# Effect of gamma irradiation on the shelf-life of vacuum-packaged silver carp surimi in 4 °C

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## Abstract

The current study investigates the effect of gamma radiation (0, 1, 3, 5, 7 kGy) and vacuum packaging on shelf-life of silver carp surimi stored at 4 ºC based on variations in pH, peroxide value (PV), thiobarbituric acid (TBA), total volatile nitrogen bases (TVB-N), free fatty acids (FFA), colorimetric parameters (L*, a*, b*), total viable bacterial count (TVC) and textural profile analysis during 15 days. The results indicated that pH did not change with gamma radiation ($P> 0.05$). Results of oxidative index showed that PV and TBA in surimi reduced significantly with an increase in gamma radiation ($P< 0.05$) while their increased by increasing the storage time. Irradiation and the storage time significantly increased TVB-N content ($P< 0.05$). The increase the radiation dose (up to 7 kGy) and the storage time (up to 15 days) had a significant increasing effect on FFA in refrigerated surimi. Colorimetric evaluations demonstrated that after irradiation, samples had generally higher L*, a*, b* indices. Furthermore, increasing the radiation dose significantly reduced the total bacterial count in surimi samples ($P< 0.05$), but this parameter exhibited a significant increase ($P< 0.05$) with increasing storage time. Based on the textural profile analysis it was found that increasing radiation dose and storage time reduced the hardness and chewing ability indices. According to the microbiological and chemical results, the optimal storage time for surimi, compare to the control (0 kGy) treatment, was measured for 7 kGy treatment which could increase the storage time by 3 days compared to the control.

**Keywords**: Gamma rays, Vacuum packaging, Surimi, *Hypophthalmichtys molitrix*

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## Introduction

Food irradiation is a promising innovative food processing technology. Gamma rays, accelerated electrons and X-rays have been successfully tested for food processing, insect

disinfection, microbial decontamination or to extend the shelf life of food (Arvanitoyannis & Tserkezou, 2014). Although there are several qualified and certified gamma irradiation facilities for food irradiation processing, some technical limitations still exist. Not all food products can be processed by this technology, as high doses would be needed to achieve the desired effect, potentially compromising the quality and shelf-life of the product (Krizek, Dadakova, Vacha, Pelikanova & Matejkova 2018).

Processing of fishery product by radiation offers a range of beneficial effects, which cannot be achieved by traditional techniques; some are in competition with conventional methods, also in respect to effectiveness; others are perfectly supplementing practices handed down to us during historical times (Altan & Turan 2016). Irradiation is perceived to be an effective non-thermal technical process to reduce microorganisms, improve food safety and increase shelf-life (Guerrero-Beltran & Barbosa-Canovas 2004; Mbarki, Miloud, Selmi, Dhib & Sadok 2009).

Fishery products and sea food are most perishable compared to other foods, due to the presence of high moisture, protein and highly oxidizable poly-unsaturated fatty acids. Fishery food irradiation is treated physically to extend storage period, enhancing the quality and safety ratio (Abdeldaiem, Mohammad & Ramadan 2018). Food irradiation up to a medium dose of 10 kGy is accepted by many countries for commercial food products, while the applied dose may vary depending on the product (Arvanitoyannis, Stratakos & Mente 2009). Researchs have shown that main nutrients like proteins, carbohydrates and fats are resistant to radiation doses up to 10 kGy (Shalaby, Anwar, Sallam & Emam 2016; Dogruyol & Mol 2016). This technique in combination with packaging has been used with success on freshwater fish. Newer attempts in food irradiation consists of combination of irradiation with other treatments like edible coatings, vacuum packaging, which may result in synergistic effects for reducing level of one or all the treatments (Harder, Arthur & Harder 2017).

Irradiation was employed in different food, such as meat products (Kawasaki, Saito, Mochida, Noviyanti, Seito & Todoriki 2019; Hassanzadeh, Tajik, Razavi Rohani, Moradi, Hashemi & Aliakbarlu 2017; Huq, Vu, Riedl, Bouchard & Lacroix 2015) and aquatic products (Boziaris 2014; Lyu, Gao & Ding 2018; Cheok, Sobhi, Mohd, Bakar, Abdul, Karim & Ghazali 2017), but the effect of gamma irradiation on shelf-life of surimi was not clear. Surimi is stabilized myofibrillar proteins obtained from deboned fish mince that is washed with cold water (Munir, Hu, Liu & Xiong 2019). Therefore, the objectives of this study were to investigate the effect of gamma radiation and vacuum packaging on the shelf life of surimi of silver carp (*Hypophthalmichthys molitrix*).

## Materials and methods

Fifteen kg of silver carp (*Hypophthalmichthys molitrix*) were obtained from aquaculture ponds in Khuzestan province and after heading, gutting, and washing, the skin and bones were minced using a mincer plate of pore size 2 mm



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(TSM model, USA). Then, the minced meat was washed with cold water (5 to 8 ºC) for 5 min, so that the minced meat to water ratio was 4:1 ($ww^{-1}$) where 1 part meat and 4 parts water were used. Washing was repeated 3 times and in the last stage of washing, 3% salt (Merk, Germany) was added to the mix of water-meat. Finally, the washed minced meat was filtered using a cleaning fabric with pore size of 1 mm (ANS, USA) and minced again using a grinder (Jr-D120) for 2 min. Surimi were vacuum-packed (model 30; Engeyac, Brazil). Then, the surimi was transferred in ice container to Atomic Energy Organization for irradiation. The surimi sample was exposed to gamma radiation 0 (control), 1, 3, 5 and 7 kGy in the gamma chamber 5000, is a compact self-shielded cobalt -60 gamma irradiator providing a dose rate ca. 6 $kGyh^{-1}$ and has an irradiation volume of approximately 5000cc (Atomic Energy Organization 2019).

**Chemical analysis**

**pH**

In order to measure pH, after the preparation of samples, 5 g of each was poured in distilled water at 1:2 ($w\ v^{-1}$) ratio and then totally homogenized using an electric mixer Then, pH of samples was measured using a meat digital pH-meter (Hanna instruments) (AOAC 2005).

