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Microbial Quality and Physiochemical Changes of Grilled Fish Paste in a Group-Meal Service Affected by Gamma-Irradiation

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감마선조사에 의해 영향을 받은 단체급식용 구운 어묵의 미생물학적 품질과 이화학적 변화

김장호 · 전진용[1] · 유상렬[1] · 김영지[2] · 서정식[2] · 이주운 · 변명우
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Abstract

In the grilled fish paste stored at 5℃, the total aerobic bacterial counts were effectively reduced by 2.5 kGy or more. In the samples stored at 30℃, the total aerobic bacterial counts of the samples irradiated at 7.5 kGy were below to the limit of detection (2 log CFU/g). The TBA values of the irradiated samples were considerably higher than those of the controls but not proportional to the irradiation dose. It is apparent that an irradiation treatment causes very little textural degradation and the sensorial quality of the sample was maintained by an irradiation at 7.5 kGy or more.

Key words : grilled fish paste, total aerobic bacterial counts, irradiation, TBA value, textural degradation, sensorial quality

Introduction

Among various processed seafoods in Korea, fish paste is one of the most favorite products and the consumer demand for this product is increasing due to its convenience in food preparation and availability as a protein source. This product is made from various kinds of fish and by comparatively advanced technology and considered as a convenient food (1). In addition, fish paste is widely used in a group-meal service due to its nutritional value, cost, flavor, and so on.

Recently, food borne diseases have frequently broken out in a group-meal service mainly due to contaminated food materials (2). The outbreak in a group-meal service may lead to severe results in which numerous cases and even casualties could occur. In 2003, 77% of all cases in food borne outbreaks resulted from group-meal services (2). Consequently, it is essential to prevent a contamination of the food material to reduce the risk of food borne outbreaks.

Gamma irradiation has proven to be an effective treatment to eliminate a microbial contamination without any defect. Food irradiation uses up a low energy, causes little increase of product temperature and residual components, and can be used in a continuous process after packaging (3-5). The wholesomeness of food irradiation has been already approved by the international expert organizations such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA), and the U. S. Food and Drug Administration (FDA).

In the present study, the irradiation effect on the microbial quality and physiochemical properties of grilled fish paste were evaluated at different storage temperatures.

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Materials and Methods

Sample Preparation and Gamma Irradiation

Grilled fish paste was obtained from a local manufacturer and packaged in air and a vacuum. The samples in bags were irradiated with a dose rate of 7 kGy per hour of gamma ray to obtain 2.5, 5.0, 7.5, and 10.0 kGy by using a Co-60 gamma ray irradiating facility (IR-79, Nordion International Ltd., Ontario, Canada, 100 kCi). The irradiation dose was validated by using 5-mm diameter alanine dosimeters (Bruker Instrument, Rheinsttten, Germany) and the free radical was measured by using an EMS 104 EPR Analyzer (Bruker Instrument). The actual doses were within ± 2 % of the target doses.

Microbiological Analysis

After an irradiation, for 0, 3, 6, and 9 days of storage at 30℃ and 0, 1, 2, and 4 weeks of storage at 5℃ the samples were blended with 0.1% (W/V) peptone solution (Difco Laboratories, Detroit, MI) using a stomacher (BagMixer 400, Interscience Inc., St. Nom, France) for 2 min. After serial dilutions, 0.1 ml aliquots from appropriate dilutions were plated onto plate count agar (Difco Laboratories) for the total aerobic bacterial counts using a standard spread plate method. The plates in duplicate were incubated at 30℃ for 48 hr.

