Stability and quality improvement of shrimp patties by *Asparagus racemosus* and gamma irradiation

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**ABSTRACT**

The present study was conducted to determine the effect of gamma irradiation and *Asparagus racemosus* on the storage stability and shelf life of shrimp patties. Gamma irradiation (3 kGy and 5 kGy) and *Asparagus racemosus* powder (3%) were applied to measure microbial activity, physiochemical chemical analysis, antioxidant potential, TVBN value, TBARS value, and POV of shrimp patties. The total aerobic bacteria and coliform count were reduced with the increase in irradiation dose. The DPPH and TPC were decreased with irradiation dose but addition of 3% ARP increased the values. TVBN values significantly decreased at 0 day of storage and increased with storage time. The TBARS and peroxide values (POV) showed significant increase with the increase in irradiation dose at different storage (0, 7, 14, and 21 day). The minimum changes were observed in sensory attributes (i.e. appearance, taste, odor, texture, and overall acceptability) on different treatments at storage intervals. The aim of this study showed that different doses of gamma irradiation and *Asparagus Racemosus* are valuable to improve the shelf stability and quality of shrimp patties.

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**Introduction**

Seafood is an essential component of the food chain in numerous developing nations due to the size and safety of the food chain. It includes a variety of essential elements which are hard to come by in all other diets. Proteins, omega-3 fats (EPA and DHA), vitamin D, B group, and minerals like iodine and selenium may all be found in seafood.[1]

Fish cells are affected by enzymatic, microbial, and oxidative spoilage and also other nutrients as well. Many additional nutrients are found in NPN (non-protein nitrogen), (amino acids), and fatty acids. The development of microbes during storage affects the structure of the protein-making tissue ingestion undesirable owing to color, texture, and textural alterations.[2] To fulfill the needs in terms of the global rising population, which will exceed nine billion people by 2050, global food production would need to expand by 50%. Fish and fish products may be able to cover a major amount of the world’s food demands by 2050. If compared to certain other products, shrimps contain large quantities of omega-3 fatty acids, animal-based protein, necessary amino acids, vitamins, and minerals.[3]

Shrimp is a species whose popularity is growing around the world. Their nutritional composition which contains amino acids, peptides, and PUFA, in particular, as well as other important elements is the major reason behind their demand particularly in Asia and some other countries like China etc.[4] Shrimps are amongst the most popular marine foods, valued due to their excellent nutritional content and excellent flavor particularly in developed nations. Fresh shrimp contains a high amount of protein...
content (average amount of protein value is about 189.0 g/kg).\textsuperscript{[5]} Shrimps contain lipophilic carotenoid Astaxanthin which is vital carotenoid pigment and a powerful antioxidant with great health benefits. Astaxanthin has a higher antioxidant activity in cells than carotene, vitamin C, vitamin E, lutein, lycopene, and other catechins. Astaxanthin has been shown to have antioxidant activity 100 to 500 times stronger than tocopherol and 5 to 15 times larger than other carotenoids.\textsuperscript{[4]} Irradiation is new technology used for preservation of seafood. Few additional methods for preservation like packaging with storage at different temperature as (at 0–1°C), frozen (at −18°C), dried, smoked, salting, boiled, and preserved products.\textsuperscript{[6]}

Irradiation is considered a safe technology and is becoming increasingly important in meat products worldwide. Types of all microorganisms in the skin can be counteracted by irradiation and also have adverse effects because it reduces the degree of environmental change to reduce oxidation. Gamma irradiation can be used in various fruit treatments to increase safety and shelf life. Another important problem in maintaining physical properties is the oxidation of lipids. Adding antioxidants can solve the problem of inflammation. The use of filters is an excellent technology to keep meat and products safe. Herbs, plants, vegetables, and fruits as well as powder form or extraction having antioxidant and antimicrobial characteristics are all examples of physical preservation.\textsuperscript{[7]} It is indeed a physical technique in which ionizing radiation is used to cure food. Ionizing energy such as gamma radiation (60-cobalt or 137-cesium), irradiation, and electron rays have been authorized Food and Drug Administration has approved it for use in food (FDA). Consumers can get benefit from better food and health as well as longer life and simpler travel, thanks to advances in food storage and irradiation technologies.\textsuperscript{[8]}

Asparagus racemosus has about 300 varieties all over the world and out of these 300 22 are exists in India. Asparagus racemosus was originally classified as a member of the Liliaceae family, but it has since been reclassified as a member of the Asparagaceae family.\textsuperscript{[9]} As a pharmaceutical plant, it is a plant of wealth and global transformation as well as a popular study preferably for breeding. Asparagus racemosus is a member of the Asparagaceae family and the genus Asparagus. A. racemosus has many physical, chemical, and biological properties, such as antioxidants, immune-stimulants, anti-hepatotoxic, antibacterial, anti-diabetic, anti-carcinogenic, anti-diarrheal, anti-ulcer genetic, and antioxidant properties with the exception of aphrodisiac.\textsuperscript{[10]} Shatavari (Asparagus racemosus) can be very important as a dietary supplement in animal feed because its nutrients such as protein, fiber crude, ether extract, nitrogen, and ash extraction as well as minerals such as Cu, Zinc, Ca, Mg, and Fe are available in large amounts.\textsuperscript{[11]} Asparagus racemosus (family: Liliaceae) is a root-like plant. Mostly this plant grows in subsurface soil and in tropical regions. Asparagus Racemosus is medicinal plant that considered important source of antioxidants. The antioxidants properties of Asparagus Racemosus aid to prevent oxidation in the cell.\textsuperscript{[12]} It comprises immune-stimulants, anti-inflammatory medications, hepatotoxic medications, and anti-cancer medications. Antioxidant and antibacterial capabilities are said to be particularly prominent in this plant. It was also discovered that the plant roots had a lot of DPPH activity which reduces their efficacy and antifungal capabilities. The roots depict the dynamical DPPH functionality of high potential reduction. The antibacterial capabilities of racemosus materials have been found to suppress the development of E. coli, Vibrio parahaemolyticus, Pseudomonas aeruginosa, and Vibrio parahaemolyticus. The plant roots contain antifungal and anti-inflammatory activities against seven different species including Aspergillus flavus, Colletotrichum acutatum, Candida albicans, Aspergillus tevatus, Aspergillus Niger, Rhizoctonia solani, and Colletotrichum coffeanum.\textsuperscript{[13]} The chemical composition and therapeutic qualities of the plant may be varying according to nutrient content of the soil, the weather, the level of development of the plant, as well as the general association with other plants.\textsuperscript{[10]} Although the effect of gamma irradiation is well known to improve the shelf life and to kill the microbes, many studies showed the effect of Asparagus racemosus to control the oxidation. This study was designed to determine the effect of gamma irradiation and Asparagus racemosus on the storage stability of shrimp patties and to check the antioxidant activity of Asparagus racemosus to control the oxidation level in shrimp patties. Furthermore, the aim of this study was to improve the safety and stability of shrimp patties with the application of gamma irradiation and with the addition of Asparagus racemosus.
Materials and Methods

Materials Procurement

The raw/unprocessed materials for the research work were shrimps and Asparagus racemosus. Shrimps were obtained from METRO Cash and Carry, Faisalabad, Pakistan, and Asparagus racemosus was purchased from local market of Faisalabad, Pakistan. The required chemicals and glassware for analysis were obtained from different laboratories of Department of Food Science, Government College University, Faisalabad, Pakistan.

Preparation of Asparagus racemosus powder

Dried Asparagus racemosus roots were washed and sliced into small pieces. Drying material was converted into a powder using a grinder. The ground material is then stored in airtight bags to keep it safe from the addition of moisture from the environment.