**Peroxide Value (PV)**

80-100 g of surimi was mixed with 200 mL of chloroform solvent (Sigma, USA) for 30 seconds. Then, the resultant blend was filtered using a filter paper and 25 mL of that was immediately transferred to a 150 mL previously weighed beaker. The existing chloroform in the first beaker (150 mL) was changed in a water bath with nitrogen circulation and it was placed in an oven with a temperature of 100 °C for a few minutes (until constant weight was reached) then dried ( the weight of oil obtained was considered as the oil level of trial). The peroxide was determined in the total lipid extracts and calculated as follow: PV (meq peroxide $kg^{-1}$) = (S-B) × F× N× 1000 $W^{-1}$, where S: titration amount of sample; B: titration amount of blank; F: titer of 0.01 N sodium thiosulfate. N: normality of sodium thiosulfate and W: weight of sample (g) (AOCS 1998).

**Thiobarbituric acid (TBA)**

The measurement of thiobarbituric acid was conducted using a method suggested by Kirk & Sawyer (1991). The reaction of various samples with TBA and their absorption at 535 nm was measured by a spectrophotometer model PharmaSpec 1700 (Shimadzu, Japan). TBA index was expressed as mg MDA $kg^{-1}$.

**Total volatile base-nitrogen (TVB-N)**

The values of total volatile nitrogen bases were measured by Kjeldahl method and by placing 10 g of sample plus 2 g of magnesium oxide and adding 300 cc distilled water in a flask. This was conducted by recovering the volatile nitrogen bases in a solution containing 2% boric acid (20 cc) and methyl red as an indicator and then titration the resultant discolored solution with 0.1 n sulfuric acid till the appearance of a purple color and TVB-N were expressed as mg N 100 $g^{-1}$ meat from the following equation: $TVB\text{-}N=A\times1.4\times100\ B^{-1}$, where A: used 0.1 mol equi $L^{-1}$ $H_2SO_4$ (mL) and B: weight of sample (g) (AOAC 2005).



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**Free fatty acid (FFA)**

To measure free fatty acids, about 20g of surimi was weighed and mixed with a sufficient amount of chloroform in a mixer (DH903-608). The filtered solution was passed through a filter impregnated with dry sodium sulfate (Sigma, USA). A known amount of the filtered solution was transferred to a flask with a specified weight and, after the evaporation of chloroform, the fats content was determined. Next, 25 mL of filtered solution was conveyed to 250 mL Erlenmeyer and 25 mL neutral alcohol was added to that. Free fatty acids were titrated using 0.1 N-sodium hydroxide solution and phenolphthalein as an indicator. Eventually, the free fatty acids were measured in terms of Oleic acid (AOAC 2005).

**Microbial assay**

A 1 $cm^2$ of surimi was transferred to sterile containers containing 9 mL of physiologic serum and stirred well (initial suspension with 0.1 dilutions). Then, it was allowed to stand a few minutes till the particles precipitate. Subsequently, using a sterile pipette, 1 mL of initial suspension was transferred to sterile tubes containing 9 mL diluter (physiologic serum) thereby dilution series of 0.001 and 0.00001 were obtained. A plate count agar was used to count total bacteria and psychrophilic bacteria in the prepared samples. After obtaining the sample and decimal dilutions, the required dilutions were cultured on the plate count agar (Merck, Germany) via pour plate method. In order to count, the cultured plates related to total viable count bacteria were counted after 48 hours of incubation at 37 °C and plates of psychrophilic bacteria were counted after 10 days of incubation at 7 °C (APHA 1992).

**Color measurements**

To evaluate color features a Hunter Lab machine (Chroma Meter CR-400) was utilized. For that purpose, each sample was placed in Hunter Lab apparatus and L (Lightness), a* (redness) and b* (yellowness) indices were determined and recorded (CIE 1978).

**Texture analysis**

Textural profile analysis was conducted using a creep meter (Japan) equipped with a cylindrical plunger of 12 mm in diameter at a speed of 3 mm $s^{-1}$ and at a penetration 2.5 mm into the flesh. Eventually, the indices related to textural evaluation were recorded from the obtained information. The typical texture analysis parameters were: hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness (Zhang, Wang, Zhang, Wang & Ye 2016).

**Statistical analysis**

The experiments were performed in a completely randomized design with three repetitions. All experiments were performed in triplicate. The results of physical, chemical, and microbiological experiments were studied to find significant difference between data through one-way ANOVA using SPSS22 software. To compare between-treatment means, Duncan's multiple range tests at 5% significance level ($P< 0.05$) was used. Excel software was also used to plot the relevant diagrams.



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## Results

### pH

Results of pH variation of samples treated with various doses of gamma radiation stored at vacuum conditions for 15 days are presented in table.1. Results indicated that pH variation (P< 0.05) was dependent upon the storage time of treated samples under vacuum conditions, but the gamma ray dose did not have a significant effect on the pH level of samples stored (P> 0.05).

**Table1.** Changes in pH of surimi samples during 15 days at 4°C

| | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| 0 kGy | $5.84 \pm 0.01^{bF}$ | $5.99 \pm 0.03^{aE}$ | $6.15 \pm 0.02^{aD}$ | $6.29 \pm 0.02^{aC}$ | $6.48 \pm 0.03^{aB}$ | $6.69 \pm 0.02^{aA}$ |
| 1kGy | $5.95 \pm 0.04^{aE}$ | $5.99 \pm 0.02^{aE}$ | $6.14 \pm 0.00^{aD}$ | $6.29 \pm 0.04^{aC}$ | $6.50 \pm 0.08^{aB}$ | $6.70 \pm 0.07^{aA}$ |
| 3kGy | $5.95 \pm 0.07^{aF}$ | $6.03 \pm 0.01^{aEF}$ | $6.12 \pm 0.03^{aDE}$ | $6.27 \pm 0.01^{aC}$ | $6.47 \pm 0.09^{aB}$ | $6.68 \pm 0.17^{aA}$ |
| 5kGy | $5.91 \pm 0.08^{aF}$ | $6.03 \pm 0.05^{aE}$ | $6.14 \pm 0.00^{aD}$ | $6.28 \pm 0.02^{aC}$ | $6.49 \pm 0.06^{aB}$ | $6.71 \pm 0.04^{aA}$ |
| 7kGy | $5.92 \pm 0.02^{aF}$ | $6.01 \pm 0.01^{aE}$ | $6.13 \pm 0.01^{aD}$ | $6.27 \pm 0.02^{aC}$ | $6.51 \pm 0.03^{aB}$ | $6.70 \pm 0.04^{aA}$ |

a- d lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.05) in each row. Values are given as means ± SD from triplicate groups.