2-Thiobarbituric Acid (TBA) Value Measurement

Using the method of Jo and Ahn (6), 2thiobarbituric acid (TBA) values of the grilled fish pastes were measured during storage. A five gram sample was homogenized in a 50-mL centrifuge tube with a 50 μL of BHA (7.2 % in ethanol) and 15 ml of distilled water using a homogenizer (DIAX 900, Heidolph Co., Ltd., Schwabach, Germany). One milliliter of the homogenate was mixed with 2 ml of thiobarbituric acid (TBA)/trichloroacetic acid (TCA) solution (20 mM TBA in 15 % TCA) and heated in boiling water for 15 min. After cooling, the mixture was centrifuged for 15 min at 2,000 rpm using a centrifuge (UNION 5KR, Hanil Science Industrial, Co., Ltd., Incheon Korea). The absorbance of the supernatant was measured at 532 nm using a spectrophotometer (UV 1600 PC, Shimadzu, Tokyo, Japan). The concentration (mg/kg sample on the basis of wet weight) of malondialdehyde was calculated by using a determination curve.

Texture Analysis

Textural property was measured by the maximum shear force and the total shear force using a texture analyzer (TA-XT2I, Stable Micro Systems Co., Ltd., Surrey, UK) equipped with a probe that consisted of a blade set with knives. Using the strength (N/mm) versus time curve, the maximum shear force and the total shear force were computerized from the maximum peak and the area inside curve, respectively.

Sensory Evaluation

The sensory evaluation of the grilled fish paste was carried out by 13 panelists. Four sensory attributes were used to grade the overall quality in terms of irradiation odor, fish meat flavor, rotten odor, and slime and the definitions of the attributes are shown in Table 1. A 7-point scoring was used to evaluate the sensory attributes based on the descriptions; where 1-very weak, 2-weak, 3-slightly weak, 4-fair, 5-slightly strong, 6-strong, and 7-very strong.

Statistical Analysis

Experimental data was analyzed using an analysis of variance (ANOVA) and General Linear Models Procedure of a Statistical Package for Social Science 10.05 (7). Duncan's multiple range test was used to separate the treatment means at a significance of $p < 0.05$.

Table 1. The definitions of the descriptive attributes for the irradiated grilled fish meat paste

Sensory Attributes	Definition
Irradiation odor	Smell detected only from the irradiated samples
Fish meat flavor	Characteristic flavor of fish paste
Rotten odor	Malodor due to the rottenness of the sample
Slime	Debvelopment of the mucus material due to the rottenness

Results and Discussion

Microbiological Analysis

Table 2 shows the total aerobic bacterial counts of the irradiated grilled fish paste at different storage conditions. The total aerobic bacterial counts of the non-irradiated grilled fish paste were approximately 3-4 log CFU/g in both the air- and vacuum- packaging (Table 2). In the present study, during the storage at 5℃, the total aerobic bacterial counts of the non-irradiated samples were not significantly increased as the storage time was extended. However, during the storage at 30℃, the total aerobic bacterial counts of the non-irradiated samples in the air- and vacuum-packaging were considerably increased up to 9.27 and 8.70 log CFU/g during 3 days of storage and then decreased slightly as the storage time was increased. Thus, the storage temperature significantly affects the microbiological quality of the fish paste. This result is in accordance with other studies. Cho et al. (1) found that the total aerobic bacterial counts of fried fish pastes were increased from 3.3 log CFU/g to 7.2 and 4.7 log CFU/g in 5 days during a storage at 20℃ and 10 days during a storage at 3℃. Cho et al. (8) reported that the viable cell counts of fish pastes were increased from 2.3 to 5 log CFU/g in 2 days during a storage at 30℃ and 6 days during a storage at 15℃. In the grilled fish paste stored at 5℃, the total aerobic bacterial counts of the 2.5 kGy-irradiated samples after 4 weeks of storage were 3.55 and 3.54 log CFU/g in the air- and vacuum-packaging, respectively, and the total aerobic bacterial counts of the samples irradiated above 2.5 kGy were below the limit of detection (k2 log CFU/g). In the grilled fish paste stored at 30℃, even irradiation at 2.5 and 5 kGy could not eliminate the total aerobic bacteria from the grilled fish paste. The total aerobic bacterial counts of the 5 kGy-irradiated samples after 3 days of storage were 4.65 and 4.54 log CFU/g and they were increased up to 6.05 and 6.37 log CFU/g in the air- and vacuum-packaging, respectively after 9 days of storage. However, the total aerobic bacterial counts of the samples irradiated at 7.5 kGy or higher were below the limit of detection (2 log CFU/g). Cho et al. (1) reported that an irradiation at 3 kGy or higher reduced the total aerobic bacterial counts of fried fish meat paste by 1.5 log CFU/g and inhibited the total aerobic bacterial count at the level of 4 log CFU/g after 35 days of storage at 3℃.