Shrimp patties development

Shrimps was converted into minced meat by using mincer machine and Asparagus racemosus powder (3%) was added in minced meat, then patties’ shape was given to the meat.

Gamma Irradiation

Gamma irradiation of the samples was performed at the Nuclear Institute for Agriculture & Biology (NIAB), Faisalabad, Pakistan, which is a research and development center functioning under the auspices of the Pakistan Atomic Energy Commission. Two different doses of radiation were applied (3 kGy and 5 kGy) for samples without ARP and the same for ARP containing samples. After the completion of radiation treatment sample were placed in freezer at −18°C. Physicochemical analysis was performed at 0, 7, 14, and 21 day, respectively.

Microbial Analysis

Bacterial colony counts were done according to Linton[14] and Karim,[15] A minimum of 10 g sample solution was homogenized in 90 ml of maximum recovery diluent (MRD). Before reaching the target dilution, dilution is performed. A sterilized glass spreader was used to apply 0.1 ml of the solution on the agar plate. The total number of bacteria detected was calculated using logarithmic bacterial suspension units per grams of test materials (logCFU/g).

Physicochemical Analysis of ARP patties

Heme pigments: Determination of heme pigments was done according to the method described by Krzywicki,[16] for example, myoglobin (Mb), Oxymyoglobin (MbO2), and Metmyoglobin (MMb) relative concentration.

Hunter’s color: ARE added shrimp patty color assessment was done by using Hunter colorimeter according to the guidelines which already standardized according to the given reference plate ($b = 0.783$ and $a = 0.921$ ($L = 89.2$). CIE a (red color), the CIE L (lightness), and the CIE b (yellowness) nine scale readings were set for the estimation of color parameters and to investigate the statistical analysis and to check the mean values.
Antioxidant profile

Diouf et al. [17] defined DPPH (2,2-diphenyl-1-picrylhydrazyl) as a persistent, strongly colored-free radical having the capability of removing free hydrogen from antioxidant compounds and forming colorless hydrazine (DPPH-H). The free radical-scavenging capability of ARE enriched shrimp patties was determined using a modified version of the Mimica-Dukic et al.’s [18] technique. 0.2 ml of homogenized material was added to the newly made 0.0012 M (2, 2 diphenyl-1-picrylhydrazyl) solution and incubated for 60 min for incubation in room conditions. A spectrophotometer is used to detect absorption at 517 nm. Each sample’s value was calculated as the proportion of DPPH decreased.

Total phenolic contents (TPC) determination

Determination of total phenolic contents of shrimp patties which were treated by ARE is showed by using the method of Folin–Ciocalteu by following the guidelines of Tezcan et al. [19] 10% of the Folin–Ciocalteu mixture is prepared and 1 ml of this 10% Folin–Ciocalteu reagent is used at the 0.5 ml targeted sample concentration. The prepared mixture is then blended in a blender and allowed to rest for 6 minutes before being added to 2 ml of prepared 20% NaCO₃. After that, the phenol content was assessed by using the spectrophotometer (Model: u2020 Irmico, Germany) set at the wavelength of 760 nm after the completion of the reaction for 60 min at 30°C. The curve was created, calibrated, and the phenolic contents were displayed as 1 g of eq. Gallic acid (GAE)/g sample.

Total Volatile Basic Nitrogen (TVB-N)

With minimal adjustments, the TVBN experiment was carried out by the method of Malle and Tao [20] using acetic acid (TCA) was added to the samples in a 1:2 (w/v) ratio and homogenized using a blender. After centrifugation at 1008 rpm for 5 min, the prepared solution was passed through the Whatman paper for filtration. 25 ml from the samples were pipetted into the Kjeldahl refining tank and treated with 5 ml of 10% sodium hydroxide. The distillation was performed against 0.05 M H₂SO₄ after steaming treatment till the color changed to pink.

Thiobarbituric Reactive Substances (TBARS)

The amount of lipid oxidation was assessed using the TBARS technique as described by Ahn et al. [21] with a few changes. The level of malonaldehyde was estimated by using equation below, in which the TBARS values are given in milligrams (mg) malonaldehyde per kilogram (kg) meat:

\[
\text{mg malonaldehydes per kg meat} = \text{sample absorbance} - \text{blank} \times \text{Total sample vol.}
\]

\[
0.00156 \times 1000
\]

Peroxide Value (POV)

Sallam et al. [22] developed a peroxide value measurement method that was conducted to recognize the peroxide value for ARE fortified shrimp patties. A sample of 3 g was taken in an Erlenmeyer flask. The lipids in the test were melted in hot water for three minutes at 60°C. To break down the fat, the vessel was stirred for 3 min with 30 ml of acetic acid–chloroform solution with the ratio of 3:2 v/v. Whatman no. 1 filter paper was used to remove the suspended particles from the supernatant. The method was finished by injecting the starch solution as a marker after adding potassium iodide (0.5 mL) to the filtrate. Titration is a procedure that is used to determine the concentration of a substance.

\[
\text{POV (meq/kg)} = \{(S \times N)/W\} \times 100
\]

where S is the volume of the titration (ml), N is the normality of the sodium thiosulfate solution (N = 0.01), and W is the weight of the sample (g).
**Sensory Evaluation of Shrimps Patties**

Sensory evaluation was performed with the help of a trained panelist. The panelists were served prepared shrimp patties for sensory evaluation and asked to grade them on a 9-point scale. 9 is used for = extremely liked, while 1 is used for = extremely disliked and the middle numbers are used for an average response, like not much good and not bad. Trained panelists had the expertise to evaluate the product and they were asked to respond to its appearance, texture, odor, taste, and overall acceptability.\[^{23}\]

**Statistical Analysis**

The data acquired from various parameters were then statistically analyzed using Statistic 8.1. Using the factorial design in CRD, the degree of significance was determined. Per each parameter, three replications were carried out, with ten observations for every color and ten panelists for sensory analysis. The mean values were compared by using the least substantial differences.\[^{24}\]

**Results and Discussion**

**Microbial quality**

The shrimp patties samples were changed significantly in different treatments and at various storage times. The results of total aerobic bacteria and coliform counts are listed in Table 1. The higher value of TAB was observed in control sample at 21 day of storage, whereas the lower content of TAB was found in 5 kGy + 3%ARP treated shrimp patties samples at 14 day.

The higher value of coliform was observed in control sample at 21 day of storage, whereas the lower coliform value was found in 3 kGy + 3%ARP treated shrimp patties samples at 21 day of storage. There was no detection of coliform bacteria in samples which were treated with 5kGy+3%ARP at all storage days. Minor detection of total aerobic bacteria (TAB) was observed in samples which were treated with gamma irradiation dose 5kGy and 3%ARP on 14 and 21 day.