### PV

Table 2 shows that peroxide variation of various samples (P< 0.05) is dependent upon the gamma ray dose and storage time. By increasing gamma ray dose, the peroxide level will decrease (P< 0.05) and by increasing the storage time, the peroxide level of irradiated surimi samples in vacuum packages will increase (P< 0.05). At day 15, the lowest and highest levels of peroxide were observed in 7 kGy treatment ($4.09 \pm 0.06$ $mgO_2$ $kg^{-1}$) and control treatment ($5.22 \pm 0.17$ $mgO_2$ $kg^{-1}$), respectively, without significant difference with 1 kGy treatment.

**Table2.** Changes in PV values ($mgO2kg^{-1}$) of surimi samples during 15 days at 4°C

| | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| 0kGy | $0.79 \pm 0.004^{aF}$ | $2.00 \pm 0.07^{aE}$ | $3.23 \pm 0.02^{aD}$ | $4.05 \pm 0.04^{aC}$ | $5.50 \pm 0.07^{aB}$ | $5.22 \pm 0.17^{aA}$ |
| 1kGy | $0.84 \pm 0.07^{aE}$ | $2.04 \pm 0.06^{aD}$ | $3.12 \pm 0.15^{aC}$ | $4.19 \pm 0.24^{aB}$ | $5.30 \pm 0.37^{aA}$ | $5.06 \pm 0.08^{aA}$ |
| 3kGy | $0.81 \pm 0.002^{aF}$ | $1.90 \pm 0.02^{aE}$ | $2.89 \pm 0.04^{bD}$ | $3.60 \pm 0.08^{bC}$ | $4.74 \pm 0.19^{bB}$ | $4.64 \pm 0.09^{bA}$ |
| 5kGy | $0.77 \pm 0.01^{aE}$ | $1.63 \pm 0.19^{bD}$ | $2.81 \pm 0.03^{bC}$ | $3.47 \pm 0.04^{bB}$ | $4.23 \pm 0.06^{cA}$ | $4.39 \pm 0.07^{cA}$ |
| 7kGy | $0.80 \pm 0.008^{aF}$ | $1.46 \pm 0.09^{bE}$ | $2.19 \pm 0.005^{cD}$ | $2.80 \pm 0.08^{cC}$ | $3.88 \pm 0.03^{dB}$ | $4.09 \pm 0.06^{dA}$ |

a- d lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.05) in each row. Values are given as means ± SD from triplicate groups.

### TBA

From Table 3, increasing the storage time will increase the TBA content and, contrarily, increasing the gamma ray dose (P< 0.05) will decrease the TBA content so that the lowest level of this parameter was measured at day 15 in 7 kGy treatment ($3.19 \pm 0.13$ mg MDA $kg^{-1}$) and with a significant difference (P< 0.05) with control, 1 and 3 kGy treatments.



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**Table3.** Changes in TBA (mg MDA $kg^{-1}$) values of surimi samples during 15 days at 4°C

| | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| 0kGy | $0.58 \pm 0.001^{bF}$ | $1.005 \pm 0.009^{aE}$ | $1.90 \pm 0.02^{aD}$ | $2.69 \pm 0.007^{aC}$ | $3.30 \pm 0.02^{aB}$ | $4.31 \pm 0.02^{aA}$ |
| 1kGy | $0.58 \pm 0.08^{bF}$ | $1.018 \pm 0.013^{aE}$ | $1.94 \pm 0.01^{aD}$ | $2.52 \pm 0.007^{aC}$ | $3.32 \pm 0.03^{aB}$ | $4.36 \pm 0.12^{aA}$ |
| 3kGy | $0.60 \pm 0.002^{aF}$ | $0.97 \pm 0.006^{bE}$ | $1.69 \pm 0.004^{bD}$ | $2.21 \pm 0.026^{bC}$ | $3.15 \pm 0.22^{aB}$ | $3.90 \pm 0.004^{bA}$ |
| 5kGy | $0.59 \pm 0.01^{abF}$ | $0.97 \pm 0.01^{bE}$ | $1.64 \pm 0.004^{bD}$ | $1.82 \pm 0.007^{bB}$ | $2.79 \pm 0.03^{bB}$ | $3.23 \pm 0.03^{cA}$ |
| 7kGy | $0.58 \pm 0.007^{bF}$ | $0.962 \pm 0.03^{bE}$ | $1.30 \pm 0.006^{cD}$ | $1.59 \pm 0.004^{cC}$ | $2.48 \pm 0.09^{cB}$ | $3.19 \pm 0.13^{cA}$ |

a- c lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.05) in each row. Values are given as means ± SD from triplicate groups.

**TVB-N**

The TVB-N values obtained for the surimi samples are shown in Tab 4. A significant increase (P< 0.05) in TVB-N content from 9.83 to 60.62 mg N $100g^{-1}$ was verified. Samples with gamma irradiated at control and 1 kGy showed no significant different in the contents of TVB-N (P> 0.05), 5 and 7 kGy (P< 0.05).

**Table 4.** Changes in TVB-N (mgN$100g^{-1}$) values of surimi samples during 15 days at 4°C

| | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| 0 kGy | $9.90 \pm 0.05^{aF}$ | $13.97 \pm 0.009^{aE}$ | $22.73 \pm 0.54^{aD}$ | $25.73 \pm 0.45^{aC}$ | $47.71 \pm 0.45^{aB}$ | $69.31 \pm 0.82^{aA}$ |
| 1kGy | $9.88 \pm 0.08^{aF}$ | $13.68 \pm 0.013^{aE}$ | $22.15 \pm 0.26^{bD}$ | $27.26 \pm 1.08^{aC}$ | $47.23 \pm 0.46^{aB}$ | $60.62 \pm 0.81^{aA}$ |
| 3kGy | $9.98 \pm 0.002^{aF}$ | $12.99 \pm 0.006^{bE}$ | $18.95 \pm 0.62^{bD}$ | $23.84 \pm 0.70^{bC}$ | $44.89 \pm 1.61^{bB}$ | $57.01 \pm 1.32^{bA}$ |
| 5kGy | $9.83 \pm 0.01^{aF}$ | $11.74 \pm 0.01^{bE}$ | $18.38 \pm 0.24^{bD}$ | $21.44 \pm 1.22^{cC}$ | $41.32 \pm 1.10^{cB}$ | $50.77 \pm 1.58^{cA}$ |
| 7kGy | $9.85 \pm 0.007^{aF}$ | $11.00 \pm 0.03^{bE}$ | $18.05 \pm 0.18^{cD}$ | $21.01 \pm 0.44^{cC}$ | $34.80 \pm 0.32^{dB}$ | $47.40 \pm 0.83^{cA}$ |

a- d lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.06) in each row. Values are given as means ± SD from triplicate groups.

