γ-Irradiation Treatment of Edible Bamboo Shoot (*Dendrocalamus hamiltonii*): Effect on Post-Harvest Retention of Storage Quality and Prevent Microbial Proliferation

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Abstract

Present investigation was performed to determine the effect of γ-irradiation on storage of *Dendrocalamus hamiltonii* species of edible bamboo shoot and explore the relationship between microbial degradation and nutritional aspects including organoleptic attributes along with induced radioactivity as food safety parameter. Edible bamboo shoots were processed for irradiation treatment at doses ranging from 0.5 to 5.0 kGy prior to storage at 5 ± 2 °C temperature dipped into 2% sodium chloride solution for up to 240 days. A significant, dose-dependent microbial load reduction was observed, result outcomes showed that a dosage of 2.5 kGy was adequate to completely eliminate the microbial population, as more than 4 log reduction was observed in treated shoots when compared with unirradiated sample. Neither γ-radiation treatment nor storage period had significant effect on physicochemical parameters including pH, moisture, protein, HCN content and minerals of shoots. Sensory acceptance of edible shoot was not compromised with radiation treatment, various selected testing markers of organoleptic evaluation were similarly lies within the acceptable criteria up to 240 days, hence the best preservation effect on edible bamboo shoots of *Dendrocalamus hamiltonii* was found at dose level of 2.5 kGy. The findings of this study suggest that irradiation may be a promising alternative technique for preserving the quality of bamboo shoots while they are being stored and extended its postharvest senescence.

Keywords: Bamboo shoot, *Dendrocalamus hamiltonii*, Microbiological quality, γ-Irradiation, Shelf-life.

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Introduction:

Bambusa vulgaris, a massive perennial arborescent grass, is a member of the *Poaceae* family and subfamily *Bambuseae*. It is widespread and endemic to the Asian continent, particularly in tropical, subtropical, and temperate climates with a mostly mesic to rainy season [1]. There are around 1,400 types of bamboo in the globe, and the majority produce edible shoots [2]. India has 125 of these species, but only 30 have commercial importance. Bamboo shoots are a classic Asian vegetable with a long history of usage. They have good nutritional properties and are frequently regarded as a highly desired diet due to their low fat and cholesterol level and higher carbohydrate content [3]. High protein, necessary amino acids, dietary fiber, and a powerful antioxidant are all present in bamboo shoots [4]. In addition, the compositions of cellulose, hemicellulose, and lignin as well as the functional groups, primarily dietary fibers, nutrient and other extract bioavailability from various biomasses [5]. However, Fresh bamboo shoots typically have a shelf life of fewer than three days at room temperature [6]. Bamboo shoots frequently experience lignification, rotting, and browning due to the active biological processes and enzyme catalysis, which diminishes their shelf life [7]. Post-harvest deterioration is brought on by environmental stresses, improper storage conditions, and microbial assault on contaminated soil. Therefore, the key to fostering the growth of the bamboo business is employing scientifically established processing technologies to preserve edible bamboo shoot [8].

For fresh edible bamboo shoots, the most widely used preservation method today is chemical preservation [7]. Earlier research found that 1-MCP (1-methylcyclopropene) might retain the postharvest quality of bamboo shoots by delaying browning and inhibiting the process of lignification during chemical preservation [9]. Now a days, users are more receptive to physical preservation methods due to concerns about the quality and safety of their food.

The γ-irradiation process has shown to be a successful way to increase the safety and shelf life of food commodities. Because it offers a secure alternative to quarantines and is tolerated by more fresh food products than any other treatment now in use, its commercial application is constantly expanding [10]. Foods exposed to radiation levels up to 10 kGy are deemed safe and do not require toxicological testing by a joint FAO/IAEA/WHO expert committee on the wholeness of irradiated foods [11]. Irradiation treatments have been used on fresh horticulture goods to delay postharvest ripening, maturity, and senescence, increase shelf life, and abate sprouting and post-packaging contamination [12]. According to the FSSAI advisory statement, food irradiation is approved in more than 60 nations, and the amount of food treated with radiation for value addition is rising. China is the largest user of the technology, followed by the USA. Currently, the main commodity groupings where irradiation technology is often utilized include fresh fruits and vegetables, spices, dry vegetable seasonings, herbal based formulations, meat and meat products [13].