In control, the higher TAB value was observed on 21 day of storage and minimum value was observed in samples on 0 day of storage. Sample treated with 3 kGy had the higher TAB value, which was measured at 21 day and lower value found on 0 day. In 5kGy the higher TAB value was showed at 21 day in samples and lower value was observed. Maximum TAB observed value in 3%ARP treated sample at 21 day of storage and minimum value observed on 0 day. Samples treated with 3 kGy+ARP had the minimum TAB value which observed at 0 day of storage. In 5 kGy+3%ARP treated sample

| Parameter                      | Treatment | 0     | 7      | 14     | 21     | Means         |
|-------------------------------|-----------|-------|--------|--------|--------|---------------|
| Coliform logCFU/g             | Control   | 3.91 ± 0.05 | 4.85 ± 0.01 | 6.11 ± 0.02 | 7.62 ± 0.03 | 5.62 ± 0.03a |
|                               | 3 kGy     | 0.94 ± 0.01 | 2.73 ± 0.02 | 3.12 ± 0.02 | 3.91 ± 0.02 | 2.67 ± 0.02c |
|                               | 5 kGy     | ND     | ND     | 0.71 ± 0.03 | 1.82 ± 02  | 1.26 ± 0.04d |
|                               | 3%ARP     | 1.84 ± 0.02 | 2.31 ± 0.02 | 3.94 ± 0.03 | 4.81 ± 0.02 | 3.22 ± 0.02b |
|                               | 3 kGy + 3%ARP | ND     | ND     | ND     | 0.63 ± 0.05 | 0.63 ± 0.05e |
|                               | 5 kGy + 3%ARP | ND     | ND     | ND     | ND     | ND            |
| Total aerobic bacteria (TAB)  | Control   | 5.37 ± 0.01 | 7.48 ± 0.02 | 7.60 ± 0.08 | 8.56 ± 0.04 | 7.25 ± 0.04a |
| (logCFU/g)                    | 3 kGy     | 3.71 ± 0.03 | 4.11 ± 0.02 | 4.43 ± 0.03 | 4.91 ± 0.03 | 4.29 ± 0.03c |
|                               | 5 kGy     | 2.13 ± 0.02 | 3.23 ± 0.03 | 3.54 ± 0.03 | 3.61 ± 0.04 | 3.13 ± 0.03d |
|                               | 3%ARP     | 4.88 ± 0.02 | 5.10 ± 0.03 | 5.91 ± 0.04 | 6.11 ± 0.02 | 5.51 ± 0.02b |
|                               | 3 kGy + 3%ARP | 2.05 ± 0.01 | 2.21 ± 0.03 | 2.71 ± 0.02 | 3.23 ± 0.02 | 2.55 ± 0.02e |
|                               | 5 kGy + 3%ARP | ND     | ND     | ND     | ND     | 1.49 ± 0.03  |

ARP: *Asparagus racemosus* powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.
there was no detection of TAB on day 0 and 7. Coliform maximum value in control was detected and in 3 kGy the minimum value observed was. Complete decontamination is achieved of coliform in shrimp patties samples treated with 5 kGy + 3% ARP in both in all storage days (0, 7, 14, and 21), while complete decontamination of TAB was in 5 kGy + 3% ARP treated sample of shrimp patties.

Our results are in agreement with the studies of Arshad et al. [8] who found that the total aerobic bacteria and coliform count decreases with the increase in radiation dose and storage interval while decreases with the addition of antioxidants and reduced in vacuum packaging as compared aerobic packaging, he further discussed that complete decontamination of TAB and coliform was achieved by combined effect of irradiation and antioxidant in all days of storage. Furthermore, Hocaoglu et al. [25] depicted that the coliform count in shrimp decreases with the application of gamma irradiation and increases with storage time. In another study of Yaqoob et al. [26] in which she discussed that the total bacterial count decreases with the addition of guava leaves and papaya leaf extract in different concentrations due the antioxidant capacity of guava and papaya leaves.

**Physicochemical assay**

**Heme Pigment:** The results were significantly decreased in treated shrimp patties samples as compared to untreated samples. The untreated sample (control) Mb contents gradually decreased with the passage of time. Mb contents of shrimp patties samples showed significant results with storage intervals. Higher Mb content was observed in control sample on 0 day of storage and the lowest value observed in treated sample on 21 day as listed in Table 2. In the treated shrimp patties samples, MbO₂ contents found in increasing form with the storage and with the increase in dose of radiation. Higher value of treated sample with radiation and 3% ARP observed and minimum. Highest value of MMb was found on the 21 day of storage in control sample. The minimum value was found in treated sample with on 0 day of storage. It is revealed about the result that MMb content decreased in shrimp patties samples which treated with radiation and 3% ARP but increased in those samples which subjected only to radiations.

Our results are in agreement with the findings of Arshad et al. [8] who reported that the myoglobin (Mb) decreases with the increase in radiation dose and increase with addition of antioxidant, he further the check the effect of packaging that Mb value decrease in vacuum packaging as compared aerobic packaging. Furthermore, he discussed the value of MbO₂ and MMb which increase with the increase in radiation dose and antioxidant. Values of MbO₂ and MMb increase with storage time and in vacuum packaging. Furthermore, Nisar et al. [7] found that the values of myoglobin decreases with storage and metmyoglobin and oxymyoglobin increase with storage time, and he further described that the values of myoglobin decreases with radiation and metmyoglobin and oxymyoglobin increase with radiation in meat balls. An et al. [27] observed the effect of e-beam radiation on physicochemical properties and microbial quality of smoked duck meat and they reported that the values of decreases with radiation and time storage, and he further observed that the metmyoglobin and oxymyoglobin increase with time and radiation doses. In another study, Khalid et al. [28] reported that myoglobin value decreases with increase in storage and metmyoglobin increases with storage time in ostrich and chicken, and he further described that values of myoglobin increases with radiation dose and kale leaf powder decreases the values. Myoglobin value increases with the addition of kale leaves powder, and he further described that the value of myoglobin decreases with irradiation and storage time.

**Hunter Color:** Results are significantly decreased with storage and increased with increase in radiation dose. The results of hunter's color for shrimp sample are listed in Table 3. The values were significantly increasing with the increase in dose of gamma irradiation. Values for L* decreased with the passage of storage time and addition of 3% ARP in sample also increased the values. Maximum value observed in 3% ARP treated sample was measured in control sample at 0 day storage. Minimum value was observed in control sample at 21 day. Maximum value observed in sample treated with 3 kGy was at 0 day. Higher value observed in sample at 21 day. Maximum value observed in treated with 5 kGy and minimum value observed at 21 day. However, the minimum value observed at
Table 2. Heme pigments of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter       | Treatment     | 0        | 7        | 14       | 21       | Means       |
|-----------------|---------------|----------|----------|----------|----------|-------------|
|                 |               |          |          |          |          |             |
| Myoglobin (%)   | Control       | 43.56 ± 0.06 | 29.43 ± 0.07 | 21.87 ± 0.04 | 13.87 ± 0.07 | 27.18 ± 0.06a |
|                 | 3 kGy         | 41.78 ± 0.07 | 27.56 ± 0.03 | 19.15 ± 0.05 | 11.89 ± 0.08 | 25.09 ± 0.05c |
|                 | 5 kGy         | 39.87 ± 0.23 | 25.42 ± 0.04 | 17.78 ± 0.03 | 10.75 ± 0.02 | 23.45 ± 0.08f |
|                 | 3%ARP         | 42.34 ± 0.04 | 28.36 ± 0.06 | 20.95 ± 0.09 | 12.85 ± 0.05 | 26.12 ± 0.06b |
|                 | 3 kGy + 3%ARP | 41.68 ± 0.07 | 27.12 ± 0.07 | 18.95 ± 0.05 | 11.23 ± 0.03 | 24.74 ± 0.05d |
|                 | 5 kGy + 3%ARP | 40.34 ± 0.04 | 25.52 ± 0.04 | 17.68 ± 0.11 | 10.55 ± 0.05 | 23.52 ± 0.06e |
| Oxymyoglobin (%)| Control       | 17.67 ± 0.09 | 19.87 ± 0.03 | 21.23 ± 0.03 | 23.54 ± 0.06 | 20.57 ± 0.05c |
|                 | 3 kGy         | 18.54 ± 0.03 | 20.56 ± 0.06 | 22.35 ± 0.07 | 24.85 ± 0.05 | 21.57 ± 0.05b |
|                 | 5 kGy         | 18.96 ± 0.05 | 21.69 ± 0.10 | 23.45 ± 0.06 | 25.89 ± 0.11 | 22.49 ± 0.08a |
|                 | 3%ARP         | 16.89 ± 0.14 | 18.56 ± 0.14 | 20.58 ± 0.05 | 22.14 ± 0.05 | 19.54 ± 0.09d |
|                 | 3 kGy + 3%ARP | 16.45 ± 0.10 | 17.86 ± 0.14 | 19.45 ± 0.05 | 21.65 ± 0.05 | 18.85 ± 0.08e |
|                 | 5 kGy + 3%ARP | 15.24 ± 0.09 | 17.25 ± 0.07 | 18.89 ± 0.12 | 20.89 ± 0.14 | 18.00 ± 0.10f |
| Metmyoglobin (%) | Control       | 46.45 ± 0.05 | 51.87 ± 0.07 | 57.67 ± 0.05 | 63.34 ± 0.07 | 54.83 ± 0.06c |
|                 | 3 kGy         | 48.56 ± 0.07 | 52.34 ± 0.07 | 58.25 ± 0.09 | 64.24 ± 0.06 | 55.84 ± 0.07b |
|                 | 5 kGy         | 49.89 ± 0.14 | 52.98 ± 0.04 | 59.45 ± 0.05 | 65.72 ± 0.08 | 57.01 ± 0.07a |
|                 | 3%ARP         | 42.52 ± 0.04 | 46.12 ± 0.05 | 51.14 ± 0.04 | 56.75 ± 0.07 | 51.63 ± 0.05d |
|                 | 3 kGy + 3%ARP | 41.85 ± 0.07 | 45.65 ± 0.02 | 50.78 ± 0.03 | 55.45 ± 0.05 | 48.43 ± 0.04e |
|                 | 5 kGy + 3%ARP | 40.56 ± 0.05 | 44.26 ± 0.07 | 49.78 ± 0.08 | 53.45 ± 0.05 | 47.01 ± 0.06f |