**FFA**

Variations of FFA content (P< 0.05) depending on the gamma radiation dose and storage time of silver carp surimi stored under vacuum conditions at refrigerator temperature are shown in Tab.5. Increasing the radiation dose will reduce the free fatty acids content (P< 0.05) while increasing the storage time from day 1 to the end of day 15 (P< 0.05) rise the free fatty acids content. At day 15, the lowest value of this parameter was measured in 7 kGy treatment (2.28 ± 0.14%) and without significant difference with 5 kGy treatment (2.73 ± 0.04%). The highest value of this parameter was associated with control treatment (3.78 ± 0.08%) and without significant difference with 1 kGy treatment (3.80 ± 0.08%).

**Table 5.** Changes in FFA (%) values of surimi samples during 15 days at 4°C

| | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| 0kGy | $0.41 \pm 0.004^{aF}$ | $0.73 \pm 0.02^{aE}$ | $1.28 \pm 0.01^{aD}$ | $2.30 \pm 0.04^{aC}$ | $3.04 \pm 0.03^{aB}$ | $3.78 \pm 0.08^{aA}$ |
| 1kGy | $0.39 \pm 0.004^{aF}$ | $0.75 \pm 0.01^{aE}$ | $1.33 \pm 0.003^{aD}$ | $2.23 \pm 0.04^{aC}$ | $3.16 \pm 0.10^{aB}$ | $3.80 \pm 0.08^{aA}$ |
| 3kGy | $0.41 \pm 0.009^{bF}$ | $0.73 \pm 0.01^{aE}$ | $1.17 \pm 0.05^{bD}$ | $1.70 \pm 0.09^{bC}$ | $2.78 \pm 0.07^{bB}$ | $3.37 \pm 0.09^{bA}$ |
| 5kGy | $0.38 \pm 0.003^{bF}$ | $0.62 \pm 0.01^{bE}$ | $0.96 \pm 0.03^{cD}$ | $1.41 \pm 0.04^{cC}$ | $2.23 \pm 0.10^{cB}$ | $2.73 \pm 0.04^{cA}$ |
| 7kGy | $0.39 \pm 0.01^{bF}$ | $0.59 \pm 0.01^{cE}$ | $0.91 \pm 0.06^{cD}$ | $1.22 \pm 0.06^{dC}$ | $2.21 \pm 0.08^{cB}$ | $2.28 \pm 0.14^{cA}$ |

a- d lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.06) in each row. Values are given as means ± SD from triplicate groups.



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**Total viable count (TVC)**

Irradiated samples at doses of 3, 5 and 7 kGy markedly decreased the levels of total bacterial count (Table 6). Gamma irradiation at dose level of 5 and 7 kGy reduced the counts of total bacterial to 9 days. At dose level of 1, 3 kGy and control treatment, the count of total bacterial were unacceptable on 9 days. During storage, a gradual increase in the total bacterial count was observed in all treatments and control, but the rate of increase was higher in control samples of surimi than irradiated samples.

**Table 6.** Changes in TVC (log cfu $g^{-1}$) values of surimi samples during 15 days at 4°C

| | **0** | **3** | **6** | **9** | **12** | **15** |
|---|---|---|---|---|---|---|
| 0kGy | $4.68 \pm 0.01^{aF}$ | $5.81 \pm 0.03^{aE}$ | $6.77 \pm 0.11^{aD}$ | $7.92 \pm 0.04^{aC}$ | $8.81 \pm 0.09^{aB}$ | $9.80 \pm 0.08^{aA}$ |
| 1kGy | $4.53 \pm 0.28^{bF}$ | $5.68 \pm 0.04^{bE}$ | $6.67 \pm 0.10^{bD}$ | $7.86 \pm 0.03^{aC}$ | $8.73 \pm 0.07^{aB}$ | $9.78 \pm 0.12^{aA}$ |
| 3kGy | $4.51 \pm 0.07^{bF}$ | $4.83 \pm 0.11^{cE}$ | $6.11 \pm 0.62^{cD}$ | $7.48 \pm 0.05^{bC}$ | $8.57 \pm 0.03^{bB}$ | $8.95 \pm 0.01^{bA}$ |
| 5kGy | $4.49 \pm 0.00^{bcF}$ | $4.72 \pm 0.13^{cE}$ | $5.80 \pm 0.11^{dD}$ | $6.82 \pm 0.09^{cC}$ | $7.03 \pm 0.07^{cB}$ | $7.72 \pm 0.06^{cA}$ |
| 7kGy | $4.46 \pm 0.03^{F}$ | $4.54 \pm 0.10^{dE}$ | $5.58 \pm 0.07^{eD}$ | $6.44 \pm 0.12^{dC}$ | $6.84 \pm 0.05^{dB}$ | $7.31 \pm 0.04^{dA}$ |

a- d lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.06) in each row. Values are given as means ± SD from triplicate groups.

**Instrumental color evaluation**

Results of changes in colorimetric parameters (L*, a* and b*) of silver carp surimi treated with various gamma ray doses shown in Table 7 indicate that changes in L*, a*, b* parameters (P< 0.05) are dependent upon radiation dose and storage time of surimi stored at 4 ºC under vacuum packaging. Rising the gamma ray dose will increase the lightness index (L*) (P< 0.05), but increasing the storage time from day 1 to end of day 15 (P< 0.05) reduces the lightness index of various treatments. Even so, a* and b* indices were lower in irradiated treatments (P< 0.05) compared to the control one. Also, b* index increased during the storage time.

