

Effects of gamma irradiation on the shelf-life of frozen tiger shrimp, *Penaeus monodon* (Fabricius, 1798)

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[Received: January 18, Accepted: May 19, 2014]

ABSTRACT

The effects of three levels of irradiation (3, 6 and 9 KGy) during storage period (0, 15, 30, 45, 60, 75 and 90 days) were evaluated in frozen tiger shrimp, *Penaeus monodon*. Biochemical composition was analyzed before and after treatment. Quality of tiger shrimp was assessed through organoleptic, chemical (Total Volatile Nitrogen, TVN and Trimethylamine, TMA) and microbiological (Total Bacterial Count (TBC); Total Mold Counts (TMC); Total Yeast Count, (TYC); Total Coliform Count, (TCC) and *Salmonella* count) evaluation at an interval of 15 days during the storage period. High doses of radiation affected on the texture of fish. While, the maximum shelf life was observed for 9 KGy irradiated sample. All the samples were acceptable during 90 days of storage period because the upper limit of all spoilage indicators did not exceed the recommended values.

Key Words: Food acceptability, microbial flora, frozen temperature, gamma radiation, *Penaeus monodon*

INTRODUCTION

In Bangladesh, shrimp and fish are frequently sold and preserved at traders and consumers level in icing or, freezing condition. It concerns with animal protein derived from marketed fish, fishery products, meats and meat products that creates a high risk commodity regarding to pathogenic/ microbial contaminations, adulterants and natural toxicity causes death^[1]. Bacteriological quality of fish concerns to the spoilage and in some cases creates chance for the outbreak of food poisoning^[2]. Besides, anthropogenic and biological contagions depreciate the water quality of the shrimp farming area which cause great difficulties in shrimp exporting with the international quality standard. Shrimps, exported principally to USA, Japan and Europe from Bangladesh^[3], is threatened for low quality of processed shrimp products due to small size, bacterial load or presence of chemical residue levels^[1, 2]. Raw or frozen shrimp deteriorated by improper handling are responsible for causing food-borne diseases^[1] and diseases transmission. Poor quality of the raw material and poor sanitary performance of freezing plant and also the freezing of decomposed shrimps are major problems encountered by the seafood industry.

Spoilage due to microbial activity is the main limitation of the shelf life of refrigerated fish^[4]. By lowering or raising the temperature, bacteria and autolytic spoilage rate can be reduced^[5]. Refrigeration inhibits the activity of food spoilage organisms and the low storage temperature greatly slows down the enzymatic and biochemical reactions that normally occur in unfrozen foods^[6]. Besides,

food irradiation is a process exposing food to ionizing such as gamma rays emitted from radioisotopes ⁶⁰Co27 and ¹³⁷Cs55 or high energy electrons and X-rays produced by machine sources^[7]. Depending on the absorbed radiation dose, various effects can be achieved resulting in reduced storage losses, extended shelf life and/ or improved micro biological and parasitological safety of foods. The interest in food irradiation is fast growing both in developed and developing countries. International bodies such as International Atomic Energy Agency (IAEA), Food and Agricultural Organization (FAO) and World Health Organization (WHO) are now actively engaged in bringing out recommendations for facilitating the acceptance of food irradiation processes, by all United Nations (UN) member states. Food irradiation ensures better public health and offers greater economic advantage to the producers in developing countries.

Since, tiger shrimp (*Penaeus monodon*), one of the exported commodities, is a valuable source of foreign currency. So, its shelf life extension is very much crucial. But, lack of proper techniques of preservation a significant amount of shrimps and prawns have been destroyed every year^[1, 2]. So, inquest of a new and pertinent technology of preservation is essential to protect the national loss. Various factors contribute to the spoilage and deterioration in the quality of the products.

The main purpose of the present study was to determine the quality of frozen exportable tiger shrimp using different doses of gamma irradiation as well as the microbiological, chemical and organoleptic scores in the control and different irradiated samples stored at -20°C.

