Development of Ice Cream with Improved Microbiological Safety and Acceptable Organoleptic Quality Using Irradiation

H. J. Kim*, A. Jang**, J. S. Ham***, S. G. Jeong***, J. N. Ahn***, M. W. Byun* and C. Jo**
Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute *,
Department of Animal Science and Biotechnology, Chungnam National University **,
Division of Animal Products and Processing, National Institute of Animal Science ***

감마선 이용 미생물학적 및 관능적 품질이 우수한 아이스크림의 개발

김현주* · 장애라** · 함준상*** · 정석근*** · 안종남*** · 변명우* · 조철훈**
한국원자력연구원 방사선과학연구소 *, 충남대학교 동물자원생명과학과 **,
축산과학원 축산물이용과 ***

요 약

감마선을 이용하여 미생물학적으로 안전하면서 관능적 품질이 우수한 아이스크림을 개발하기 위해 감마선에 안정적인 spearmint, mint 및 citrus향을 선발하고 이를 이용하여 감마선 조사에 의한 특유의 냄새변화가 없는 아이스크림을 제조한 후 품질을 비교하였다. 일반적인 조성은 향 무첨가 대조구와 처리구 사이에 차이가 없었으며, 총균수는 향 무첨가 대조구, spearmint, mint 및 citrus향 첨가구가 각각 2.38, 1.23, 1.38 및 1.15 log CFU/g 수준에서 검출되었다. 그러나 대조구는 3 kGy, 그 외 처리구는 1 kGy 선량에서 균이 검출되지 않았다. 관능검사 결과 mint향을 첨가하고 1 kGy 감마선 처리한 아이스크림과 citrus향을 첨가하고 3 kGy에서 감마선 처리한 아이스크림이 유의적으로 높은 기호도를 보였다. 따라서 3 kGy 이하의 감마선 조사와 mint 또는 citrus향의 선택적 첨가는 관능적으로 문제가 없으면서 유아, 노약자, 환자 등 민감한 소비자들에 대한 미생물학적 안전성을 확보하는 기술로 사용될 수 있을 것으로 판단된다.

(**Key words** : Ice cream, Irradiation, Safety, Sensory)

Ⅰ. INTRODUCTION

Ice cream is highly likely to be contaminated by microorganisms due to its high nutrients, neutral pH (6~7), and a relatively longer storage period (Kanbakna et al., 2004). A relatively low storage temperature and pasteurization steps during its processing are considered to eliminate most of hazard microorganisms. However, there is still a remained concern over the microbial safety of ice creams. During the processing after a pasteurization step, there is a potential hazard by an addition of contaminated ingredients or an improper handling of the final products including an abuse of the storage temperature. This is especially important in the preparation of soft ice cream as its final stage of production is carried out at the point of sale (M-E-Elahi et al., 2002).

Corresponding author : Cheorun Jo, Department of Animal Science and Biotechnology, Chungnam National University, Tel. : +82-42-821-5774 Fax : +82-42-825-9754. E-mai : cheorun@cnu.ac.kr

Incidence of *Bacillus cereus, Salmonella, Listeria,* and *Yersinia* in ice cream have been reported (Farber et al., 1991; Walker et al., 1990). Kanbakana et al. (2004) reported that 3~5 log CFU/g of general aerobic microbes had been detected in the ice cream when testing contamination from production to distribution stage. In Korea, Kim et al. (1998) pointed out that there was neither pathogenic microbe tracking program established to cope with free imports of dairy product, nor sufficient experimental data on *E. coli* O157:H7 and *L. monocytogenes* which recently drew attention as a main cause of food poisoning. National surveillances of milk and milk products conducted around the world have revealed that generally up to 5% of the ice cream produced is contaminated with *L. monocytogenes* (WHO, 1988). Infants, children, elderly people, and immunosuppressed patients, in particular, are very likely to acquire food borne diseases from this situation. This makes their food intake very restricted, avoiding all those products that could be a source of microorganisms. Pasteurization of dairy products inactivates many pathogens, but does not produce a sterile product (Adeil Pietranera et al., 2003; Warke et al., 2000).

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). Gamma 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 (Urbain, 1986). Therefore, very few references can be found about ice cream products under irradiation.

A research article was published for mentioning its inclusion to immunosuppressed children's diet at the Charring Cross Children's Hospital in London, United Kingdom (Pryke et al., 1994; Pryke and Taylor, 1995). Adeil Pietranera et al. (2003) reported that a gamma irradiation with 3 kGy reduced the microbial load of ice creams remarkably without impairing the quality for immunosuppressed patients. Kim et al. (2005a) also indicated that irradiation of 3 kGy can eliminate all the microorganisms present in commercial ice cream product. However, the improvement of sensory quality of the ice cream was needed.