**Table7.** Changes in color of surimi samples during 15 days at 4°C

| **L*** | **0** | **3** | **6** | **9** | **12** | **15** |
|---|---|---|---|---|---|---|
| 0kGy | $51.14 \pm 0.01^{eA}$ | $49.16 \pm 0.01^{eB}$ | $46.71 \pm 0.01^{bC}$ | $45.59 \pm 0.01^{eD}$ | $43.15 \pm 0.01^{eE}$ | $42.57 \pm 0.01^{dF}$ |
| 1kGy | $51.21 \pm 0.01^{DA}$ | $49.22 \pm 0.01^{DB}$ | $46.82 \pm 0.00^{bC}$ | $45.97 \pm 0.00^{dD}$ | $43.40 \pm 0.00^{dE}$ | $42.83 \pm 0.01^{cF}$ |
| 3kGy | $51.28 \pm 0.00^{cA}$ | $50.24 \pm 0.02^{cB}$ | $46.87 \pm 1.16^{bC}$ | $46.20 \pm 0.02^{cD}$ | $44.37 \pm 0.01^{cE}$ | $42.85 \pm 0.01^{cF}$ |
| 5kGy | $51.38 \pm 0.01^{bA}$ | $50.54 \pm 0.02^{bB}$ | $48.49 \pm 0.01^{aC}$ | $46.36 \pm 0.01^{bD}$ | $45.65 \pm 0.01^{bE}$ | $43.19 \pm 0.01^{bF}$ |
| 7kGy | $51.41 \pm 0.01^{aA}$ | $50.97 \pm 0.01^{aB}$ | $48.63 \pm 0.02^{aC}$ | $47.39 \pm 0.01^{aD}$ | $46.32 \pm 0.05^{aE}$ | $44.37 \pm 0.01^{aF}$ |
| **a*** | | | | | | |
| 0kGy | $1.43 \pm 0.005^{aA}$ | $1.39 \pm 0.01^{aB}$ | $1.29 \pm 0.005^{aC}$ | $1.26 \pm 0.01^{aD}$ | $1.21 \pm 0.01^{aE}$ | $1.16 \pm 0.01^{aF}$ |
| 1kGy | $1.42 \pm 0.005^{aA}$ | $1.35 \pm 0.005^{bB}$ | $1.28\pm 0.05^{abC}$ | $1.24 \pm 0.005^{abD}$ | $1.20 \pm 0.01^{aE}$ | $1.14 \pm 0.01^{abF}$ |
| 3kGy | $1.40 \pm 0.005^{bA}$ | $1.34 \pm 0.01^{bB}$ | $1.27 \pm 0.005^{bcC}$ | $1.24 \pm 0.01^{bcD}$ | $1.20 \pm 0.01^{aE}$ | $1.13 \pm 0.01^{bcF}$ |
| 5kGy | $1.40 \pm 0.005^{bA}$ | $1.32 \pm 0.005^{cB}$ | $1.27 \pm 0.01^{cC}$ | $1.22 \pm 0.005^{cD}$ | $1.16 \pm 0.01^{bE}$ | $1.11 \pm 0.01^{cdF}$ |
| 7kGy | $1.38 \pm 0.005^{cA}$ | $1.27 \pm 0.005^{dB}$ | $1.22 \pm 0.005^{dC}$ | $1.21 \pm 0.01^{dD}$ | $1.15 \pm 0.01^{bE}$ | $1.09 \pm 0.01^{dF}$ |
| **b*** | | | | | | |
| 0kGy | $-3.56 \pm 0.01^{aF}$ | $-2.18 \pm 0.00^{aE}$ | $-1.81 \pm 0.01^{aD}$ | $-1.33 \pm 0.01^{aC}$ | $0.86 \pm 0.00^{aB}$ | $1.53 \pm 0.01^{aA}$ |
| 1kGy | $-3.64 \pm 0.01^{bF}$ | $-2.61 \pm 0.01^{bE}$ | $-1.94 \pm 0.01^{bD}$ | $-1.41 \pm 0.01^{bC}$ | $0.95 \pm 0.00^{bB}$ | $1.34 \pm 0.01^{bA}$ |
| 3kGy | $-3.71 \pm 0.01^{cF}$ | $-3.21 \pm 0.01^{cE}$ | $-2.22 \pm 0.01^{cD}$ | $-1.86 \pm 0.01^{cC}$ | $-1.04 \pm 0.01^{cB}$ | $1.32 \pm 0.01^{bA}$ |
| 5kGy | $-3.77 \pm 0.01^{dF}$ | $-3.30 \pm 0.02^{dE}$ | $-2.45 \pm 0.00^{dD}$ | $-2.15 \pm 0.01^{dC}$ | $-1.34 \pm 0.01^{dB}$ | $-1.11 \pm 0.01^{cA}$ |
| 7kGy | $-3.94 \pm 0.00^{eF}$ | $-3.45 \pm 0.01^{eE}$ | $-2.76 \pm 0.01^{eD}$ | $-2.22 \pm 0.02^{eC}$ | $-1.46 \pm 0.01^{eB}$ | $-1.20 \pm 0.01^{dA}$ |

a- e lowercase letters indicate a significant difference at 95% confidence level (P< 0.05) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level (P< 0.06) in each row.



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**Textural Profile Analysis**

Based on the results of table 8, it was clear that textural property changes in terms of hardness, chewiness and gumminess in surimi ($P< 0.05$) are dependent upon radiation dose and storage time. By increasing the storage time and also the gamma ray dose, hardness and chewiness indices of surimi reduce ($P< 0.05$). On the other hand, an increase occurs in the gumminess of samples by increasing the storage time and radiation dose ($P< 0.05$). Nonetheless, cohesiveness and elasticity indices of various treatments were not influenced by storage time and radiation dose.