As more research is done to demonstrate that irradiation is a technology that has been scientifically confirmed for enhancing the ability of fruits and vegetables, such as sliced mushrooms, to be stored [14], apple pomace flour [15], and fresh-cut watercress [16] additionally, irradiation preservation's safety is becoming better known. γ-Radiation may reduce the lignification of immature bamboo shoots and the lignin concentration by 12.5% after 28 days of storage at 2 °C [17]. In many foods, particularly minimally processed foods, the use of γ-radiations for fruit and vegetable preservation has been proven to be beneficial in inactivating and eliminating spoilage and foodborne bacteria [18]. Numerous studies have shown that γ-irradiation treatment successfully exterminates the microbes responsible for decay from fresh-cut fruits and vegetables without degrading the quality overall [19,20].

There are presently no effective techniques that totally prevent quality decline and senescence of postharvest shoots, which correspond with the postharvest physiology of the bamboo shoots, due to the intricacy of bamboo shoot growth. To the best of our knowledge, γ-irradiation's impact on *Dendrocalamus hamiltonii* bamboo shoots has not yet been reported. Therefore, our current study demonstrated the impact of γ-radiation on post-harvest retention of storage quality and prevention of microbial proliferation of *Dendrocalamus hamiltonii* shoot by assessing the physicochemical and microbial parameters

including sensory evaluation at varied storage time.

Materials and Methods

Sample collection and preparation: The edible shoots of *Dendrocalamus hamiltonii* were gathered from northeastern region of India as Shillong. The shoots were procured during rainy season (June to August month). Before γ-irradiation, to get rid of any clinging dirt, dust, or other foreign matters, the shoot with sheath was washed. Afterward, for extraction of tender shoot the sheath was removed. Edible shoots were divided into thin portions and placed in PET Jars with a wide opening. Each PET jar had a yellow-coloured chemical indicator and precise markings applied to it to ensure that the bamboo sprout received the desired dosage, upon exposure to γ-radiation, this yellow colour changed to red.

Application of γ-radiation: The bundled bamboo shoot was irradiated with γ-radiation at SARC (Shriram applied radiation center), Shriram institute, Delhi, at varied dosage rates ranging from 0.5 to 5.0 kGy the dosage rate at 3.617 kGy per hour using Co-60. Ceric-cerous dosimetry was used to measure the dosage rate. To ensure the bamboo shoot gets the precise dose, the dosimeter was placed in each box of bamboo shoots for each treatment at a low dosage point and a high dose area. The dosage distribution employed during irradiation is provided in Table-1 at normal temperature and environment. Bamboo shoots were sent right away to the microbiology laboratory for additional processing when irradiation was finished.

TABLE-1

γ-IRRADIATION DOSE DISTRIBUTION TABLE

Requested dose	Dose in kGy (Min)	Dose in kGy (Max)	Over dose ratio
0.5	0.50	0.57	1.15
1.0	1.0	1.15	1.15
2.5	2.74	3.15	1.15
5.0	5.49	6.31	1.15
Uncertainty of administered dosage was ± 10%.			

Storage conditions: The bamboo shoots were stored in pet jars that had been immersed in a brine solution at a temperature of 5 ± 2 °C, which was regarded the ideal storage condition for periodic assessment. From day 0 through day 240 of storage, the samples were evaluated at various time intervals. The periodic quality assessment took into account sensory, microbiological, and physico-chemical analysis [13].