The objective of the present study was to develop the manufacturing method of ice cream with microbiologically safe and proper sensory quality using irradiation for sensitive consumers such as children, elderly people, and immunosuppressed patients.

Ⅱ. MATERIALS AND METHODS

1. Sample preparation

Ten different flavors including apple, banana, chocolate, citrus, hazelnut, mint, peach, spearmint, strawberry and vanilla were irradiated at 0, 1, 3, and 5 kGy and sensory analysis was performed to see the flavor changes by irradiation (data not shown). Finally 3 flavors were selected because of the consistency of flavors after irradiation. Then, the ice creams with different flavors (control, spearmint, mint, and citrus) were manufactured in a pilot scale processing facility (National Livestock Research Institute, Suwon, Korea) with 40% cream, 15% sugar, 25% milk, 5.5% skim milk powder, 2% egg yolk, 12.5% water, and 0.2% flavor. Water (0.2%) was added instead of the flavor for the control. The manufacturing process for the ice creams is shown in Fig. 1. The ice cream was placed into a plastic container (approximately 100 g weight) and stored in a freezer (−45℃) before the analysis.

Materials
↓
Mix
↓
Pasteurization (64℃, 30 min)
↓
Homogenization
↓
Cooling (Tap water, 40℃~20℃)
↓
Flavor (control, spearmint, mint, and citrus)
↓
Ripening (4℃, 4 hrs)
↓
Freezing
↓
Hardening (−30℃)

Fig. 1. Manufacturing process for the ice cream with different selected flavors.

2. Gamma irradiation

The two days after manufacturing, the plastic container with ice cream were put in the carton box. The packed samples were irradiated in a cobalt-60 gamma irradiator (point source, ACEL, IR-79, MDS Nordion, Ontario, Canada) at the Korea Atomic Energy Research Institute, Daejeon, Korea. The source strength was approximately 100 kCi with a dose rate of 10 kGy/h at 12 ± 0.5℃. 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 Analyser. The dosimeters were calibrated against an international standard set by the International Atomic Energy Agency (Vienna, Austria). The applied doses in this study were 0, 1, 3 and 5 kGy with a frozen temperature kept using a dry ice in the carton box. The total time for irradiation process was 30 min. After irradiation, the samples stored in a freezer with temperature set at -20℃ for further analysis.

3. Analysis of general composition

Moisture content of ice cream was determined using a IR moisture analyzer (Scaltec instrument, SMO01, Germany). Total fat content was determined by Folch's extraction method (Folch et al., 1957). The crude protein content was determined using micro-Kjeldahl method.

4. Microbiological analysis

The prepared sample (10 g) was thawed in a 4℃ refrigerator and aseptically homogenized for 2 min in a sterile stomacher bag containing 90 mL of sterile 0.1% peptone water using a stomacher (bag mixer® 400, Interscience Co, France). Media for the enumeration of the total aerobic microbes was prepared by a total plate count agar (Difco Laboratories, Detroit, MI, USA). The plates were incubated at 37℃ for 48 h and the colony forming units (CFU) per gram were counted at a dilution of 30 to 300 CFU per plate. Experiments with each bacteria culture were independently conducted twice.

5. Sensory evaluation

Semi-trained panelists (n = 10) were used to evaluate sensory properties of the irradiated and non-irradiated ice cream with different flavors. The sensory parameters tested were color, odor, taste, overall acceptability, and off-flavor intensity. 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). The off-flavor intensity was scored as; no off-flavor (0) to very high off-flavor (7).

6. Statistical Analysis

Each set of data represents the mean values of two different experiments with four measurements of each experiment. Mean values and the standard deviation (SD, for microbial analysis) or standard errors of the mean (SEM) were calculated using a Statistical Analysis System (SAS Institute, 1990) and reported.

Ⅲ. RESULTS AND DISCUSSIONS

1. General composition

Table 1 shows the general composition of the ice cream manufactured with different flavors and different irradiation doses. The results indicate that gamma irradiated ice cream did not show any differences in all parameters including moisture, crude fat, and crude protein. Adeil Pietranera et al. (2003) reported that no major alterations on the macronutrients fraction were expected to occur on ice cream irradiated, considering the low radiation doses employed and the products were frozen state. According to Food Composition (Food composition and nutritional table, 1994), cream-based ice cream present a total solids content between 35% and 40%. This consists of 20~25% of carbohydrates, 3~6% of proteins and 4~10% of fat. In Korea, the general compositions of ice cream products present 60% water, 6.0% fat, and 4.2 % protein (Chae et al., 1997).