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MATERIALS AND METHODS

Experimental specimen and sampling

Tiger shrimp, *Penaeus monodon* (Fabricius, 1798) locally known as 'Bagda Chingri', was considered as an experimental specimen for this study. The specimen tiger shrimp, *P. monodon* at -20°C was collected from Snow King Frozen Foods (pvt.) Ltd., Mirpur, a fish processing factory of Dhaka, where the factory authority collected the shrimp from Rupsa, Khulna. Collected blocked shrimp was immediately transferred to pre-sterilize polythene bag and carried to the laboratory of Food Processing and Preservation Division, Institute of Food and Radiation Biology (IFRB), Atomic Energy and Research Establishment (AERE), Savar, Dhaka, Bangladesh for analysis.

Research and sampling design

The present study has symmetrically done for biochemical composition and quality assessment of tiger shrimp. The entire samples were at first randomly grouped into four lots for biochemical, microbiological and nutritional studies. The four lots were taken in four polypropyl polythene bags for preservation purposes under control and 3, 6, 9 KGy doses of gamma irradiation. Therefore, shrimps were divided into the following treatment groups - Treatment A: Control (without irradiation), Treatment B: Irradiated (3 KGy), Treatment C: Irradiated (6 KGy), Treatment D: Irradiated (9 KGy). Treatment A was kept at -20°C without irradiation. Treatment B, C and D were subjected to irradiation in 3, 6 and 9 KGy with a panoramic ^{60}Co source supplied by the Atomic Energy of Canada Ltd. After irradiation, the irradiated treatment B, C and D were kept at -20°C . All treatments were considered for biochemical and microbiological analysis at the 0, 15, 30, 45, 60, 75 and 90 days of storage period. The data were taken at an interval of 15 days up to 90 days during the storage periods.

each sample was taken and homogenized in mortar and pastel to prepare sample. Sterilization media (Nutrient agar media for TBC, PDA media for TMC and Yeast media) were used for microbial analysis^[12]. Dehydrated nutrient agar (Difco) consisting of peptone was used as the media for the bacterial growth and potato dextrose agar media was used for the mold growth. Yeast extract media was used for yeast growth and SS media used for *Salmonella* count. Colonies that developed on the plates after incubation at 37°C and 30°C after 24 and 48 hours were counted with the help of colony counter. The number of bacterial, mold, yeast, coliform and *Salmonella* colonies was obtained by standard method and expressed as cfu/g^[12].

Data analysis

Statistical analyses were performed among the various content of bio-chemical compositions as well as in between treatments and storage periods on various quality evaluation indices with the SPSS software package (version 11.5, SAS Institute Inc, USA) to present the data as mean \pm SEM.

RESULTS AND DISCUSSION

Moisture, protein, lipid, ash and mineral (calcium and phosphorus) contents of *P. monodon* are presented in Table 3 where the major constituent of tiger shrimp was moisture. Average moisture content was $78.45 \pm 0.26\%$ that agreed with the findings of Khan *et al.*^[13], Akintola *et al.*^[14], Nisa and Sultana^[15], NIN^[16], Begum and Hoque^[17], Aykroyed *et al.*^[18] in shrimps and Ferdose and Hossain^[19] in prawn (*Macrobrachium rosenbergii*). On the other hand, a little bit less amount of moisture than that of the present study were reported by Abdel-Salam^[20], Shalini *et al.*^[21], Puga-López *et al.*^[22] in shrimp. The protein content of tiger shrimp is also a focal point, average protein content was $18.45 \pm 0.3\%$ in *P. monodon*. Similar results were also found by Khan *et*

Table 1. Mean (\pm SEM) biochemical composition of frozen *Penaeus monodon*.

Moisture (%)	Protein (%)	Lipid (%)	Ash (%)	Calcium (mg/ 100g)	Phosphorus mg/ 100g)
78.45 ± 0.26	18.45 ± 0.30	1.73 ± 0.04	1.12 ± 0.03	210.78 ± 6.90	102.80 ± 7.10

Laboratory assay

All samples were examined for proximate composition according to AOAC^[8]. The stored samples were evaluated organoleptically for odor, appearance, color and texture by a panel of judges on a 9 point hedonic scale as described by Peryam and Pilgram^[9]. Trimethylamine (TMA) and Total Volatile Nitrogen (TVN) were examined by using Conway micro diffusion technique method^[10].