ARP: Asparagus racemosus powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.

21 day and maximum value measured at 0 day. The sample treated with 3%ARP had higher value of L* at 0 day storage. Minimum L* value in 3%ARP treated sample was observed on 21 day. Higher value observed in treated sample with 5kGy+3%ARP on 0 day and lower value was on 21 day. There was decrease in L* values with increase in radiation dose. The values were significantly decreased with the increase in dose of gamma irradiation. The a* values were increased with the time of storage and addition of 3%ARP in sample also increased the values. Maximum value observed in 5 kGy + 3%ARP treated sample was at 21 day storage. Minimum value in control sample was observed at 0 day. Maximum value observed in sample treated with 3 kGy was at 21 day, and lower value observed in the same sample was at 0 day. Maximum value observed in treated sample (5 kGy) was at 21 day and minimum value observed at 0 days. The sample treated with 3%ARP had higher value of a* at 21 day of storage. Minimum a* value in 3%ARP treated sample was on 0 days.

Higher value found in treated sample with 5 kGy + 3%ARP was on 21 day and lower value was on 0 days. The values are significantly decreasing with the increase in dose of gamma irradiation. Values for b* are increasing with the time of storage and addition of 3%ARP in sample also increasing the values. Maximum value observed in 3%ARP treated sample at 0 day storage. Minimum value observed in treated sample with 5 kGy was at 21 day. Maximum value observed in sample treated with 3%ARP was at 0 day, and lower value records in the same sample on 21 day. Maximum value observed in treated sample with 5 kGy was on 0 day and minimum value observed at 21 day. The sample treated with 3%ARP had higher value of b* at 0 day storage. Minimum b* value in 3%ARP treated sample observed on 21 day. Higher value found in treated sample with 5 kGy + 3% ARP was on 0 days. There was decrease in b* values with increase in radiation dose. Results are significantly decreased with storage and radiation dose.

There were significant changes observed in the values of b* with the increase of radiation dose and 3%ARP. At 21 day, the highest value of b* was observed in treated sample with 3%ARP on 0 day. Minimum value was observed in treated sample (5kGy) on 21 day. Values of b* decreased with the increase in radiation dose and decreased with storage time.

The results are in agreement with the findings of Arshad et al.\[8\] who reported that the L* (Lightness) of chicken meat increases with the addition of antioxidants and decreases with the storage time, and he further found that L* is in vacuum packaging as compared to aerobic packaging. Arshad
Table 3. Hunter’s color of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter | Treatment | 0   | 7   | 14  | 21  | Means   |
|-----------|-----------|-----|-----|-----|-----|---------|
| L*        | Control   | 75.85 ± 0.07 | 71.55 ± 0.08 | 67.17 ± 0.02 | 65.27 ± 0.05 | 69.96 ± 0.05d |
|           | 3 kGy     | 76.28 ± 0.13 | 72.18 ± 0.02 | 69.06 ± 0.08 | 67.33 ± 0.03 | 71.21 ± 0.06c |
|           | 5 kGy     | 76.34 ± 0.06 | 73.14 ± 0.07 | 70.29 ± 0.01 | 67.47 ± 0.18 | 71.81 ± 0.08b |
|           | 3%ARP     | 77.10 ± 0.04 | 74.78 ± 0.11 | 71.53 ± 0.15 | 68.45 ± 0.04 | 72.96 ± 0.08a |
|           | 3 kGy + 3%ARP | 76.65 ± 0.05 | 74.10 ± 0.06 | 71.05 ± 0.04 | 68.03 ± 0.08 | 72.45 ± 0.05a |
|           | 5 kGy + 3%ARP | 76.40 ± 0.03 | 73.56 ± 0.10 | 70.45 ± 0.05 | 67.76 ± 0.07 | 72.04 ± 0.04a |
| a*        | Control   | 1.40 ± 0.07 | 1.54 ± 0.02 | 1.59 ± 0.03 | 1.60 ± 0.04 | 1.65 ± 0.03 |
|           | 3 kGy     | 1.55 ± 0.01 | 1.59 ± 0.03 | 1.64 ± 0.02 | 1.65 ± 0.03 | 1.61 ± 0.02d |
|           | 5 kGy     | 1.61 ± 0.02 | 1.67 ± 0.03 | 1.87 ± 0.02 | 1.89 ± 0.03 | 1.76 ± 0.02d |
|           | 3%ARP     | 3.32 ± 0.02 | 3.56 ± 0.03 | 3.89 ± 0.02 | 3.91 ± 0.02 | 3.64 ± 0.02c |
|           | 3 kGy + 3%ARP | 3.78 ± 0.02 | 3.84 ± 0.01 | 3.98 ± 0.03 | 4.09 ± 0.02 | 3.92 ± 0.02b |
|           | 5 kGy + 3%ARP | 3.97 ± 0.02 | 4.20 ± 0.16 | 4.27 ± 0.02 | 4.29 ± 0.02 | 4.18 ± 0.05a |
| b*        | Control   | 5.83 ± 0.04 | 4.65 ± 0.05 | 3.47 ± 0.05 | 2.53 ± 0.03 | 4.12 ± 0.04d |
|           | 3 kGy     | 5.64 ± 0.01 | 4.09 ± 0.03 | 2.91 ± 0.01 | 1.64 ± 0.03 | 3.57 ± 0.02e |
|           | 5 kGy     | 5.51 ± 0.01 | 3.92 ± 0.01 | 2.65 ± 0.04 | 1.37 ± 0.01 | 3.36 ± 0.03e |
|           | 3%ARP     | 7.31 ± 0.01 | 6.65 ± 0.02 | 5.54 ± 0.07 | 4.34 ± 0.04 | 5.96 ± 0.03a |
|           | 3 kGy + 3%ARP | 6.80 ± 0.02 | 5.91 ± 0.03 | 5.15 ± 0.04 | 4.05 ± 0.05 | 5.47 ± 0.03b |
|           | 5 kGy + 3%ARP | 6.21 ± 0.01 | 5.65 ± 0.02 | 5.03 ± 0.01 | 3.97 ± 0.02 | 5.21 ± 0.01c |

ARP: Asparagus racemosus powder. The values are mean ± SD of ten independent determinations, and means carrying different letters in rows differed significantly.

et al. [8] reported that a* (redness) and (yellowness) increases with the application of irradiation and with addition of antioxidant and decreases with storage interval. In another study of Yaqoob et al. [26] who reported that the values of L* (lightness), a* and b* increase with the addition of different concentration of papaya leaf extract and guava leaf extract and L* value decreases with the increase in storage time. Furthermore, Mehrzadeh and Roomiani [29] also reported that the values of L* (lightness), a* (redness), and b* increases with radiation dose and decreases with time intervals.