Table 1. General composition of the ice cream manufactured with selected flavors at different irradiation doses

Flavors	Irradiation dose (kGy)	General composition (%)		
		Moisture	Fat	Protein
Control	0	56.7	17.6	3.9
	1	58.6	18.9	4.7
	3	59.3	18.9	4.4
	5	56.8	15.9	4.8
	SEM[1)]	1.52	2.95	0.33
Spearmint	0	57.5	18.0	4.2
	1	56.8	17.1	4.2
	3	58.0	17.4	4.7
	5	59.3	16.6	4.4
	SEM	1.87	0.90	0.39
Mint	0	58.8	16.7	4.2
	1	57.7	14.2	4.4
	3	59.1	15.5	4.5
	5	58.0	17.3	4.5
	SEM	0.52	1.72	0.40
Citrus	0	58.2	16.5	4.4
	1	56.6	17.8	4.8
	3	59.8	16.8	4.8
	5	58.8	15.1	4.5
	SEM	1.43	1.03	0.40

1) Standard errors of the mean.

2. Microbial analysis

The initial microbial population of the ice cream with none (control), spearmint, mint, and citrus flavor were 2.4 ± 0.12, 1.2 ± 0.33, 1.4 ± 0.12, and 1.2 ± 0.21 log CFU/g, respectively (Table 2), in spite of the use of research purpose pilot plant for manufacturing the ice cream sample. Kamat et al. (2000) reported that 1 mL of ice cream contained an average of 5.5×10^6, 3.4×10^5, and 2.0×10^3 CFU of bacteria, yeast and moulds, and coliforms, respectively. Irradiation of 1 and 2 kGy reduced the respective microbial load by approximately a 1 or 2 log from the original microbial load. It was considered that the decrease of the microbial population after irradiation during storage was due to the post irradiation effect where the surviving cells that had been damaged by an irradiation were gradually inactivated, thus not adapting to the surrounding environment during a storage.

Total aerobic bacteria were not detected when

Table 2. Total aerobic bacterial count of the ice cream manufactured with those selected flavors at different irradiation doses

Flavors	Irradiation dose (kGy)	Viable cell counts (log CFU/g)
None	0	2.4 ± 0.12[1)]
	1	1.2 ± 0.21
	3	ND[2)]
	5	ND
Spearmint	0	1.2 ± 0.33
	1	ND
	3	ND
	5	ND
Mint	0	1.4 ± 0.12
	1	ND
	3	ND
	5	ND
Citrus	0	1.2 ± 0.21
	1	ND
	3	ND
	5	ND

1) Mean ± standard deviation.
2) Viable colony was not detected at detection limit < 10^1 CFU/g.

irradiated at 1 kGy in the ice cream manufactured with spearmint, mint, and citrus flavor. Recent investigations have found that the major monoterpenes, (S)-(-)-carvone and (S)-(-)-limonene were responsible for the antibacterial property of the spearmint, mint, and citrus oils (Valero and Salmeron, 2003; Moreira et al., 2005). Mint had a characteristically terpenic composition, with a predomination of methanol (40.55%), isomenthone (18.42%), and 1,8 cineole (5.26%). Limonene and carvone are the principal components of both spearmint and dill oil, while limonene was a monoterpene hydrocarvone and carvone is an oxygenated monoterpene (Aggarwal et al, 2002). There was no report on anti-microbial properties of gamma-irradiated spearmint and mint flavors. However, Kim et al. (2005b) reported that the antimicrobial activity of citrus essential oil was not changed by gamma irradiation. In another work, growths of *Bacilus subtilis*, *Staphylococcus aureus*, and *Escherichia coli* were inhibited by adding 0.1% citrus essential oil in designated broth, resulting into approximately 2-3 decimal reduction. *Trichophyton rubrum* and *T. mentagrophytes* were also showed 90.9 and 81.7% reductions, respectively by addition of 0.1% citrus essential oil (Jo et al, 2004).

3. Sensory evaluation

Table 3 shows the sensory results of the ice cream treated by gamma irradiation. The results indicate that irradiation of the ice cream did not show any differences in color. Interestingly, the taste and overall acceptability of the mint flavored ice cream obtained higher scores in 1 kGy-irradiated sample than that in control (P<0.05). Similar to this, the citrus flavored ice cream showed higher odor, taste and overall acceptability when irradiated at 3 kGy than control. The control and spearmint-flavored sample showed a less acceptance by increase of irradiation dose.