The Total Bacterial Count (TBC), Total Mould Count (TMC) and Total Yeast Count (TYC) were estimated by the method described by Sharf^[11] using pour plate technique. Two (2) g shrimp muscle of

al.^[13] as $18.41 \pm 0.54\%$ protein in *Metapenaeus monoceros*, Nisa and Sultana^[15] as 19.00% in muscle of matured *Fenneropenaeus penicillatus*, Begum and Hoque^[17] found 17.35% protein; Aykroyed *et al.*^[18] and NIN^[16] were recorded 19.1% protein in shrimps that were quite similar with the present findings. But Puga-López *et al.*^[22] reported $20.04 \pm 0.93\%$ and $20.47 \pm 0.61\%$ protein in *Litopenaeus vannamei* and *L. stylirostris*, respectively; and Shalini *et al.*^[21] recorded higher $25.01 \pm 0.02\%$ and $22.17 \pm 0.02\%$ in tissues of *L. vannamei* and *F. indicus*, respectively. On the contrary, Abdel-Salam^[20] found $42.88 \pm 1.11\%$ and $40.68 \pm 2.28\%$ in male and female *P.*

indicus, respectively and Akintola *et al.*^[14] estimated $64.74 \pm 0.45\%$ in fresh *P. monodon* in dry weight basis.

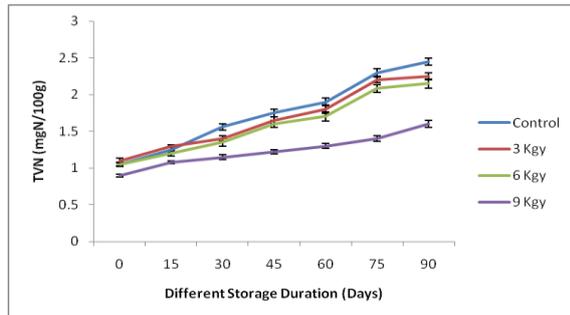


Fig. 1. Mean (\pm SEM) TVN values (cfug^{-1}) of *Penaeus monodon* during 90 days of storage period at -20°C with control and different doses of radiation treatments.

There is no significant difference in lipid content of treated shrimp samples. Average fat content was $1.73 \pm 0.04\%$ that was similar with the findings of Begum and Hoque^[17] in shrimps (1.68%), Nisa and Sultana^[15] (1.5%) in muscle of matured *F. penicillatus*, Puga-López *et al.*^[22] ($1.27 \pm 0.16\%$ and $1.03 \pm 0.15\%$, respectively) in *L. vannamei* and *L. stylirostris*; and also the findings (1.65%) by NIN^[16] and Aykroyed *et al.*^[18] in shrimps. The results of Khan *et al.*^[13] ($2.84 \pm 0.42\%$) in *M. monoceros*, Shalini *et al.*^[21] ($2.13 \pm 0.02\%$ and $0.01 \pm 0.02\%$, respectively) in tissues of *F. indicus* and *L. vannamei* also support the present finding. But Akintola *et al.*^[14] recorded higher ($4.88 \pm 0.04\%$) lipid in *P. monodon* in dry weight basis and Abdel-Salam^[20] reported quite higher 8.57 ± 0.24 and $8.92 \pm 0.02\%$ in male and female *P. indicus*, respectively than that of the present finding. In the present investigation, average ash content was $1.12 \pm 0.03\%$ of shrimp that was paralleled with the judgment of Khan *et al.*^[13] ($1.31 \pm 0.14\%$) in *M. monoceros*, Nisa and Sultana^[15] (1.86%) in muscle of matured *F. penicillatus* and NIN^[16] in shrimps. However, Begum and Hoque^[17] found 2.60% ash in shrimp, Puga-López *et al.*^[22] recorded higher ash content ($2.26 \pm 1.66\%$ and $2.30 \pm 0.71\%$) in *L. vannamei* and *L. stylirostris*, respectively; Akintola *et al.*^[14] estimated $12.66 \pm 0.17\%$ in *P. monodon* (in dry weight basis) than that of the present one.