Microbiological analysis

Quantitative estimation of bioburden: At each sampling interval and storage treatment for 240 days, the American Public Health Association [22] standard technique for microbiological testing of food was utilized to calculate the quantitative estimation of microorganisms as colony forming unit (cfu) per gram [23]. Counts of mesophilic bacteria, yeast and mould were performed with the use of serial dilution technique and melted pour plate agar method. Homogenized sample of bamboo shoot 10 g was introduced in 90 mL of sterile 0.1% peptone with saline treated as diluent to make first dilution, serially diluted the first dilution up to maximum of 10^{-7} dilutions (dilution by ten times in each tube). Two sterile Petri dishes (90 mm × 15 mm size) were used for transfer one mL from each subsequent dilution. To enumeration of total bacterial count each petri dish was pre-inoculated with diluent, and approximately 15 to 20 mL of melting plate count agar media were added, mix it well then kept the plates in stag for media solidification [24]. The bacterial colonies were counted as colony forming unit after 24 hours of incubation at 37 °C. Whereas, total mold and yeast counts were obtained using the pour plate technique with potato dextrose agar during a five-day period of incubation at 25 °C temperature. With

the use of Quebec colony counter, the plates were examined after incubation for bacterial, yeast, and mold colonies and counted them within the range specified in the procedure. The number of colony forming unit (cfu) per gram of bamboo stalk used to represent the microbes counts. Each testing parameter was carried out in triplicate.

Quantification of coliform bacteria: The pour plate method and the serial dilution approach were employed to count the number of coliform bacteria from irradiated shoot sample. 10 g of homogenized sample mixed in 90 mL diluent as 0.1% peptone to achieve 1:10 dilution. Serial dilutions of the sample up to 10^{-5} were made (each tube contains 1:9 dilution). Two sterile Petri plates (90 mm × 15 mm size each) inoculated one milliliter inoculum of sample from each dilution. Melted media as violet red bile salt agar, 15 to 20 mL was poured for coliform count according to standard testing method and incubated the plates for 24 h at 37 °C in BOD incubator as in inverted position. With the use of Quebec colony Count instrument, the plates were examined for distinctive colonies of coliform after incubation, colonies measured afterwards if observed and expressed as cfu per gram.

Qualitative assessment of food borne pathogens

Detection of *Escherichia coli:* To make tenfold dilution of sample for pre-enrichment, 25 g homogenized sample of bamboo shoot was added in 225 mL nutrient broth medium (1:10 dilution), flask was incubated at 37 °C for 24 h. Sub cultured using streaked on EMB (eosin methylene blue) agar and MCA (maconkey agar) as selective agar petri dishes. Plates were observed for distinctive colonies once the incubation time was over, for instance, pink or red colonies on macconkey agar plates and metallic-shimmer green colonies on eosin methylene blue agar plates and Gram's staining with biochemical test was performed for further morphological and biochemical confirmation [25].

Detection of *Salmonella* spp.: In order to find *Salmonella* to prepare for pre-enrichment, a 25 g homogenized sample of edible shoot was mixed in 225 mL pre enrichment broth as buffer peptone water and incubated for 24 h at 37 °C. 100 µL from pre-enriched sample was transferred in 10 mL of Rappaport Vassiliadis soya medium as selective enrichment then incubated at 42 °C for 24 hours, sub cultured by streaking on the petri-plates of bismuth sulphide agar & brilliant green agar. On selective agar plates, distinctive colonies were seen, including pink colonies on brilliant green agar and black metallic shine colonies containing H_2S on bismuth sulphide agar petri-plates. Further confirmation done by using morphological, biochemical and serological tests [26].

Physicochemical parameters

Determination of moisture content: The gravimetric technique was used to determine the moisture content as per the Association of Official Analytical Chemists [27].

pH: Accordance with Association of Official Analytical Chemists' procedure, the pH of a sample of edible bamboo shoots was measured [28].

Protein content: The Kjeldahl technique was used to determine the protein content [28].

HCN content: The association of official analytical chemist's recommended titration technique was used to determine the hydrogen cyanide concentration [27].