**Antioxidant potential**

The shrimp patties samples were changed significantly on different treatment and at various storage times. The higher value of DPPH was observed in samples treated with 3%ARP and showed on 0 day, whereas the lower value of DPPH was found in sample treated with 5 kGy at 21 day of storage as listed in Table 4.

DPPH values decreased with the increase in gamma irradiation and decreased with the passage of time as well. In control sample of shrimp patties, the higher DPPH value was observed on 0 days and minimum value was observed on 21 day of storage. Shrimp patties samples treated with 3 kGy had higher DPPH value at 0 days and minimum value was on 21 day. In 5 kGy treated sample of patties, the higher DPPH value was observed at 0 day. Maximum DPPH value in 3%ARP treated sample was observed at 0 day of storage and minimum value was observed on 21 day. Shrimp patties samples treated with 3 kGy + ARP had minimum DPPH value at 21 day of storage and had higher value on 0 days. Sample treated with 5 kGy + ARP had maximum value on 0 day while lowest value was on 21 day. This has been shown to be a simple approach, in which the potential chemical or extract is combined with DPPH solution and the absorbance is measured after a certain amount of time.

Our results are in agreement with the findings of Arshad et al. [8] who reported that the addition turmeric powder in chicken meat increases the DPPH value in both aerobic and vacuum packaging and decreases with storage intervals. Another study of Yaqoob et al. [26] correlated with our outcomes in which she observed that the values of DPPH are less in control sample of shrimp as compared to the treated samples with papaya leaf and guava leaf extract. She further reported the values of DPPH decrease with time intervals in both untreated and treated samples. Karuna et al. [10] described the
Table 4. 2, 2-diphenyl-1-picrylhydrazyl (DPPH) of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter | Treatment | 0     | 7     | 14    | 21    | Means |
|-----------|-----------|-------|-------|-------|-------|-------|
| DPPH (%)  | Control   | 49.94 ± 0.02 | 48.31 ± 0.01 | 46.92 ± 0.52 | 45.53 ± 0.04 | 47.67 ± 0.14d |
|           | 3 kGy     | 41.31 ± 0.01 | 40.12 ± 0.03 | 38.91 ± 0.01 | 37.10 ± 0.04 | 39.36 ± 0.02e |
|           | 5 kGy     | 35.37 ± 0.04 | 34.23 ± 0.20 | 32.41 ± 0.03 | 30.82 ± 0.08 | 33.20 ± 0.08f |
|           | 3%ARP     | 59.84 ± 0.07 | 57.97 ± 0.18 | 55.77 ± 0.07 | 53.40 ± 0.005 | 56.74 ± 0.09a |
|           | 3 kGy+3%ARP | 55.13 ± 0.08 | 54.40 ± 0.05 | 53.59 ± 0.04 | 51.65 ± 0.06 | 53.69 ± 0.05b |
|           | 5 kGy+3%ARP | 52.41 ± 0.03 | 51.10 ± 0.05 | 49.91 ± 0.09 | 47.80 ± 0.00 | 50.30 ± 0.05c |

ARP: Asparagus racemosus powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.

activity of Asparagus racemosus as an antioxidant, and he further described that racemosus has potential to control the oxidation rate. Karim et al.\textsuperscript{[15]} reported that moringa leaves has antioxidant capacity and moringa leaf extract increases the DPPH value with concentration.

**Total phenolic contents (TPCs)**

TPC values of shrimp patties samples were decreased significantly on different treatment and at various storage times. The higher value of TPCs was observed in samples treated with 3%ARP at 0 day of storage, whereas the lower value of TPCs was found in 5 kGy + 3%ARP shrimp patties samples at 21 day of storage as listed in Table 5.

TPC values decreased with the increase in radiation dose and also decreased with the passage of time. In control sample of shrimp patties, the higher TPC value was observed on 0 days and minimum value was observed in on 21 day of storage. Shrimp patties samples treated with 3 kGy higher TPC value measured was at 0 day and minimum value was in patties samples on 21 day of storage. In 5 kGy-treated sample of patties, the higher TPC value was showed at 0 day. Maximum TPC value in 3%ARP-treated sample was observed at 0 day of storage and minimum value was on 21 day. Shrimp patties samples treated with 3 kGy + 3%ARP had minimum TPC value at 21 day of storage. Sample treated with 5 kGy + ARP had maximum value TPCs on 0 day, while lowest value was measured on 21 day of storage.

Our results are in agreement with the finding of Arshad et al.\textsuperscript{[18]} who reported that TPC values increase with turmeric powder in chicken meats and decrease with the increase in irradiation dose and with storage interval. Yaqoob et al.\textsuperscript{[26]} depicted the addition of guava and papaya leaf extract in different percentage in shrimp patties increase TPC values and decrease with the storage of patties. Pawar et al.\textsuperscript{[30]} further depicted that the aqueous and methanolic extraction of Asparagus racemosus has positive antioxidant activity but less than other natural antioxidants.

**Total Volatile Basic Nitrogen (TVBN) assay**

The shrimp patties samples were changed significantly on different treatment and at various storage times. The higher value of TVBN was observed (18.23 ± 0.04 mg/100 ml) in control sample at 21 day of storage, whereas the lower value of TVBN was found in 5 kGy + 3%ARP shrimp patties samples at 0 day of storage as shown in the Table 6.

TVBN values decreased with the increase in gamma irradiation dose and increased with the storage time. In control sample of shrimp patties, the higher TVBN value was observed on 21 days and minimum value was observed on 0 day of storage. Shrimp patties samples treated with 3 kGy higher TVBN value measured was 21 day and minimum value was in patties samples on 0 day of storage. In 5 kGy-treated sample of patties, the higher TVBN value was showed at 21 day. Maximum TVBN value in 3%ARP treated
Table 5. Total phenolic contents (TPCs) of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter | Treatment   | 0          | 7          | 14         | 21         | Means        |
|-----------|-------------|------------|------------|------------|------------|--------------|
| TPC (mg/g GAE) | Control     | 115.10 ± 0.05 | 114.15 ± 0.07 | 113.85 ± 0.06 | 110.58 ± 0.03 | 113.42 ± 0.05c |
|           | 3 kGy       | 114.25 ± 0.11 | 112.35 ± 0.04 | 110.50 ± 0.07 | 109.45 ± 0.11 | 111.63 ± 0.06d |
|           | 5 kGy       | 110.75 ± 0.13 | 110.54 ± 0.14 | 108.15 ± 0.17 | 107.25 ± 0.11 | 109.17 ± 0.13f |
|           | 3%ARP       | 118.67 ± 0.03 | 116.39 ± 0.07 | 115.34 ± 0.12 | 114.67 ± 0.10 | 116.26 ± 0.08a |
|           | 3 kGy + 3%ARP | 116.35 ± 0.03 | 113.89 ± 0.05 | 112.78 ± 0.05 | 111.56 ± 0.03 | 113.64 ± 0.04b |
|           | 5 kGy + 3%ARP | 112.65 ± 0.01 | 110.34 ± 0.05 | 109.45 ± 0.08 | 108.67 ± 0.10 | 110.27 ± 0.06e |

ARP: Asparagus racemosus powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.