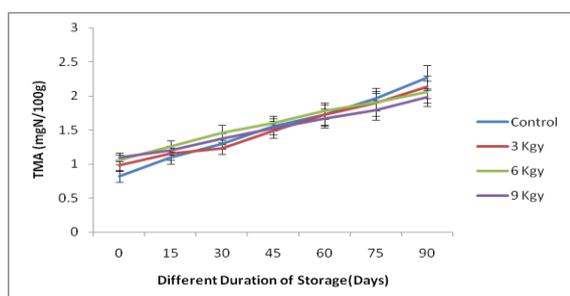


Fig. 2. Mean (\pm SEM) TMA values (cfug^{-1}) of frozen (at -20°C) *Penaeus monodon* with control and different doses of radiation treatments during 90 days of storage period.

Nurullah *et al.*^[23] reported that the average moisture content of fish increased during freezing, whereas protein, lipid and ash reduced in fresh condition. As fat deposition and moisture have inverse relationship^[4,7], greater percentage of moisture was observed in shrimp. Similar inverse relation between fat and moisture content was also recorded by Mustafa *et al.*^[7], Sayed *et al.*^[4] and Chakraborty *et al.*^[24] for different fish during gamma irradiation at low temperature. The body composition seems to depend on age, sex, seasons^[4], size, temperature, stages of maturity, and diet^[25] and varies from species to species and even within the same species from one individual to another. The composition varies with season, size, stages of maturity, temperature and deviation may occur due to natural feeding habits and availability of feed, fasting duration during spawning and migration^[23].

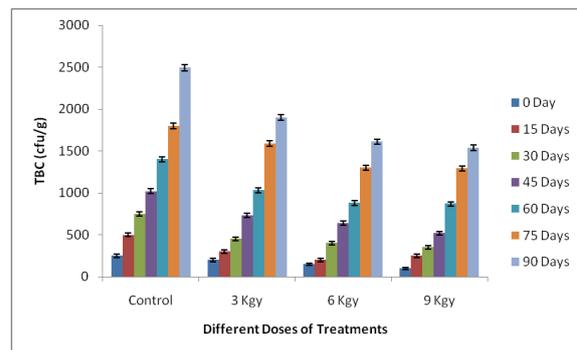


Fig. 3. Mean (\pm SEM) TBC values in cfug^{-1} of irradiated frozen (at -20°C) *Penaeus monodon* sampled from control and different doses treatments at different storage period.

In the present study, average calcium (Ca) content was 210.78 ± 6.90 mg/100g of shrimp muscle. Similar Ca content was recorded by Shalini *et al.*^[21] as 279.00 ± 0.03 and 273.30 ± 5.73 mg/100g in tissues of *L. vannamei* and *F. indicus*, respectively. But Abdel-Salam^[20] found 45.09 ± 1.30 and 39.96 ± 2.20 mg/100g Ca in edible muscle of male and female *P. indicus*, respectively; and Begum and Hoque^[17] reported 114.65 mg/100g of Ca in shrimp which are lower than the present finding, whereas NIN^[16] estimated 323 mg/100g of calcium in shrimp which is higher than the present result. In the present research, average phosphorus (P) content was 102.80 ± 7.1 mg/100g of shrimp muscle. Abdel-Salam^[20] found more less P content (74.32 ± 1.99 and 75.45 ± 1.78 mg/100g in male and female *P. indicus*, respectively) in edible muscle than the present finding. On the other hand, Shalini *et al.*^[21] reported 215.06 ± 0.02 and 251.39 ± 0.53 mg/100g P in tissues of *L. vannamei* and *F. indicus*, respectively; and NIN^[16] estimated 278 mg/100g of phosphorus in shrimp which are higher than the present result (Table 1).

The highest organoleptic score (OS) was found in the 6 Kgy treatment group, whereas the lowest score was measured in the control group. Among durations

and treatments scores were significantly different. Under the investigation, best result of OS was found in the treatment of 6 KGy (Table 2). The treated samples with 6 KGy were better organoleptically than those with 9 KGy. It might be the high dosage of irradiation damages the texture. Similar trend was found by Sayed *et al.*^[4] and Ahmed *et al.*^[26] in fish during irradiation at low temperature. It was clear that with the increase of storage period the OS were rapidly decreased in the control shrimps than those irradiated shrimps at different doses. Besides, the sub-tropical environment might also be the crucial reason for the presence of different types of bacteria in fishes might be the reason to spoilage as well as acceptability^[1,2]. Due to microbial spoilage with the increase of storage period, the appearance, odor, color and texture will also be deteriorated^[4,7], therefore the OS were decreased.