**Table8.** Variation in textural indices of samples under various radiation doses at 4 ºC under vacuum packaging

| **Hardness (N)** | **0** | **3** | **6** | **9** | **12** | **15** |
|---|---|---|---|---|---|---|
| 0kGy | 56.40± 0.04$^{aA}$ | 54.23± 1.74$^{aB}$ | 50.68 ± 0.14$^{aC}$ | 47.48± 0.02$^{aD}$ | 44.58± 0.02$^{aE}$ | 41.24± 0.02$^{aF}$ |
| 1kGy | 55.60± 0.05$^{bA}$ | 53.16± 0.03$^{bB}$ | 50.57± 0.02$^{bC}$ | 46.31± 0.00$^{bD}$ | 43.18± 0.02$^{bE}$ | 40.48± 0.02$^{bF}$ |
| 3kGy | 55.36± 0.04$^{cA}$ | 52.77± 0.04$^{cB}$ | 49.12± 0.03$^{cC}$ | 46.26± 0.01$^{bD}$ | 42.51± 0.03$^{cE}$ | 39.69± 0.02$^{cF}$ |
| 5kGy | 55.27± 0.05$^{cA}$ | 52.37± 0.03$^{dB}$ | 48.69± 0.03$^{dC}$ | 45.59± 0.01$^{cD}$ | 41.67± 0.01$^{dE}$ | 38.29± 0.02$^{dF}$ |
| 7kGy | 55.19± 0.04$^{cA}$ | 52.36± 0.03$^{dB}$ | 48.41± 0.04$^{eC}$ | 45.60± 0.01$^{cD}$ | 41.44± 0.02$^{eE}$ | 37.55± 0.01$^{eF}$ |
| **Chewiness(N)** | | | | | | |
| 0kGy | 38.55± 0.03$^{aA}$ | 35.68± 0.04$^{aB}$ | 30.60± 0.04$^{aC}$ | 29.55± 0.01$^{aD}$ | 27.68± 0.02$^{aE}$ | 25.68± 0.02$^{aF}$ |
| 1kGy | 37.27± 0.02$^{bA}$ | 33.43± 0.04$^{bB}$ | 28.65± 0.03$^{bC}$ | 25.84± 0.02$^{bD}$ | 24.37± 0.02$^{bE}$ | 23.28± 0.03$^{bF}$ |
| 3kGy | 35.36± 0.01$^{cA}$ | 31.54± 0.03$^{cB}$ | 27.66± 0.02$^{cC}$ | 23.89± 0.01$^{cD}$ | 22.95± 0.03$^{cE}$ | 21.28± 0.03$^{cF}$ |
| 5kGy | 34.23± 0.03$^{dA}$ | 28.38± 0.01$^{dB}$ | 25.44± 0.01$^{dC}$ | 22.89± 0.03$^{dD}$ | 20.43± 0.02$^{dE}$ | 19.68± 0.02$^{dF}$ |
| 7kGy | 32.49± 0.05$^{eA}$ | 25.18± 0.02$^{eB}$ | 23.59± 0.02$^{eC}$ | 20.50± 0.02$^{eD}$ | 18.12± 0.03$^{eE}$ | 16.55± 0.02$^{eF}$ |
| **Gumminess** | | | | | | |
| 0kGy | 31.55± 0.01$^{aC}$ | 31.66± 0.02$^{aD}$ | 31.54± 0.07$^{aC}$ | 32.67± 0.02$^{aA}$ | 31.77± 0.02$^{aB}$ | 31.59± 0.02$^{aC}$ |
| 1kGy | 31.48± 0.02$^{bC}$ | 31.55± 0.02$^{bBC}$ | 31.49± 0.04$^{abC}$ | 32.45± 0.02$^{bC}$ | 31.67± 0.02$^{bB}$ | 31.44± 0.02$^{bC}$ |
| 3kGy | 31.29± 0.02$^{cE}$ | 31.52± 0.02$^{bB}$ | 31.46± 0.02$^{bC}$ | 32.17± 0.02$^{cA}$ | 31.45± 0.02$^{cC}$ | 31.38± 0.01$^{cD}$ |
| 5kGy | 31.24± 0.02$^{dC}$ | 31.43± 0.01$^{cB}$ | 31.23± 0.02$^{cC}$ | 31.69± 0.03$^{dA}$ | 31.43± 0.02$^{cB}$ | 31.25± 0.03$^{dC}$ |
| 7kGy | 30.69± 0.02$^{eD}$ | 31.27± 0.02$^{dB}$ | 31.16± 0.02$^{cC}$ | 31.47± 0.02$^{eA}$ | 31.27± 0.02$^{dB}$ | 31.14± 0.01$^{eC}$ |
| **Cohesiveness** | | | | | | |
| 0kGy | 0.46± 0.00$^{aC}$ | 0.47± 0.00$^{aC}$ | 0.50± 0.00$^{aBC}$ | 0.54± 0.00$^{aB}$ | 0.58± 0.00$^{aB}$ | 0.71± 0.00$^{aA}$ |
| 1kGy | 0.45± 0.00$^{abD}$ | 0.46± 0.00$^{abD}$ | 0.50± 0.00$^{aCD}$ | 0.54± 0.00$^{aBC}$ | 0.57± 0.00$^{abB}$ | 0.68± 0.00$^{bA}$ |
| 3kGy | 0.45± 0.00$^{abC}$ | 0.46± 0.00$^{abC}$ | 0.49± 0.00$^{abBC}$ | 0.53± 0.00$^{abBC}$ | 0.57± 0.00$^{abB}$ | 0.66± 0.00$^{cA}$ |
| 5kGy | 0.44± 0.00$^{bcD}$ | 0.46± 0.00$^{abD}$ | 0.48± 0.00$^{bcCD}$ | 0.52± 0.00$^{bcBC}$ | 0.56± 0.00$^{bB}$ | 0.64± 0.00$^{dA}$ |
| 7kGy | 0.43± 0.00$^{cD}$ | 0.45± 0.00$^{bD}$ | 0.48± 0.00$^{bcCD}$ | 0.51± 0.00$^{cBC}$ | 0.56± 0.00$^{bB}$ | 0.63± 0.00$^{dA}$ |
| **Elasticity** | | | | | | |
| 0kGy | 0.76± 0.00$^{aA}$ | 0.74± 0.00$^{aB}$ | 0.73± 0.00$^{aBC}$ | 0.71± 0.00$^{aC}$ | 0.69± 0.00$^{aCD}$ | 0.67± 0.00$^{aD}$ |
| 1kGy | 0.74± 0.00$^{bA}$ | 0.73± 0.00$^{abAB}$ | 0.72± 0.00$^{abB}$ | 0.71± 0.00$^{aBC}$ | 0.69± 0.00$^{aCD}$ | 0.66± 0.00$^{abD}$ |
| 3kGy | 0.74± 0.00$^{bA}$ | 0.73± 0.00$^{abAB}$ | 0.72± 0.00$^{abB}$ | 0.70± 0.00$^{abC}$ | 0.68± 0.00$^{abD}$ | 0.66± 0.00$^{abE}$ |
| 5kGy | 0.73± 0.00b$^{cA}$ | 0.72± 0.00$^{bAB}$ | 0.71± 0.00$^{bcB}$ | 0.69± 0.00$^{bcC}$ | 0.67± 0.00$^{bcD}$ | 0.65± 0.00$^{bcE}$ |
| 7kGy | 0.72± 0.00$^{cA}$ | 0.72± 0.00$^{bA}$ | 0.70± 0.00$^{cB}$ | 0.68± 0.00$^{cC}$ | 0.66± 0.00$^{cD}$ | 0.64± 0.00$^{cE}$ |

a- e lowercase letters indicate a significant difference at 95% confidence level ($P< 0.05$) in each column and A-F uppercase letter indicate a significant difference at 95% confidence level ($P< 0.05$) in each row.