Table 2. The total aerobic bacterial counts of irradiated grilled fish meat paste stored at different conditions

Storage period	Air packaging					Vacuum packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
	Total aerobic bacterial counts at 30℃									
0d	3.17[bx1)]	ND[2)]	ND	ND	ND	3.74[cx]	ND	ND	ND	ND
3d	9.17[ax]	6.52[bw]	4.65[x]	ND	ND	8.70[by]	6.51[bw]	4.54[x]	ND	ND
6d	8.36[aw]	6.83[abw]	6.82[wx]	ND	ND	8.41[awx]	7.59[abw]	6.48[wx]	ND	ND
9d	8.38[aw]	7.35[aw]	6.05[wx]	ND	ND	8.17[aw]	7.23[aw]	6.37[wx]	ND	ND
	Total aerobic bacterial counts at 5℃									
0wk	3.17[cy]	ND	ND	ND	ND	3.74[cy]	ND	ND	ND	ND
1wk	3.35[bcz]	ND	ND	ND	ND	3.42[z]	ND	ND	ND	ND
2wk	3.65[abxy]	ND	ND	ND	ND	3.81[z]	ND	ND	ND	ND
4wk	3.91[ax]	3.55[x]	ND	ND	ND	3.84[y]	3.54[y]	ND	ND	ND

1) Means followed by different letter are significantly different ($P<0.05$).

2) ND means 'not detected'.

2-Thiobarbituric Acid (TBA) Value

Table 3 shows the changes of the 2-thiobarbituric acid (TBA) values of the irradiated the grilled fish paste stored at different storage conditions. In the present study, the TBA values of the grilled fish paste were slightly increased as the storage period was extended. The TBA values of the irradiated samples were considerably higher than those of the non-irradiated sample but they did not increase in proportion to the irradiation dose (Table 3). This result was slightly different from the studies of irradiated fried fish paste (1) and irradiated chicken patty (9). Zhu et al. (10) stated that the TBA values were increased by the oxidation caused by the free radicals during the irradiation process. They reported that the TBA values of the irradiated samples were proportionally increased depending on the irradiation dose and storage period. The TBA values of the air-packaged samples were higher than those of the vacuum-packaged samples (Table 3). This result is in accordance with several other studies (1, 9, 10) and it is likely that the vacuum-packaging inhibits the rancidification of the irradiated samples by blocking the oxygen inflow.

Table 3. Changes of 2 thiobarbituric acid (TBA) values of irradiated grilled fish paste stored at different conditions

Storage period	Air packaging					Vacuum packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
	TBA value (μg malondialdehyde/g sample) at 30℃									
0 d	2.52^{bx}[1)]	3.60^{cw}	3.54^{w}	3.53^{bw}	3.91^{w}	2.52^{cx}	3.73^{x}	2.77^{x}	2.90^{x}	2.83^{x}
3 d	3.70^{awx}	3.90^{bw}	3.47^{x}	3.65^{bwxy}	3.55^{xy}	3.35^{by}	2.84^{z}	2.93^{z}	2.98^{z}	2.84^{z}
6 d	3.95^{aw}	3.99^{abw}	3.75^{wx}	3.50^{abx}	3.62^{wx}	3.78^{awx}	2.78^{y}	2.96^{y}	3.08^{y}	2.96^{y}
9 d	4.23^{aw}	4.14^{aw}	4.05^{wx}	3.73^{ax}	3.74^{x}	4.09^{aw}	2.98^{y}	2.96^{y}	3.04^{y}	2.99^{y}
	TBA value (μg malondialdehyde/g sample) at 5oC									
0 wk	2.52^{cy}	3.60^{cx}	3.54^{x}	3.53^{bx}	3.91^{x}	2.52^{cy}	3.73^{y}	2.77^{y}	2.90^{y}	2.83^{y}
1 wk	2.79^{bcz}	3.46^{xy}	3.18^{yz}	3.39^{xy}	3.79^{x}	2.73^{z}	2.92^{yz}	3.08^{yz}	2.96^{yz}	2.88^{yz}
2 wk	3.42^{abxy}	3.70^{x}	3.22^{xyz}	3.49^{xy}	3.72^{x}	2.67^{z}	2.81^{yz}	2.98^{yz}	3.00^{yz}	2.91^{yz}
4 wk	3.78^{ax}	3.82^{x}	3.67^{x}	3.74^{x}	3.79^{x}	2.80^{y}	3.15^{y}	3.13^{xy}	3.12^{xy}	3.19^{xy}