Sample was observed at 21 day of storage and minimum value was observed on 0 days. Shrimp patties samples treated with 3 kGy + 3%ARP had minimum TVBN value at 0 day of storage. Sample treated with 5 kGy + 3%ARP had maximum value on 21 day, while lowest value was measured on 0 day of storage.

Our results are in agreement with finding of Hocaoglu et al.[25] who reported that TVBN values increases in the shrimps with storage interval and decrease with the increase in the irradiation dose. Furthermore, Yaqoob et al.[26] depicted the addition of guava and papaya leaf extract in shrimp patties that TVBN values increase with the storage interval and decrease with the increase in the percentage of the leaf extract. Another study of Mehrzadeh and Roomiani[29] proved that by extending the storage duration, the concentration of volatile nitrogenous compounds increases as the microbial count grows. These findings were consistent with the findings of the other investigations. The effect of modest irradiation dosage on the production of soluble nitrogenous substances in chub mackerel was investigated.

Thio-barbituric acid reactive substances (TBARS)

The shrimp patties samples were changed significantly on different treatment and at various storage times. According to the results of TBARS value of shrimp patties, samples have a vital effect in the treatment way and storage time. It was observed the maximum value of TBARS in sample treated with 3%ARP on 21 day of storage and on the other side the lowest value for samples which treated with 5 kGy + 3%ARP and kept freezing condition at −18°C. The outcomes for TBARS values are mentioned in Table 7. The higher value of TBARS was observed in samples treated with 3%ARP at 21 day of storage, whereas the lower value of TBARS was observed in 5 kGy + 3%ARP treated shrimp patties samples at 0 day of storage.

TBARS values decreased with the increase in gamma irradiation dose and increased with the passage of time. In control sample, the lower TBARS value was observed on 0 days and maximum value was observed on 21 day of storage. In 3 kGy, the higher TBARS value was measured at 21 day and the minimum value was observed in patties samples on 0 days. In 5 kGy, the higher TBARS value

Table 6. Total Volatile Basic Nitrogen (TVBN) assay of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter | Treatment   | 0          | 7          | 14         | 21         | Means        |
|-----------|-------------|------------|------------|------------|------------|--------------|
| TVBN (mg/100 mL) | Control     | 9.90 ± 0.03 | 13.14 ± 0.02 | 15.45 ± 0.06 | 18.23 ± 0.04 | 14.18 ± 0.03a |
|           | 3 kGy       | 9.65 ± 0.05 | 12.84 ± 0.09 | 15.05 ± 0.24 | 17.65 ± 0.02 | 13.79 ± 0.10b |
|           | 5 kGy       | 9.56 ± 0.17 | 12.14 ± 0.05 | 14.85 ± 0.11 | 17.15 ± 0.05 | 13.42 ± 0.09c |
|           | 3%ARP       | 9.05 ± 0.05 | 11.95 ± 0.05 | 14.10 ± 0.04 | 16.45 ± 0.04 | 12.88 ± 0.04d |
|           | 3 kGy + 3%ARP | 8.81 ± 0.02 | 11.23 ± 0.04 | 13.45 ± 0.06 | 15.35 ± 0.05 | 12.21 ± 0.04e |
|           | 5 kGy + 3%ARP | 8.59 ± 0.08 | 10.56 ± 0.11 | 12.85 ± 0.07 | 14.50 ± 0.03 | 11.62 ± 0.07f |

ARP: Asparagus racemosus powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.
was observed on 21 day, while lower value was observed on 0 days. Maximum TBARS value in 3%ARP treated sample was observed at 21 day of storage. In 3 kGy + ARP treated samples, the minimum TBARS value was measured at 0 day of storage. Sample treated with 5 kGy + 3%ARP had maximum value on 21 day, while lowest value was at 0 day. Our results are in agreement with finding of Hocoaoglu et al.[25] who reported that TBA values increase in shrimps with storage interval and TBA values increase with irradiation dose. Furthermore, Yaqoob et al.[26] depicted the addition of guava and papaya leaf extract in shrimp’s patties that TBAR values increase with the storage interval and decrease with the increase in percentage of the leaf extract. In another study, Arshad et al.[8] found that TBAR values decrease with the addition of antioxidant in chicken meats and increase with irradiation dose and storage interval. In another study of Mehrzadeh and Roomiani,[29] they observed that TBAR values decrease with gamma irradiation and modified atmosphere packaging of white shrimps whereas increase with storage interval.

**Peroxide value**

The shrimp patties samples were increased significantly on different treatments and at various storage times. The higher value of POV was observed in samples treated with 5 kGy and showed on 21 day whereas, the lower value of POV was found in sample treated with 3%ARP, which was at 0 day of storage as listed in Table 8.

POV values increased with the increase in gamma irradiation and increased with the passage of time. In control sample of shrimp patties, the higher POV value was observed on 21 day and minimum value observed on 0 day of storage. Shrimp patties samples treated with 3 kGy had higher POV value, which was measured on 21 day and minimum value was observed in the same sample on 0 day. In 5 kGy-treated sample of patties, the higher POV value was observed on 21 day. Maximum POV value in 3%ARP-treated sample was observed at 21 day of storage and minimum value was observed on 0 days.

**Table 7.** Thio-barbituric acid reactive substances of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter | Treatment            | 0    | 7     | 14    | 21    | Means       |
|-----------|----------------------|------|-------|-------|-------|-------------|
| TBARS     | Control              | 0.49 ± 0.02 | 1.62 ± 0.04 | 2.25 ± 0.03 | 3.05 ± 0.11 | 1.85 ± 0.05c |
|           | 3 kGy                | 0.48 ± 0.02 | 1.52 ± 0.03 | 2.55 ± 0.04 | 2.95 ± 0.05 | 1.87 ± 0.03b |
|           | 5 kGy                | 0.49 ± 0.05 | 1.38 ± 0.06 | 2.15 ± 0.18 | 3.35 ± 0.07 | 1.84 ± 0.09d |
|           | 3%ARP                | 0.40 ± 0.10 | 1.44 ± 0.05 | 2.31 ± 0.02 | 4.12 ± 0.03 | 2.06 ± 0.05a |
|           | 3 kGy + 3%ARP        | 0.35 ± 0.04 | 1.37 ± 0.02 | 2.10 ± 0.07 | 3.49 ± 0.01 | 1.82 ± 0.03e |
|           | 5 kGy + 3%ARP        | 0.29 ± 0.04 | 1.29 ± 0.03 | 1.91 ± 0.02 | 2.93 ± 0.03 | 1.60 ± 0.03f |

ARP: Asparagus racemosus powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.