Organoleptic evaluation: Using a nine-point hedonic scale, a skilled sensory panel of ten people evaluated the sensory quality in order to assess the overall acceptability of the sample of processed bamboo shoots. Texture, colour, aroma & overall acceptability of preserved edible shoot conditions were among the sensory characteristics. On a hedonistic scale of 1 to 9, the sensory panelists were asked to score their evaluation. Edible sample of shoot with 9 point, like extremely or very characteristic of the tested shoot and 1, dislike enormously or not characteristic to tested shoot. Sample considered to be unacceptable to the consumers which values were less than 4. At various time intervals of 0, 15, 30, 60, 120, and 240 days with a storage temperature of 5 ± 2 °C, the sensory evaluation was conducted.

Measurement of induced radioactivity: Before customers ingest the samples of edible shoots were assessed for parameters of induced radioactivity, generated by gamma exposure and to determine the amount of radioactivity left behind after time-dependent decay. γ-Ray

spectrometer of nucleonic private limited make used a solid scintillation detector of sodium iodide (thallium) of 2 cubic inch measuring the radioactivity in the usual mode. The pulp and pericarp were separated., and separate samples of the pericarp and pulp were prepared. For each sample radioactivity was assessed twice using the same counter settings utilizing a 1 g sample of each placed in a 5 mL counting tube. For the background measurement, two blank samples were used in a similar manner. By deducting the average background counts per minute (c.p.m) from the average c.p.m of test sample, net radio activity was computed shown in Table-1.

Analytical statistics:

GraphPad Prism version 9 was used to analyse each and every statistical analysis. The statistical findings were derived using one-way ANOVA and standard deviation. Three replicates of each sample were evaluated for each treatment, and the mean ± standard deviation was recorded for each measurement. The *p* value determines the requirements for significance at a 95% level of assurance. Differences were considered statistically significant when $p \leq 0.05$.

Result and Discussion:

The study's primary objective was to evaluate certain treatments of γ-radiation dose level from 0.5 to 5.0 kGy given to the edible bamboo shoot of *Dendrocalamus hamiltonii* after processing for 240 days, the edible shoots were stored at 5 ± 2 °C with dipped under 2% saline, if any changes regarding the shelf-life of bamboo shoot was concerned. In order to extend the shelf-life of bamboo shoots, metabolic fingerprinting was done by analysing non-irradiated control and irradiated processed samples as physico-chemical, including nutritional parameters, microbiological quality evaluation, and organoleptic tests. The outcomes of various studies are conferred here.

Microbiological population effect: The microbial growth is a solemn constraint during preservation of edible bamboo shoots after post harvesting of culms also, restraint their storage and limits the average shelf life of edible bamboo shoot under lower temperature condition up to a maximum of 10 days only. Microbiological quality evaluation was carried out for *Dendrocalamus hamiltonii* as enumeration of bacterial load, total yeast and mold and coliforms count at the same time *Salmonella* Spp. and *Escherichia coli* two specific food-borne pathogens were also assessed. Microbial load was found as total bacterial count rest all were found as below detection limit, whereas both food borne pathogens were not detected in preliminary microbiological assessment. The effect of γ-irradiation on microbial burden as total bacterial count of *Dendrocalamus hamiltonii* while being stored at 5 ± 2 °C appears in Table-2. Data revealed that irradiation treatment had significant ($p \leq 0.05$) effect on the bacterial population and inhibited the bacterial count in bamboo shoot of *Dendrocalamus hamiltonii* up to long storage at lower temperature conditions. Samples exposed to 2.5 kGy and 5.0 kGy of radiation and kept at 5 ± 2 °C for up to 240 days showed no signs of microbial load, thus result pertaining after 240 days of storage, the bacterial count decreased by 4 to 6 log values. Even though radiation has a radio-static impact, which cause cells become completely destroyed with level of exposure to 2.5 kGy and more radiations for prolonged period by virtue of radiation-induced technology. When stored at lower temperatures, radiation dosages of 2.5 kGy and higher have the positive effect of maintaining the bacterial count below the threshold of detection for 240 days.