[1)] Means followed by different letter are significantly different ($P<0.05$).

Texture Analysis

Tables 4 and 5 show the maximum shearing force (N/mm) and total work of shearing (N/mm · S) of the irradiated grilled fish paste stored at different temperatures. In this study, there was no significant difference in the maximum shearing force between the non-irradiated samples and the irradiated samples. However, the maximum shearing force was slightly decreased as the irradiation dose was increased and as the storage period was extended even if the maximum shearing force was not proportional due to the different physical properties such as the thickness and homogeneity between the samples (Table 4). The total work of shearing of the grilled fish paste was slightly changed in a similar manner with the maximum shearing force (Table 5). Cho et al. (1) found that an irradiation at 5 kGy decreased the hardness of the fried fish paste but did not affect the other textural parameters such as adhesiveness, cohesiveness, elasticity, and chewiness. Lacroix et al. (11) reported that no significant difference in the pork meat texture was found in irradiated samples during 20 days of storage at 4℃. According to these findings, it is apparent that irradiation treatment causes very little textural degradation of the samples.

Table 4. Determination of the maximum shearing force (N/mm) of irradiated grilled fish stored at different conditions

Storage period	Air packaging					Vacuum packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
	Maximum shearing force (N/mm) at 30℃									
0 d	2.36^{ax}[1)]	2.41^{aw}	2.23^{ax}	2.34^{ax}	2.29^{ax}	2.27^{ax}	1.03^{bxy}	1.45^{by}	2.45^{ax}	2.13^{ax}
3 d	2.06^{abx}	0.99^{cz}	2.11^{abx}	2.43^{ax}	1.83^{bxy}	1.35^{ay}	1.85^{ax}	2.18^{ax}	1.87^{axy}	1.83^{ax}
6 d	1.80^{ax}	2.06^{ax}	1.99^{axy}	1.77^{ay}	1.92^{axy}	1.38^{by}	0.50^{cy}	1.88^{abxy}	2.32^{ax}	1.68^{abx}
9 d	2.19^{ax}	1.76^{by}	1.81^{by}	1.10^{cz}	1.75^{by}	0.95^{by}	1.35^{abxy}	1.43^{ay}	1.36^{aby}	0.99^{bx}
	Maximum shearing force (N/mm) at 5℃									
0 wk	2.36^{ax}	2.41^{ax}	2.23^{ax}	2.34^{ax}	2.29^{ax}	2.27^{ax}	1.03^{by}	1.45^{by}	2.45^{ax}	2.13^{ax}
1 wk	1.99^{bx}	2.42^{ax}	1.84^{abx}	1.38^{bcz}	0.96^{cy}	2.10^{axy}	1.57^{axy}	0.75^{bz}	1.89^{ax}	1.87^{axy}
2 wk	2.32^{ax}	1.83^{aby}	1.46^{bx}	1.54^{bcyz}	0.95^{cx}	1.56^{by}	2.07^{ax}	1.11^{cyz}	2.14^{ax}	1.76^{aby}
4 wk	2.24^{ax}	2.42^{ax}	2.03^{abx}	2.12^{abxy}	1.55^{bx}	2.10^{abxy}	1.38^{cy}	2.73^{ax}	2.18^{abx}	1.82^{bcxy}

[1)] Means followed by different letter are significantly different ($P<0.05$).