Adeil Pietranera et al. (2003) reported that non-irradiated, and irradiated vanilla ice cream did not show any differences in color, flavor, and overall acceptability. However, irradiated chocolate ice cream presented a very unpleasant taste, mostly rancid or burn-like (Adeil Pietranera et al, 2003). Hashisaka et al. (1990) reported that exposing dairy products to 40 kGy of gamma irradiation at －78℃ resulted in a little change in the color or texture, but it generally decreased the overall acceptability due to increased levels of off flavors and an after taste. However, certain flavors such as peppermint and specific desirable flavors notes in certain products survived at even higher irradiation dose. The

Table 3. Sensory evaluation of ice cream manufactured with those selected flavors at different doses of irradiation[1)]

Flavors	Irradiation dose (kGy)	Color	Odor	Taste	Overall acceptability	Off-flavor
Control	0	4.5	4.1	5.1[a]	5.3[a]	1.6[b]
	1	4.6	3.8	3.3[b]	3.4[b]	3.0[a]
	3	5.1	3.0	2.9[b]	3.3[b]	4.1[a]
	5	4.9	3.0	3.5[b]	3.4[b]	3.7[a]
	SEM[2)]	0.6	0.6	0.6	0.6	0.7
Spearmint	0	4.5	4.6	5.4[a]	5.1[a]	2.8[ab]
	1	4.6	4.5	5.1[a]	5.4[a]	2.4[b]
	3	5.3	4.3	3.6[b]	3.8[b]	3.1[ab]
	5	5.3	3.8	3.5[b]	3.4[b]	4.2[a]
	SEM	0.5	0.5	0.5	0.5	0.7
Mint	0	4.9	4.5	2.7[b]	3.0[b]	2.8[ab]
	1	4.9	5.3	5.6[a]	5.4[a]	1.9[b]
	3	5.2	4.0	3.1[b]	3.3[b]	3.7[a]
	5	4.5	4.0	3.4[b]	3.4[b]	2.9[ab]
	SEM	0.6	0.6	0.6	0.6	0.6
Citrus	0	4.7	4.4[ab]	4.3[ab]	4.0[ab]	3.1
	1	4.7	4.1[b]	4.6[a]	4.4[ab]	2.4
	3	4.4	5.1[a]	5.4[a]	5.1[a]	2.0
	5	4.9	4.1[b]	3.3[b]	3.6[b]	3.1
	SEM	0.6	0.5	0.6	0.7	0.6

[1)] Semi-trained panelists (n = 10) were used to evaluate sensory properties (7 : like very much; 6:like moderately; 5: like slightly; 4: neither like nor dislike; 3: dislike slightly; 2: dislike moderately; 1: dislike very much).
[2)] Standard errors of the mean.
[a-b] Different letters within the same column with same sample differ significantly ($P < 0.05$).

preliminary data from our laboratory indicated that spearmint, mint, and citrus flavors did not change flavor compounds or sensory characteristics by gamma irradiation among 10 different flavors including apple, banana, chocolate, citrus, hazelnut, mint, peach, spearmint, strawberry and vanilla (Unpublished data).

Ⅳ. CONCLUSIONS

It is well known that irradiation technology is one of the best methods to control the pathogens in foods, especially for the foods that are not applicable for heat treatment such as ice cream. However, the sensory property of irradiated ice cream should be considered for consumer acceptance. Irradiation of ice cream with citrus and mint flavors showed no changes of general composition but significantly enhanced the microbiological safety. Choosing a proper flavor for the ice cream and an application of irradiation may enhance the microbiological safety for a sensitive consumer group including children, elderly, and immuno-compromised patient with proper sensory quality.

Ⅴ. ABSTRACT

To develop the manufacturing method of ice cream with microbiologically safe and proper sensory quality using irradiation for sensitive consumer, 3 different flavors, which were resistant to their flavors against irradiation, were selected and used for ice cream manufacturing to reduce the irradiation-induced off-flavor problem. The general composition was not different among treatments. Total aerobic bacteria were detected as 2.38, 1.23, 1.38, and 1.15 log CFU/g level in ice cream with control (no flavor added), spearmint, mint, and citrus flavor, respectively. No viable cells were observed by irradiation at 1 kGy except for the control. Sensory evaluation indicated that the irradiated ice cream with spearmint flavor at 1 kGy and citrus flavor at 3 kGy had higher overall acceptability. Therefore, a low dose irradiation (less than 3 kGy) with mint or citrus flavors may enhance the safety of ice cream with proper sensory quality for sensitive consumer.

(**Key words** : Ice cream, Irradiation, Safety, Sensory)

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