TABLE-2
EFFECT OF DIFFERENT DOSES OF γ-IRRADIATION ON TOTAL BACTERIAL COUNT (log cfu/g SAMPLE) OF BAMBOO SHOOT DURING STORAGE PERIOD AT 5 °C IN BRINE

Irradiation dose (kGy)	Storage period (days)					
	0	15	30	60	120	240
Control	4.98 ± 0.03	5.04 ± 0.01	5.45 ± 0.01	6.13 ± 0.02	6.79 ± 0.01	7.80 ± 0.03
0.5	3.02 ± 0.02	3.17 ± 0.03	3.29 ± 0.03	4.01 ± 0.01	4.11 ± 0.04	4.39 ± 0.03
1.0	2.90 ± 0.03	3.01 ± 0.01	3.45 ± 0.03	3.79 ± 0.02	3.98 ± 0.01	4.05 ± 0.03
2.5	0	0	0	0	0	0
5.0	0	0	0	0	0	0
Values are mean ± Standard deviation (n = 3)						

Data analysis indicated that the mean of the control sample's initial bacterial count at zero time was log value 4.98. These numbers are considered as a high amount of total bacteria in edible shoot of *Dendrocalamus hamiltonii*. this may be due to the several sources of contamination during manual process of post harvesting culms and packaging of that, upsurge the bacterial load. Irradiation process of gamma triggered a great reduction in total bacterial count and this decrease diminution was proportional with dosage of radiation.

Irradiation at 0.5, 1.0, 2.5 and 5.0 kGy reduced the bacterial population of bamboo shoot samples at zero time by 39.4, 42.0 and 99.9% respectively as the counts reached from log value 3.02, 2.90 and 0 in above mentioned irradiated samples, respectively. Whereas no bacterial count was found in samples exposed to 2.5 and 5 kGy of γ-radiation.

Over more progression in storage, overall counts in bacterial cell increased irrespective of treatment; however, compared to control samples, the numbers were lower in the irradiated samples. Afterward 240 days of storage at lower temperature 5 ± 2 °C, among treatments; 2.5 kGy dose was significantly ($p \leq 0.05$) efficient to keeping bacterial load of edible bamboo shoots of *Dendrocalamus hamiltonii* at lowest levels and resulted in about 6 log reduction in bacterial population while storage up to 240 days. *Dendrocalamus hamiltonii* shoot shelf-life data revealed that bacterial proliferation was significantly ($p \leq 0.05$) faster in unirradiated and irradiation samples at lower doses as low as 0.5 kGy. The control and lower 0.5 kGy irradiated samples were inept to restrict the bacterial burden over the first 240 days of storage. However, samples that received a dosage of 1.0 kGy of radiation were showing diminution in bacterial count but after 240 days of storage at a lower temperature, the bamboo shoot's microbial growth could not be completely removed (Fig. 1). Despite this, control sample revealed the greatest bacterial count under the same storage condition Comparatively to other irradiation dosages, irradiating *Dendrocalamus hamiltonii* shoots at doses of 2.5 kGy significantly increased the shelf-life of the plant.

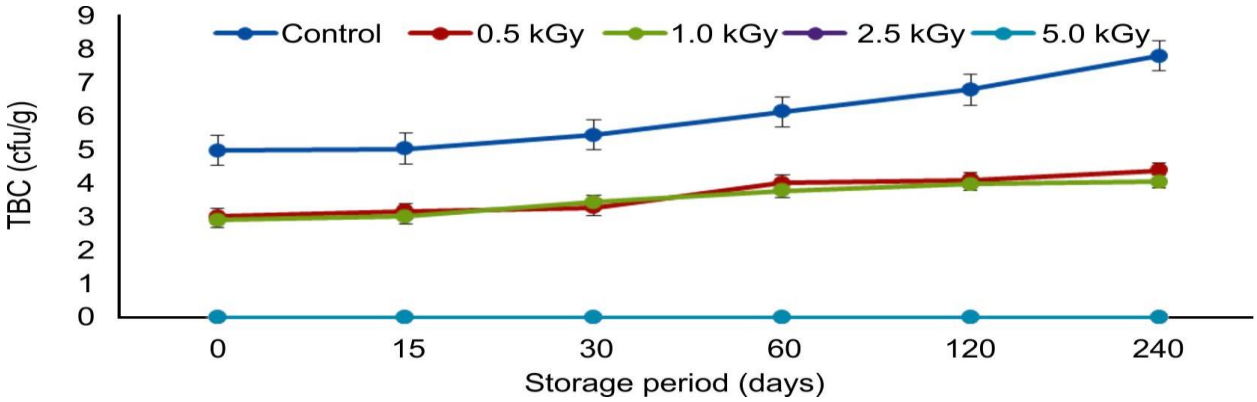

Fig. 1.Effect of γ-radiation treatments on total bacterial count (TBC) of bamboo shoot during 240 days of storage