Table 5. Determination of the total work of shearing (N/mm • s) of irradiated grilled fish meat paste stored at different conditions

Storage period	Air packaging					Vacuum packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
Maximum shearing force (N/mm) at 30℃										
0 d	$10.54^{ax1)}$	10.91^{ax}	10.72^{ax}	11.54^{ax}	10.60^{ax}	10.98^{ax}	5.51^{bxy}	7.50^{bxy}	11.66^{ax}	10.90^{ax}
3 d	9.22^{ax}	5.08^{cz}	9.18^{axy}	10.62^{ax}	8.67^{axy}	5.91^{by}	8.50^{abx}	9.76^{ax}	8.50^{abyz}	8.80^{aby}
6 d	8.94^{ax}	9.80^{ax}	9.31^{axy}	8.42^{ay}	8.92^{axy}	7.33^{ay}	2.94^{cy}	9.20^{abxy}	10.97^{axy}	7.96^{aby}
9 d	11.16^{ax}	7.74^{bz}	8.47^{by}	5.15^{cz}	7.89^{by}	5.31^{ay}	6.43^{axy}	6.91^{ay}	6.53^{az}	5.04^{ay}
Maximum shearing force (N/mm) at 5℃										
0 wk	10.54^{ax}	10.91^{ax}	10.72^{ax}	11.54^{ax}	10.60^{ax}	10.98^{ax}	5.51^{bc}	7.50^{by}	11.66^{ax}	10.90^{ax}
1 wk	8.64^{ax}	10.44^{axy}	8.21^{abxy}	6.74^{aby}	4.51^{by}	9.65^{axy}	7.28^{axy}	4.98^{bz}	8.61^{ax}	9.06^{ay}
2 wk	1050^{ax}	8.40^{by}	6.52^{by}	6.96^{bcy}	4.51^{cy}	7.91^{bcy}	9.60^{abx}	6.32^{cyz}	11.36^{ax}	8.77^{by}
4 wk	10.16^{ax}	10.94^{ax}	9.00^{abxy}	9.43^{abxy}	6.93^{bxy}	9.65^{abxy}	6.60^{by}	12.39^{ax}	9.77^{abx}	8.69^{by}

[1)] Means followed by different letter are significantly different ($P<0.05$).

Sensory Evaluation

Tables 6 and 7 show the changes of the sensory attributes such as irradiation odor, fish meat flavor, rotten odor, and slime formation of the irradiated grilled fish paste at different storage conditions. The irradiation odor of the sample was increased while the fish meat flavor was decreased as the irradiation dose was increased. The data showed that the irradiation odor and the fish meat flavor of the air-packaged samples were considerably changed compared to those of the vacuum-packaged samples (Tables 6 and 7). The rotten odor and the slime formation of the samples were increased as the storage period was extended or the storage temperature was increased. However, the rotten odor and slime formation were reduced as the irradiation dose was increased (Table 6 and 7). Similarly, Cho et al. (1) reported that sensory evaluation such as the flavor and appearance showed that an irradiation at 3 kGy was the optimum dose level to extend the shelf-life of fried fish paste up to twice as long at room temperature and three to four times as long at a low temperature, respectively compared with the non-irradiated control and stated that irradiation odor occurred in the samples irradiated at 5 kGy. In the present study, the irradiation odor was increased and the fish meat flavor was decreased in the irradiated samples but these changes were effectively reduced by vacuum packaging. And, it was concluded that the sensorial quality of the grilled fish paste was maintained by an irradiation at 7.5 kGy or more.