**Table 8.** Peroxide value (POV) of shrimp patties treated with Asparagus racemosus powder and gamma irradiation during different storage times.

| Parameter  | Treatment            | 0    | 7     | 14    | 21    | Means       |
|------------|----------------------|------|-------|-------|-------|-------------|
| POV        | Control              | 0.39 ± 0.05 | 1.20 ± 0.03 | 1.45 ± 0.04 | 1.75 ± 0.02 | 1.19 ± 0.03c |
|            | 3 kGy                | 0.40 ± 0.01 | 1.31 ± 0.03 | 1.47 ± 0.03 | 1.81 ± 0.05 | 1.24 ± 0.03b |
|            | 5 kGy                | 0.42 ± 0.02 | 1.35 ± 0.05 | 1.49 ± 0.02 | 1.95 ± 0.04 | 1.30 ± 0.03a |
|            | 3%ARP                | 0.31 ± 0.07 | 1.05 ± 0.13 | 1.15 ± 0.04 | 1.35 ± 0.06 | 0.96 ± 0.07f |
|            | 3 kGy + 3%ARP        | 0.35 ± 0.06 | 1.22 ± 0.07 | 1.35 ± 0.04 | 1.45 ± 0.04 | 1.09 ± 0.05e |
|            | 5 kGy + 3%ARP        | 0.38 ± 0.02 | 1.29 ± 0.05 | 1.43 ± 0.03 | 1.64 ± 0.05 | 1.16 ± 0.03d |

ARP: Asparagus racemosus powder. The values are mean ± SD of three independent determinations, and means carrying different letters in rows differed significantly.
Table 9. Sensory evaluation of shrimp patties treated with *Asparagus racemosus* powder and gamma irradiation during different storage times.

| Parameter          | Treatment               | 0     | 7     | 14    | 21    | Means  |
|--------------------|-------------------------|-------|-------|-------|-------|--------|
| Appearance         | Control                 | 7.5 ± 0.01 | 7.3 ± 0.04 | 7.1 ± 0.09 | 6.9 ± 0.01 | 7.2 ± 0.03a |
|                    | 3 kGy                   | 7.4 ± 0.04 | 7.2 ± 0.05 | 7.0 ± 0.06 | 6.8 ± 0.06 | 7.1 ± 0.05b |
|                    | 5 kGy                   | 7.3 ± 0.03 | 7.1 ± 0.11 | 6.9 ± 0.08 | 6.7 ± 0.03 | 7.0 ± 0.06c |
|                    | 3%ARP                   | 6.5 ± 0.05 | 6.3 ± 0.04 | 6.1 ± 0.04 | 6.0 ± 0.06 | 6.2 ± 0.04e |
|                    | 3 kGy + 3%ARP           | 6.9 ± 0.05 | 6.8 ± 0.04 | 6.5 ± 0.05 | 6.2 ± 0.04 | 6.6 ± 0.04d |
|                    | 5 kGy + 3%ARP           | 6.7 ± 0.05 | 6.4 ± 0.04 | 6.1 ± 0.05 | 5.9 ± 0.06 | 6.2 ± 0.05e |
| Texture            | Control                 | 7.4 ± 0.07 | 7.1 ± 0.11 | 6.9 ± 0.31 | 6.8 ± 0.04 | 7.05 ± 0.13a |
|                    | 3 kGy                   | 7.2 ± 0.03 | 7.0 ± 0.05 | 6.8 ± 0.04 | 6.6 ± 0.04 | 6.9 ± 0.04b |
|                    | 5 kGy                   | 7.1 ± 0.03 | 6.7 ± 0.05 | 6.5 ± 0.06 | 6.3 ± 0.05 | 6.6 ± 0.06c |
|                    | 3%ARP                   | 6.5 ± 0.03 | 6.2 ± 0.05 | 6.0 ± 0.06 | 5.8 ± 0.04 | 6.1 ± 0.04f |
|                    | 3 kGy + 3%ARP           | 6.8 ± 0.04 | 6.7 ± 0.05 | 6.5 ± 0.05 | 6.3 ± 0.04 | 6.5 ± 0.04d |
|                    | 5 kGy + 3%ARP           | 6.6 ± 0.06 | 6.4 ± 0.05 | 6.3 ± 0.04 | 6.1 ± 0.06 | 6.3 ± 0.05d |
| Taste              | Control                 | 7.8 ± 0.03 | 7.4 ± 0.05 | 7.3 ± 0.03 | 7.1 ± 0.07 | 7.4 ± 0.04a |
|                    | 3 kGy                   | 7.4 ± 0.04 | 7.3 ± 0.04 | 7.2 ± 0.05 | 7.0 ± 0.04 | 7.2 ± 0.04b |
|                    | 5 kGy                   | 7.2 ± 0.06 | 7.0 ± 0.09 | 6.9 ± 0.02 | 6.8 ± 0.04 | 6.9 ± 0.05c |
|                    | 3%ARP                   | 6.5 ± 0.02 | 6.4 ± 0.04 | 6.0 ± 0.09 | 5.9 ± 0.05 | 6.2 ± 0.05f |
|                    | 3 kGy + 3%ARP           | 6.9 ± 0.03 | 6.7 ± 0.05 | 6.6 ± 0.12 | 6.3 ± 0.05 | 6.6 ± 0.06d |
|                    | 5 kGy + 3%ARP           | 6.8 ± 0.05 | 6.5 ± 0.03 | 6.3 ± 0.03 | 6.2 ± 0.06 | 6.4 ± 0.04e |
| Odor               | Control                 | 7.8 ± 0.05 | 7.6 ± 0.03 | 7.3 ± 0.06 | 7.1 ± 0.07 | 7.4 ± 0.05a |
|                    | 3 kGy                   | 7.5 ± 0.05 | 7.3 ± 0.04 | 7.1 ± 0.07 | 6.8 ± 0.05 | 7.1 ± 0.05b |
|                    | 5 kGy                   | 7.3 ± 0.06 | 7.2 ± 0.06 | 7.0 ± 0.07 | 6.6 ± 0.06 | 7.0 ± 0.06c |
|                    | 3%ARP                   | 5.8 ± 0.04 | 6.0 ± 0.07 | 6.1 ± 0.05 | 6.2 ± 0.07 | 6.0 ± 0.05e |
|                    | 3 kGy + 3%ARP           | 6.5 ± 0.07 | 6.3 ± 0.08 | 6.0 ± 0.09 | 5.8 ± 0.05 | 6.1 ± 0.07d |
|                    | 5 kGy + 3%ARP           | 6.3 ± 0.06 | 6.1 ± 0.07 | 5.9 ± 0.05 | 5.8 ± 0.18 | 6.0 ± 0.09e |
| Overall acceptability | Control               | 7.6 ± 0.03 | 7.4 ± 0.05 | 7.3 ± 0.03 | 7.3 ± 0.05 | 7.4 ± 0.04a |
|                    | 3 kGy                   | 7.7 ± 0.06 | 7.5 ± 0.05 | 7.4 ± 0.08 | 7.2 ± 0.07 | 7.4 ± 0.06a |
|                    | 5 kGy                   | 7.4 ± 0.07 | 7.3 ± 0.07 | 7.2 ± 0.07 | 7.1 ± 0.05 | 7.2 ± 0.06b |
|                    | 3%ARP                   | 5.9 ± 0.04 | 5.7 ± 0.06 | 5.5 ± 0.05 | 5.5 ± 0.05 | 5.6 ± 0.05e |
|                    | 3 kGy + 3%ARP           | 6.2 ± 0.05 | 6.3 ± 0.04 | 6.6 ± 0.06 | 6.5 ± 0.04 | 6.4 ± 0.04d |
|                    | 5 kGy + 3%ARP           | 6.8 ± 0.04 | 6.9 ± 0.06 | 7.0 ± 0.15 | 6.9 ± 0.06 | 6.9 ± 0.07c |

ARP: *Asparagus racemosus* powder. The values are mean ± SD of ten independent determinations, and means carrying different letters in rows differed significantly.

Shrimp patties samples treated with 3 kGy + ARP had minimum POV value at 0 day of storage and had higher value on 21 day. Sample treated with 5 kGy + ARP had maximum value on 21 day, while lowest value was measured on 0 day.