## Discussion

Prolong the storage time led to an increase in pH ($P< 0.05$) of various samples but radiation dose did not have a significant effect on the pH level ($P> 0.05$). As the storage time is increased, some basic compounds like alkaline volatile amines, ammonia, and other nitrogenous compound may



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be produced as a result of bacterial spoilage (Al-Bachir 2016). Following these reactions, pH of surimi is increased. On the other hand, using vacuum packaging probably prevents air accessibility for surimi samples during the storage time which hinders $CO_2$ penetration and consequently the formation of carbonic acid and causes a reduction in pH (Monteiro et al 2019). Yang *et al.* (2014) found that by combined application of electron beam and vacuum packaging to extend the shelf-life of trout fillet, their pH continuously increased with the storage time of samples under refrigerator conditions. However, radiation dose did not have a significant effect on the pH of treated samples.

Despite favorable effects of radiation on deactivation of microorganisms and consequently, increasing the shelf-life of sea food, irradiation leads to the oxidation of lipids and production of unpleasant odor through facilitating the conversion of unsaturated fatty acids to free fatty acids and production of hydro-peroxides (Boziaris 2014). Even so, using combined treatments like vacuum packaging and low temperatures may reduce the oxidation of lipids through reducing available oxygen and also diminishing the water free radicals (produced from radiolysis of polar molecules of water) (Hassanzadeh, Tajik, Razavi Rohani, Moradi, Hashemi, & Aliakbarlu 2017). Based on the statistical analysis through Duncan's multiple range it was found out that the peroxide content in various treatments was dependent upon gamma ray dose and their storage time. Increasing the radiation dose to treat surimi samples reduced the peroxide content, while increasing their storage time led to an increase in peroxide ($P< 0.05$). Therefore, using vacuum packaging and low temperatures combined with gamma radiation will reduce available oxygen for lipids oxidation and subsequently the formation of hydro-peroxides. These results were consistent with that of other studies (Al-Bachir & Zeinou 2009; Fallah, Saei-Dehkordi & Rahnama 2010). In study of Noori Hashemabad, Shabanpour, Azizi, Ojagh, Alishahi (2018) concluded irradiated samples had higher PV compared to control but using hurdle technology in combination with irradiation decreased oxidation.

TBA is widely used as an indicator of lipids oxidation which indicates the secondary products of oxidation. During the second stage of oxidation, some unstable substrates are formed which change into aldehydes and ketones that are able to react with thiobarbituric acid and produce a pink color whose intensity represents the oxidation level (Zhao, Zhang, Pan, Venkitasamy, Zhang, Xiong, Guo, Xia & Liu 2018). Increasing the radiation dose and storage time influences the indices related to secondary products of oxidation, so that increasing the gamma ray dose will reduce thiobarbituric acid and increasing the storage time will enhance this oxidation index. The occurrence of primary (slow oxidation) and secondary (dissipation) stages of oxidation aredependent upon the concentration of oxygen available in medium, so that if sufficient oxygen is available primary hydroperoxides break down and form carbonyl compounds (specially MDA) which are an indicator of advanced stages of oxidation and promotion of



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rancidity (Harder, Arthur & Harder 2017). Similarly, Hocaoğlu, Demirci, Gümüs & Demirci (2012) reported that by increasing the storage time of irradiated shrimp samples, TBA increased. Mbarki *et al*. (2009) studied the effect of gamma rays and vacuum packaging on the chemical properties of king mackerel fish during storage time. Their results suggested that using combined treatments of vacuum packaging and gamma radiation significantly reduced the thiobarbituric acid content compared to the control sample.

TVB-N is an indicator of spoilage level in sea foods which is primarily produced from bacterial growth and activity of enzymes inherent in these products. TVB-N index of 5-20 mg N100 $g^{-1}$ indicates a good quality, while indices in range of 30-35 mg N100 $g^{-1}$ generally are suggestive of a low accessibility, and values higher than 50 mg N100$g^{-1}$ represent a low quality in these products (Ryou, Titlow, Mays, Bae, & Kim 2016). Increasing the storage time enhanced TVB-N index, while increasing gamma ray dose reduce the total volatile basic nitrogen content of silver carp surimi. This is probably due to hindering microbial and enzyme activity which is obtained through using gamma rays and vacuum packaging (Zhang et al 2016). Also, a low temperature reduces the bacteria's capability for oxidative deamination of non-protein nitrogen compounds (Abdeldaiem et al 2018). Yang, Wang, Wang, Qi, Yue & Ye (2014) and Zhang *et al*. (2016) found that using electron beam for trout and grass carp fillets led to a reduction in TVB-N and increasing the storage time resulted in an increase in this parameter. TVB-N in the surimi sample treated with 7 kGy of gamma radiation and vacuum packaging and stored under refrigerator conditions for 15 days was measured to be 47.50 mg N100$g^{-1}$. In other treatments, however, the level of TVB-N ($p< 0.05$) was higher than 50 mg N100$g^{-1}$ at the end of storage time.

Measurements of fatty acids released from existing lipids in surimi samples treated in this study showed that increasing the gamma ray dose reduces the content of these free fatty acids while it increases with increasing the storage time from day 1 to day 15 ($P< 0.05$), so that the highest levels (3.8 %) of free fatty acids were observed at the end of the storage time in samples treated with 1 kGy of gamma radiation. The formation of free fatty acids in full-fat foods especially foods containing unsaturated fatty acids like sea-foods is of utmost importance, since such compounds are considered to be suitable substrates for initiation and continuation of chain oxidation reactions which minimize the nutritional value of foods or create rancidity due to formation of volatile compounds (Dogruyol & Mol 2016). Lipase is able to break the ester bond between glycerol and fatty acids in triglycerides' structure, a reaction which releases free fatty acids. Therefore, through proliferation of existing microorganisms in the surimi samples, lipase enzyme may be produced which increases the content of free fatty acids (Waraho, McClements, & Decker 2011). Probably due to a higher gamma ray dose, the lipase-producing microorganisms in the treated samples are deactivated or their activity is declined which causes a reduction in the free



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fatty acid content of irradiated sampled compared to the control. Ahn, Kim I.S and Lee (2013) found that applying gamma radiation reduced the microbial count followed by the content of free fatty acids in poultry meat. Bari, Sabina, Kusunoki and Uemura (2000) and Cortez-Vega et al. (2014) reported that by increasing the storage time, a significant increase was observed in the free fatty acid content of fish.