The shelf life of banana was extended up to 20 days by treated lower dose of γ-irradiation [29]. Similar results were also showed that 2.5 kGy of γ-irradiated bamboo shoots maintained the quality capable of long storage periods [30]. The utmost reduction in the bacterial population is mainly due to the direct or indirect effects of γ-irradiation on the microorganisms as reported in various conducted research studies [31-35].

It was possible to draw the following conclusion that the application of γ-irradiation treatment was more efficient cold process to reduce the bacterial population from analyzed bamboo shoot samples compared to control sample. On the basis of single-strand or double-strand DNA molecule breaking, radiation's efficiency in lowering the microbial burden was explained [36]. Thus, shelf-life of *Dendrocalamus hamiltonii* shoot has been increased to 240 days at 5 ± 2 °C storage as a result of the influence of γ-irradiation dose of 2.5 kGy that not only extending its postharvest senescence but also prevent microbial proliferation responsible for decay of shoots.

Physico-chemical properties

Moisture: Moisture content is a vital metric because it is regarded as a fundamental component that accelerates main chemical, biological and enzymatic reactions, and whenever evaluating shelf-life studies, it may have a direct impact on the product [37]. Table-3 displays the percentage moisture content in bamboo shoots kept at a temperature of 5 ± 2 °C following exposure to varied doses of γ-radiation (kGy). The moisture value of the control bamboo shoot varied from 87.36% to 92.45% throughout the storage period whilst that of irradiated bamboo shoots ranged between 87.53% to 92.39%. The moisture content of the bamboo shoot was significantly ($p \leq 0.05$) affected by γ-irradiation.

TABLE-3

EFFECT OF DIFFERENT DOSES OF γ-IRRADIATION ON MOISTURE CONTENT (%) OF BAMBOO SHOOT DURING STORAGE PERIOD AT 5 ° C IN BRINE

Irradiation dose (kGy)	Storage period (days)					
	0	15	30	60	120	240
Control	88.36±0.02	88.46±0.01	90.90±0.06	91.90±0.06	92.23±0.06	92.45±0.05
0.5	87.53±0.03	88.17±0.02	90.04±0.01	91.04±0.01	91.69±0.04	91.96±0.07
1.0	88.59±0.04	88.97±0.02	90.39±0.02	91.07±0.02	91.45±0.03	92.39±0.05
2.5	88.63±0.01	88.70±0.04	91.06±0.03	91.84±0.03	92.16±0.03	92.38±0.09
5.0	88.74±0.07	89.01±0.01	90.53±0.02	91.19±0.04	92.18±0.04	92.33±0.02
Values are mean ± standard deviation (n = 3)						

From Day 0 to Day 30, the moisture content of control bamboo shoot sample did not vary significantly ($p \leq 0.05$). On day 240, however, the% moisture content in control shoots sample increased significantly ($p \geq 0.05$). In general, on 0-day storage,% Moisture Content within radiation doses did not change significantly ($p \leq 0.05$). However, Bamboo shoots with 1 and 2.5 kGy dosage of gamma exposure showed significant differences ($p \geq 0.05$) from Days 0 to 60.

