	5.40[a]
SEM	0.40	0.52	0.62	0.50	0.67

[1] Standard errors of the mean (n = 3).
[a-c] Means with the same letter in each sample are not significantly different ($p<0.05$).

bare eyes. However, gamma and electron beam irradiation of sliced and pizza cheeses influenced all other sensory parameters. Odor, taste, and overall acceptability of irradiated cheeses scored lower than those of non-irradiated sample and the scores were even lower when irradiation dose was increased. Off-odor can be detected by panelists at 1 kGy of gamma irradiation and 3 kGy of electron beam and the off-odor significantly increased when 5 kGy was applied. There was not much different in sensory score between gamma and electron beam irradiation. Sensory changes of cheddar cheeses and fried-frozen cheeses ball also affected other sensory quality by gamma irradiation (Lee et al., 2005; Kim et al., 2007b). During irradiation free radicals are produced and consequently lipid and/or protein oxidation are expected to be triggered. Free radicals are the precursors of lipid hydroperoxides that are regarded as primary oxidation products which, as oxidation progresses, lead to the production of secondary oxidation products (alkanes, alkenes, aldehydes, alcohols, ketones, and acids) (Nawar, 1985) that have been sensorially described as "fishy", "metallic", "rancid" and "oxidized" (Kochhar, 1996). From the results, the method to decrease or mask the sensory changes should be developed to obtain consumer's choice. Hashisaka et al. (1990) discussed that exposing dairy products to 40 kGy of gamma irradiation at -78°C resulted in little change in color or texture, but generally decreased the overall acceptability and characteristic flavors due to increased levels of off-flavors and after taste. However, certain flavors such as mint or citrus, and specific desirable flavor notes in certain products survived from high irradiation doses and it was successfully applied for the production of irradiated ice cream without any off-flavor (Kim et al., 2007a).

Previous studies reported that higher sterilization efficiencies were obtained in foods treated with gamma irradiation when compared with electron beam (Miller, 2005; Song et al., 2009; Waje et al., 2009). One of the reasons of this, in addition to penetration depth, can be explained as the difference of dose rate. Much higher dose rate of electron beam causes suppression of oxidation damage of microorganisms (Ito and Islam, 1994). However, in the aspect of cheese quality, no difference between gamma and electron beam irradiation was found.

In conclusion, both gamma and electron beam irradiations for improve the safety of sliced and pizza cheeses with less than 3 kGy may not influence significantly on the physicochemical quality of sliced and pizza cheeses. However, a processing method to remove or minimize the changes of sensorial quality of irradiated cheese should be a prerequisite for industrial application.

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