Our results are in agreement with finding of Arshad et al.\[8] who reported that POV increases in chicken meats with the increase in irradiation dose and storage interval and decrease with the addition of antioxidant. Furthermore, Yaqoob et al.\[26] depicted the addition of guava and papaya leaf extract in shrimp patties that POV increases with the storage interval and decreases with the increase in the percentage of the leaf extract. In another study of Mehrzadeh and Roomiani,\[29]\ they observed that POV slightly increase with gamma irradiation and modified atmosphere packaging of white shrimps and increases with storage interval.

**Sensory evaluation**

Mean values of the sensory evaluation (appearance, texture, odor, taste, and overall acceptability) of the shrimp patties samples are listed in the Table 9. The mean values gradually decline as the gamma irradiation dose increases and the addition of 3%ARP, the storage period has an impact on the score. They also decreased as the storage period increased, while sensory characteristics increased in control samples over treated samples. The maximum sensory score for appearance in control sample was on 0 day and minimum score was on 21 day. Higher sensory score of treated sample (5kGy+3%ARP) was
on 0 days and minimum score was on 21 day. Maximum appearance score for treated sample (5kGy) was on 0 days and minimum score was on 21 day. Sensory score for texture decreased with storage. Texture score for control sample on 0 day was higher and minimum score was observed on 21 day. Treated sample of shrimp patties (5 kGy) on 0 day had maximum score minimum score was given on 21 day. Texture score for treated sample (3 kGy + 3%ARP) on 0 day was higher and lower on 21 day of storage. Sensory score for taste was decreased with treatments and storage. Score for control sample on 0 day was higher and minimum score was on 21 day. Taste score for treated sample (3 kGy) on 0 day was higher and minimum on 21 day. For the treated sample (3 kGy + 3%ARP), taste score on 0 day was higher and lower on 21 day. Odor of the samples was changed with treatments and with storage. Odor score for control sample on 0 day was higher and minimum on 21 day. Treated sample of patties (5kGy) had maximum sensory score on 0 day and minimum score on 21 day. The overall acceptability of the samples was good and the score given by the panelist was higher on 0 day and due to the changes in sample with storage got less score on 21 day. The overall acceptability for control sample on 0 day was higher and on lower on day 21. Score for treated sample (3 kGy) on 0 day was maximum and on minimum on 21 day. Sensory score for treated sample (3%ARP) is less as compared to all other the treated samples. On 0 day, overall acceptability score for treated sample (3%ARP) was higher and lower on 21 day.

Our observation in agreement with the findings of Kumar et al.[31] reported that with the storage time sensory properties of the nuggets decrease significantly. Furthermore, Yaqoob et al.[26] depicted that sensory properties significantly decrease with the addition of different concentration of papaya leaf extract and guava leaf extract with storage. Another study of Arshad et al.[8] showed that the addition of antioxidant agent and increase in radiation dose reduce the sensory attributes of chicken meat. Our result relates to previous research conducted on ostrich meat that was irradiated (0, 1, and 3 kGy) at different storage intervals (0, 7, 14, and 21 days). Its results showed that by increasing the irradiated dose, sensory parameters decreased.[32] Our results are correlated with Akram et al.[33] who conducted research on ostrich and goat meats. Sensory results were seen high in ostrich meat as compared to goat meat. Another study by Banerjee et al.[34] proved that texture parameters like gumminess, chewiness, and hardness vacuumed packed mutton patties decrease with the passage of time and treated with irradiation. In another study of Khalid et al.[28] in which they observed that sensory parameters such as appearance, taste, flavor, texture, and overall acceptability of ostrich and chicken meats decrease with the application of gamma irradiation and kale leaf powder and with storage intervals.

CONCLUSION
Our research concluded that the use of high dose of gamma irradiation enhanced the quality and stability of the shrimp patties samples at freezing temperature (−18°C). Use of 3 kGy reduced maximum microbial activity and addition of Asparagus racemosus powder controlled the oxidation during storage intervals (0, 7, 14 and 21 d). Different doses of gamma irradiation (3 kGy and 5 kGy) were used with and without 3%ARP to check the stability and quality of shrimp patties. The results of color, TBARS, TPC, DPPH, heme pigment, TVBN, and POV changed significantly at different storage periods. Minimum changing was observed in sensory attributes of shrimp samples on different treatments during storage intervals.

Disclosure statement
No potential conflict of interest was reported by the author(s).

References
[1] Al-Busaidi, M. A.; Jukes, D. J.; Bose, S. Seafood Safety and Quality: An Analysis of the Supply Chain in the Sultanate of Oman. Food Cont. 2016, 59, 651–662. DOI: 10.1016/j.foodcont.2015.06.023.
[26] Yaqoob, Z.; Arshad, M. S.; Imran, M.; Munir, H.; Qaisrani, T. B.; Khalid, W.; Suleria, H. A. R. Ultrasound-assisted Extraction of Guava and Papaya Leaves for the Development of Functional Shrimp Patties. *Food Sci. Nut.* 2020, 8 (7), 3923–3935. DOI: 10.1002/fsn3.1706.

[27] An, K. A.; Arshad, M. S.; Jo, Y.; Chung, N.; Kwon, J. H. E-beam Irradiation for Improving the Microbiological Quality of Smoked Duck Meat with Minimum Effects on Physicochemical Properties during Storage. *J. Food Sci.* 2017, 82(4), 865–872. DOI: 10.1111/1750-3841.13671.

[28] Khalid, W.; Arshad, M. S.; Yasin, M.; Imran, A.; Ahmad, M. H. Quality Characteristics of Gamma Irradiation and Kale Leaf Powder Treated Ostrich and Chicken Meat during Storage. *Int. J. Food Prop.* 2021, 24(1), 1335–1348. DOI: 10.1080/10942912.2021.1963274.

[29] Mehrzadeh, S.; Roomiani, L. Effect of Gamma Irradiation and Modified Atmosphere Packaging on the shelf-life of White Shrimp (Metapenaeus Affinis). *Iranian J. Fish. Sci.* 2021, 20(4), 1004–1021. [http://jifro.ir/article-1-3735-fa.html](http://jifro.ir/article-1-3735-fa.html).

[30] Pawar, N.; Arora, S.; Bijoy, R. R.; Wadhwa, B. K. The Effects of Asparagus Racemosus (Shatavari) Extract on Oxidative Stability of Ghee, in Relation to Added Natural and Synthetic Antioxidants. *Int. J. Dairy Technol.* 2012, 65(2), 293–299. DOI: 10.1111/j.1471-0307.2011.00816.x.

[31] Kumar, D.; Tanwar, V. K. Effects of Incorporation of Ground Mustard on Quality Attributes of Chicken Nuggets. *J. Food Sci. Technol.* 2011, 48(6), 759–762. DOI: 10.1007/s13197-010-0149-3.

[32] Yazdi, F. T.; Jouki, M. Chemical and Sensory Quality Changes of Ostrich Meat Treated by Gamma Irradiation. *Sci. J. Anim. Sci.* 2012, 1(5), 159–165.

[33] Akram, M. B.; Khan, M. I.; Khalid, S.; Shoaiib, M.; Azeema, S. Quality and Sensory Comparison of Ostrich and Goat Meat. *Int. J. Life Sci.* 2019, 5(1), 2175–2183.

[34] Banerjee, R.; Jayathilakan, K.; Chauhan, O. P.; Naveena, B. M.; Devatkal, S.; Kulkarni, V. V. Vacuum Packaged Mutton Patties: Comparative Effects of High Pressure Processing and Irradiation. *J. Food Proces. Preser.* 2017, 41 (1), e12880. DOI: 10.1111/jfpp.12880.