Increasing the gamma radiation raised the lightness index ($P< 0.05$), while prolong the storage time from day 1 to the end of day 15 ($P< 0.05$) reduced the lightness index (L*) of various treatments. On the other hand, it was found that yellowness (b*) and redness (a*) indices were lower in treated samples compared to the control. The yellowness index, however, had a remarkable increasing trend during the storage time ($P< 0.05$). The yellowness increase may occur as a result of oxidation reactions and proteolysis. Following these reactions, carbonyl and amine groups are exposed to each other and provide the conditions for browning and millard reactions which eventually lead to the formation of brownish-yellow polymer compounds (Simpson 2012). Similarly, Tomac, Cova, Narvaiz & Yeannes (2015) found that applying gamma ray on the fish fillet reduced the lightness index and increase the yellowness index during the storage time.

Texture is an important attribute of silver carp surimi quality. There were significant differences ($P< 0.05$) in hardness and chewiness between the irradiated and control groups. During storage, hardness, chewiness and gumminess decreased, probably due to protein degradation and surimi firmness reduction. The hardness index is defined as the maximum force required for deformation of samples under compression test, while chewiness is defined as the required work to chew food to be easily swallowed which is proportional to the hardness index in textural tests (Bourne 2002). It was clear that weak textural properties (hardness and chewiness) as a result of radiation and storage at various conditions are probably due to enzyme activity and the effect of radiation on protein structures and their breakdown into smaller and denaturation structures which reduce the hardness and subsequently the chewiness index (Nishinari, Kohtama, Kumagai, Funami & Bourne 2013). Similarly, results of the current study were in agreement with that of other works. Suggested that applying gamma radiation on the fisheries products would reduce the hardness and chewiness indices during the storage time. The action of endogenous and microbial peptidases during storage leads to protein breakdown, resulting in a softer texture Cohesiveness and gumminess were not affected, either by preservation methods or by the refrigerated storage period. Gamma irradiation induces protein denaturation, favoring proteolysis and increasing the softness of surimi (Ocaño-Higuera *et al*. 2011; Tomac *et al*. 2015).

The initial TVC ranged 4.68- 9.88 log cfu $g^{-1}$ at end of storage in control treatment. TVC count at the end of storage for irradiated at 1, 3, 5 and 7 kGy became 9.78, 8.95, 7.72 and 7.31 log cfu $g^{-1}$, respectively. Gamma irradiation mainly reduces TVC in seafood products. The



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antibacterial action of ionizing irradiation is linked to the damage of bacterial DNA by free radicals produced during the irradiation. Damage to cell membranes is another mechanism of irradiation (Ehlermann 2016). At 12$^{th}$ day, total count of microorganisms in surimi was 6.84 log cfu g$^{-1}$ which was lower than the limit (7 log cfu g$^{-1}$) allowed for fish products (Lung, Cheng, Chang, Huang, Yang & Wang 2015). These results indicate that irradiation may well reduce the microorganisms count and approach it to an acceptable limit. Furthermore, the concomitant use of ionizing rays and vacuum packaging effectively prevents the growth of microorganisms (Zhang et al. 2016). The microbial quality of the irradiated surimi samples was maintained during cold storage of 12 days. Yue (2014) had reported reduction of bacterial count by 3-5 logs at 2.5-5 kGy in shrimp. Hocaoğlu et al. (2012) observed reduction of TVC by 3 logs at 3 kGy in fresh prawn.

**Concliusion**

According to the microbiological, chemical and sensory results, the optimal storage time for surimi, compared to the control treatment, was measured for 7 kGy which could lengthen the storage time by 3 days compared to the control.

## Conflicts of interest

None of the authors has any conflicts of interest to declare.

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# تأثیر اشعه دهی گاما بر ماندگاری سوریمی کپور نقره ای در بسته بندی تحت خلاء

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**چکیده:**

مطالعه اخیر تأثیر اشعه گاما (۰، ۱، ۳، ۵ و۷ کیلوگری) و بسته‌بندی تحت خلاء روی ماندگاری سوریمی کپور نقره‌ای نگهداری شده در دمای ۴ درجه سانتی‌گراد از طریق متغیرهای pH، میزان پراکسید، اسیدتیوباربیتیوریک، بازهای نیتروژنی فرار کل، اسیدهای چرب آزاد، پارامترهای رنگ، شمارش باکتری‌های زنده و آنالیز بافت طی ۱۵ روز را بررسی کرد. نتایج نشان داد که pH با افزایش میزان اشعه‌دهی تغییر معنی‌داری نکرد ($P> 0.05$). نتایج میزان پراکسید و اسیدتیوباربیتیوریک در سوریمی کاهش معنی‌داری با افزایش میزان پرتودهی نشان داد ($P< 0.05$)، درحالیکه با افزایش زمان نگهداری افزایش نشان داد. با افزایش پرتودهی و زمان نگهداری، میزان بازهای نیتروژنی فرار کل افزایش معنی‌داری نشان داد ($P< 0.05$). افزایش پرتودهی (تا دوز ۷ کیلوگری) و زمان نگهداری (تا ۱۵ روز) افزایش معنی‌داری روی میزان اسیدهای چرب فرار در دمای یخچال داشت. ارزیابی رنگ ثابت کرد که بعد از پرتودهی، نمونه‌ها در شاخص‌های *L، *a و *b افزایش نشان دادند. علاوه بر این، افزایش در دوز پرتودهی میزان باکتری‌های زنده کل نمونه‌های سوریمی را بطور معنی داری کاهش داد ($P< 0.05$)، اما با افزایش زمان نگهداری تعداد باکتری‌ها زیاد شد ($P< 0.05$). بر اساس آنالیز پروفایل بافت افزایش دوز اشعه و زمان نگهداری شاخص سختی و جویدنی را کاهش داد. بر طبق نتایج میکروبی و شیمیایی، نمونه‌های سوریمی پرتودهی شده با ۷ کیلوگری نسبت به گروه کنترل (۰ کیلوگری) ماندگاری خود را ۳ روز بیشتر حفظ کردند.

**واژگان کلیدی:** اشعه گاما، بسته‌بندی خلاء، سوریمی، کپور نقره‌ای

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