Table 6. Change of sensory attribute based on the results of the QDA test of irradiated grilled fish paste during storage at 30℃

Storage period	Air packaging					Vacuum packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
Irradiation odor										
0 d	1.8^{fx}[1)]	3.0^{defx}	3.6^{cd}	6.0^{abx}	6.4^{ax}	1.8^{fx}	2.0^{efx}	2.2^{defx}	3.4^{cdex}	4.8^{bcx}
3 d	1.8^{ex}	3.0^{cdex}	3.6^{b}	6.2^{ax}	6.2^{ax}	2.0^{dx}	2.2^{cdx}	2.8^{cdx}	3.2^{bcx}	4.6^{bx}
6 d	2.0^{dx}	2.8^{cdxy}	4.0^{b}	6.0^{ax}	6.4^{ax}	1.8^{dx}	2.2^{cdx}	2.8^{cdx}	3.2^{bcx}	4.2^{bx}
9 d	1.4^{dx}	1.6^{dy}	2.4^{cd}	4.4^{by}	5.8^{ax}	1.4^{dx}	2.4^{cdx}	2.4^{cdx}	3.4^{bcx}	4.0^{bx}
Fish meat flavor										
0 d	5.4^{ax}	5.0^{ax}	4.6^{abx}	3.0^{bcx}	2.2^{cx}	6.0^{ax}	6.0^{ax}	5.2^{ax}	4.4^{abcx}	4.4^{abx}
3 d	3.2^{bcy}	4.4^{abcx}	4.8^{abx}	3.6^{abcx}	2.8^{cx}	4.8^{aby}	5.4^{ax}	5.4^{ax}	4.2^{abcx}	4.6^{abx}
6 d	3.0^{cdey}	4.0^{abcdx}	4.4^{abx}	3.2^{bcdex}	2.8^{dex}	2.6^{cz}	3.8^{abcdy}	4.8^{axy}	4.8^{ax}	4.2^{abcx}
9 d	2.4^{cy}	2.6^{cy}	4.2^{abx}	3.4^{abcx}	3.2^{bcx}	2.6^{cz}	2.8^{cz}	3.4^{abcy}	4.4^{abx}	4.6^{ax}
Rotten odor										
0 d	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{ay}	1.0^{ay}	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{ay}
3 d	5.0^{ay}	2.8^{bcy}	2.2^{bcdy}	1.6^{dexy}	1.0^{exy}	5.2^{ay}	3.2^{by}	2.4^{bcdy}	2.0^{cdez}	1.0^{ey}
6 d	6.4^{ax}	4.2^{cdx}	3.4^{dex}	2.0^{fgxy}	1.2^{gy}	5.6^{abx}	4.8^{bcx}	3.6^{cdex}	2.8^{efg}	1.4^{gy}
9 d	6.6^{ax}	6.0^{abw}	3.6^{cx}	2.2^{dx}	2.0^{dx}	6.6^{ax}	6.0^{abw}	5.0^{bx}	3.8^{cx}	1.8^{dx}
Slime										
0 d	1.0^{az}	1.0^{az}	1.0^{ay}	1.0^{ay}	1.0^{ay}	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{ay}
3 d	4.6^{ay}	2.8^{by}	2.0^{bcdy}	1.6^{cdxy}	1.0^{dy}	4.0^{ay}	2.8^{by}	2.4^{bcyz}	1.6^{cdz}	1.0^{dy}
6 d	6.4^{ax}	4.2^{cdx}	3.4^{dex}	2.0^{fgx}	1.2^{gy}	5.6^{abx}	4.8^{bcx}	3.6^{cdexy}	2.8^{efy}	1.4^{gxy}
9 d	6.6^{ax}	6.0^{abw}	3.6^{cx}	2.2^{dx}	2.0^{dx}	6.6^{ax}	6.0^{abw}	5.0^{bx}	3.8^{cx}	1.8^{dx}

[1)] Means followed by different letter are significantly different ($P<0.05$).