Regarding the biochemical parameters, the best result of TVN value was found at the treatment dose of 9 KGy (Fig. 1) and the TVN values gradually increased with the progress of storage periods. During the storage period of 90 days, the TVN value of all the samples was comparatively lower in 9 KGy

The TMA values were gradually increased with the progress of storage period (Fig. 2). Comparing the TMA values, the lowest value was found in 9 KGy treatment group while the highest value was measured in the control group. The TMA value of 3 KGy and 6 KGy treatments were also different. Among the durations and the treatments, the values were significantly different. Under this investigation, best result of TMA value was found for 9 KGy. The production of TMA was retarded considerably in the irradiated samples as compared to the controlled samples. Such pattern was also obtained from the observations of Mustafa *et al.*^[7], Sayed *et al.*^[4], Chakraborty *et al.*^[24], Ahmed *et al.*^[26]. Suppression of TMA accumulation in the irradiated samples indicated that micro flora was capable of producing TMA were probably selectively removed by irradiation^[26]. So, the effect of irradiation was well effective in the rate of TMA accumulation^[6].

The TBC during different storage period presented in Fig. 3 for *P. monodon* illustrated that at the beginning of 90 days storage period bacterial growth were affected by the radiation and differs significantly. The results showed that bacterial

Table 2. Organoleptic score (mean ± SEM) obtained from control and different irradiation treatments of frozen *Penaeus monodon* during 90 days storage period at -20°C.

Duration (day)	Level of Radiation (KGy)			
	Control	3	6	9
Control	9.00 ± 0.00	9.00 ± 0.00	9.00 ± 0.00	9.00 ± 0.00
15	8.25 ± 0.05	8.55 ± 0.10	8.60 ± 0.05	8.80 ± 0.05
30	8.00 ± 0.15	8.10 ± 0.01	8.18 ± 0.02	8.37 ± 0.07
45	7.45 ± 0.05	7.75 ± 0.05	8.13 ± 0.03	8.03 ± 0.03
60	7.05 ± 0.10	7.35 ± 0.10	7.68 ± 0.03	7.18 ± 0.08
75	6.55 ± 0.20	6.95 ± 0.10	7.28 ± 0.07	6.90 ± 0.05
90	6.00 ± 0.15	6.75 ± 0.05	7.07 ± 0.04	6.58 ± 0.07

treated storage of the experiments due to retardation of enzymatic action at higher irradiation^[4, 7]. Among durations and treatments, the values were significantly different. Increased value of TVN decreased the acceptability of fish. Such pattern of result was also obtained from the observations of Sayed *et al.*^[4], Mustafa *et al.*^[7], Chakraborty *et al.*^[24] and Ahmed *et al.*^[26].

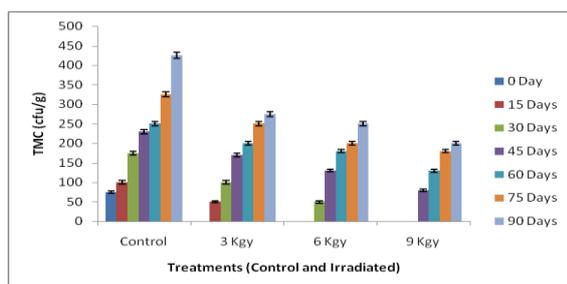


Fig. 4. Mean (± SEM) TMC (cfug⁻¹) values of *Penaeus monodon* during 90 days of storage period at -20°C with control and different doses of treatments.

counts were increased rapidly under controlled but slowly in 9 KGy treated samples. Similar trend was also found from the observations of Sayed *et al.*^[6], Mustafa *et al.*^[7], Chakraborty *et al.*^[24], Ahmed *et al.*^[26], Haque *et al.*^[27] for freshwater fish and Hossain *et al.*^[28] for marine fish. The lowest value of TBC was found in 9 KGy treated group, while the highest value was measured in the control group. The TBC of 3 KGy and 6 KGy treatments were also different. Irradiated samples remained acceptable according to ICMSF^[29] up to 90 days of storage period (Fig. 3). To detect the days when level of TBC exceed the acceptable limit research should be conducted for long time. The TMC value (cfug⁻¹) was also affected by different doses of irradiation. The lowest value was found in the 9 KGy treatment group, while the highest value was measured in the control group (Fig. 4). Among the durations and the treatments the values were significantly different. The best result of TMC value was found at the treatment dose of 9 KGy. From the present study, it was found that the fish samples treated by 9 KGy dose contained less mold than all other treated and controlled samples and with the increase of storage time, the control

samples obtained more mold than that of irradiated samples. Similar trend was also found from the observations of Mustafa *et al.*^[7], Sayed *et al.*^[6] and Chakraborty *et al.*^[24] for different freshwater irradiated fish. So, from the total mold count it was found that 9 KGy irradiated fish sample gave high antimicrobial efficacy.

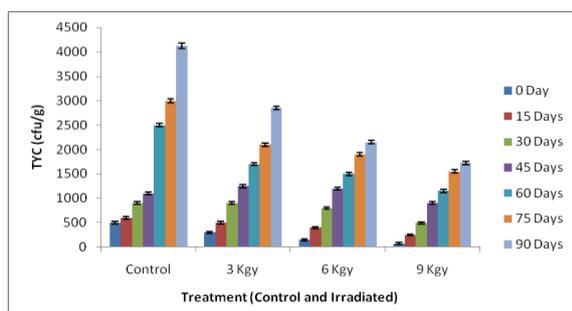


Fig. 5. Mean (\pm SEM) TYC values in cfug^{-1} of *Penaeus monodon* at -20°C with control and different doses of treatments during 90 days of storage period.

Among the treatments, the lowest TYC value was found in the 9 KGy treatment groups whereas the highest value was measured in the control groups. The TYC of 3 KGy and 6 KGy treatments were also different. The results showed that yeast colony increased with storage period rapidly under controlled but slowly under 9 KGy treatments (Fig. 5). Since, a very few work on TYC of fresh fish has been reported in the literature, so, the results obtained from the study could not be compared widely. Mustafa *et al.*^[7] also found that the population was increased with the increase of storage period for *Puntius* sp. From the present study, it was found that the shrimps samples treated by 9 KGy dosage contained less yeast than all other treated and controlled samples and with the increase of storage times, the control samples obtained more yeast than that of irradiated samples. So, from the total yeast count it was found that 9 KGy irradiated shrimps sample gives the best result as preservation method.

During the investigation of 90 days of storage period, Coliform and *Salmonella* were totally absent. Hossain *et al.*^[28] stated that *Salmonella* was absent in all (control and 150 Krad) hilsha (*H. ilisha*) fish samples at 5°C temperature storage. According to ICMSF^[29] guideline, acceptable *Salmonella* for irradiated fish is absent per 25g of sample. So it is unveiled that all the samples were acceptable during whole storage period.

The actual extension of shelf-life is dependent on the level of dose and the condition of fish at the time of treatment. The use of irradiation in food preservation is based on the theory that at certain dosage levels of irradiation, spoilage is prevented and pathogenic bacteria destroyed without altering the characteristics of the food. It is reported that low doses of ionizing radiation are known to reduce the spoilage causing factors in food and thereby extended the shelf-life of irradiated products^[28].

CONCLUSION

This study revealed that 9 KGy irradiation is a good treatment for long time preservation of tiger shrimp, though it has an effect on organoleptic conditions. So, it might be effective to preserve this valuable source of foreign exchange earning shrimp with an extended shelf-life for maintaining all the international standards needed for consumer satisfaction and safety.

ACKNOWLEDGEMENT

The authors greatly acknowledged about the laboratory supports provided by Food Processing and Preservation Division, Institute of Food and Radiation Biology, Atomic Energy Commission, Savar, Dhaka.

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