Table 7. Change of sensory attribute based on the results of the QDA test of irradiated grilled fish paste during storage at 5℃

Storage period	Air packaging					Vacuum packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
Irradiation odor										
0 d	1.8^{ax}[1)]	3.0^{ax}	3.6^{ax}	6.0^{ax}	6.4^{ax}	1.8^{ax}	2.0^{ax}	2.2^{ax}	3.4^{ax}	4.8^{ax}
3 d	1.6^{dx}	2.6^{cdx}	3.4^{cx}	5.6^{abx}	6.2^{ax}	1.6^{dx}	1.8^{dx}	2.2^{cdx}	3.2^{cx}	4.6^{bxy}
6 d	2.0^{dx}	$2.8b^{cdx}$	3.8^{bx}	5.6^{ax}	6.2^{ax}	1.8^{dx}	1.8^{dx}	2.2^{cdx}	3.4^{bcx}	3.6^{by}
9 d	1.8^{ex}	2.8^{dex}	3.6^{cdx}	5.8^{ax}	5.6^{abx}	1.6^{ex}	2.2^{cx}	1.8^{ex}	2.6^{dex}	4.4^{bcxy}
Fish meat flavor										
0 d	5.4^{ax}	5.0^{ax}	4.6^{ax}	3.0^{ax}	2.2^{ax}	6.0^{ax}	6.0^{ax}	5.2^{ax}	4.4^{ax}	4.4^{ax}
3 d	5.8^{ax}	3.4^{bcx}	3.8^{bcx}	3.8^{bcx}	2.4^{cx}	5.6^{ax}	5.8^{ax}	5.6^{ax}	4.8^{abx}	3.8^{bcx}
6 d	4.8^{abcdx}	4.0^{cdex}	4.2^{bcdex}	3.8^{cdex}	3.4^{ex}	5.0^{abcdx}	6.0^{ax}	5.6^{abx}	5.2^{abcx}	3.6^{dex}
9 d	5.6^{ax}	4.4^{abx}	3.2^{bx}	3.2^{bx}	3.0^{bx}	5.2^{ax}	4.4^{abx}	5.4^{ax}	4.2^{abx}	3.4^{bx}
Rotten odor										
0 d	1.0^{az}	1.0^{az}	1.0^{ay}	1.0^{ay}	1.0^{ay}	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{ay}	1.0^{az}
3 d	2.8^{ay}	2.2^{aby}	2.0^{aby}	1.6^{bxy}	1.2^{b}	2.8^{aby}	2.2^{aby}	2.0^{aby}	1.8^{aby}	1.4^{byz}
6 d	4.6^{ax}	3.2^{abx}	3.4^{abx}	3.0^{bx}	1.6^{c}	3.6^{abx}	3.8^{abx}	3.2^{abx}	3.0^{bx}	2.4^{bcx}
9 d	5.6^{ax}	4.8^{abw}	4.4^{abcx}	2.8^{dex}	2.2^{e}	5.0^{abx}	5.2^{abw}	4.0^{bcdx}	3.0^{cdex}	2.0^{exy}
Slime										
0 d	1.0^{az}	1.0^{az}	1.0^{ay}	1.0^{ay}	1.0^{az}	1.0^{az}	1.0^{az}	1.0^{ay}	1.0^{ay}	1.0^{ay}
3 d	1.6^{ayz}	1.0^{bz}	1.0^{by}	1.0^{by}	1.0^{bz}	1.4^{abyz}	1.0^{bz}	1.0^{by}	1.0^{by}	1.0^{by}
6 d	2.6^{ay}	2.4^{aby}	2.4^{ab}	2.0^{abx}	1.6^{by}	2.4^{abxy}	2.0^{aby}	2.2^{abx}	2.0^{abx}	1.8^{abx}
9 d	4.2^{ax}	3.6^{abx}	2.2^{cx}	2.6^{bcx}	2.4^{bcx}	3.0^{abcx}	2.6^{bcx}	2.0^{cx}	2.2^{cx}	1.8^{cx}

[1)] Means followed by different letter are significantly different ($P<0.05$).

Conclusions

Consequently, it is apparent that the microbial and physiochemical quality of grilled fish paste was effectively maintained by an irradiation and vacuum-packaging. In addition, further researches are necessary to study the appropriate irradiation doses at which the textural and sensorial quality of the food is minimally affected.

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