From Fig. 2, On Day 0, it can be shown that bamboo shoots exposed to radiation at dose levels between 1.0 and 5.0 kGy had significantly ($p \leq 0.05$) greater moisture contents than those exposed to radiation at a lower dosage level of 0.5 kGy. Bamboo shoots treated with 2.5 kGy to 5 kGy exhibited significantly higher moisture content than the other treatments on day 120. Radiation-treated bamboo shoots at all doses, including the unirradiated control shoots, showed no differences on day 240. These outcomes are consistent with a few prior investigations [38]. Fresh shoots' moisture content is vital, and all treatments were found to have levels that were over 90% despite the temperature or period of storage. Recent data analysis showed that the radiation treatment at different dose levels significantly ($p \leq 0.05$) affected the moisture value in percent of bamboo shoots preserved at 5 ± 2 ℃ for up to 240 days.

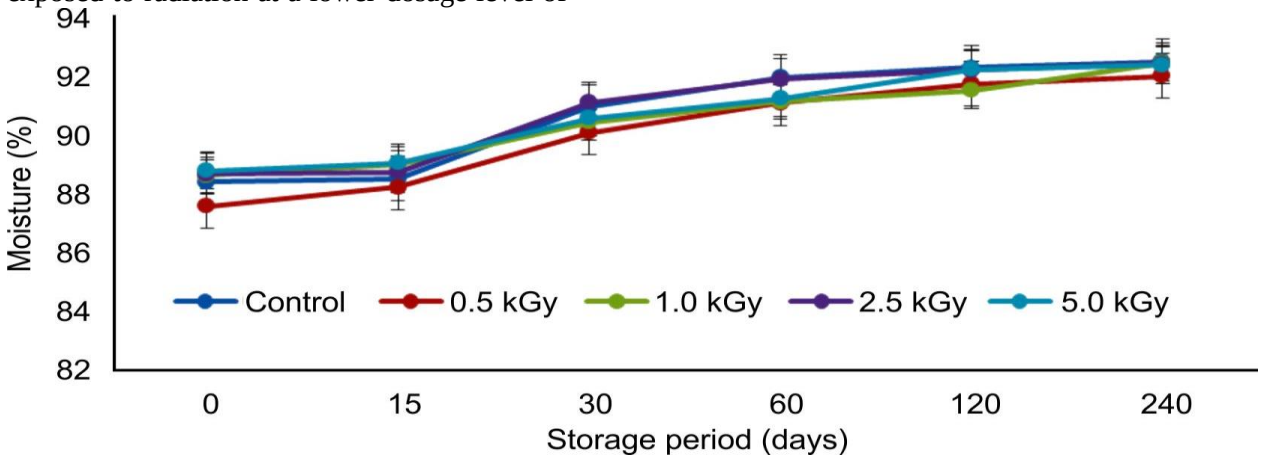

Fig. 2.Effect of γ-radiation treatments on moisture content of bamboo shoot during 240 days of storage

pH: Since entire safety and quality characteristics directly depend on the pH value, pH plays a crucial role in studies of the shelf-life of fruits and vegetables. For the non-irradiated control sample, the pH was determined to be between 4.88 and 5.42, whereas irradiated samples at various dosage levels ranged from 4.90 to 5.39. The obtained results showed slight diminution of pH up to 240 days with storage retention period for control sample and in irradiated samples, modest depletion in pH was discovered. pH values that are the most stable were seen at treatment levels of 2.5 kGy or higher dosage. Throughout all of the treatments, value of pH for bamboo shoot was found to be slightly acidic (Table-4). On day 240, the pH value γ-radiation treated shoots was lower as compared to other shoots This might be as a result of γ-radiation inhibiting the action of a class of enzymes known as polyphenol oxidase (PPO). The pH decreases as PPO action is more strongly inhibited [39]. As seen by observation that neither the control nor the irradiated bamboo shoots pH value changed significantly throughout storage. Irradiated samples had comparable pH values that were not significantly distinct from controls (Fig. 3). Almost similar outcomes were noticed for other treatment at different storage intervals. Fruits and vegetables can efficiently be given γ-irradiation dosages up to 2.5 kGy to extend shelf life and reduce postharvest deterioration and weight loss without drastically changing in the pH [40]. Moreover, the pH value is also considered as vital factor to prevent the growth of microorganisms or production of toxins in food. A sample of bamboo shoots with a lower pH value also helps to prevent the growth and multiplication of microbes.

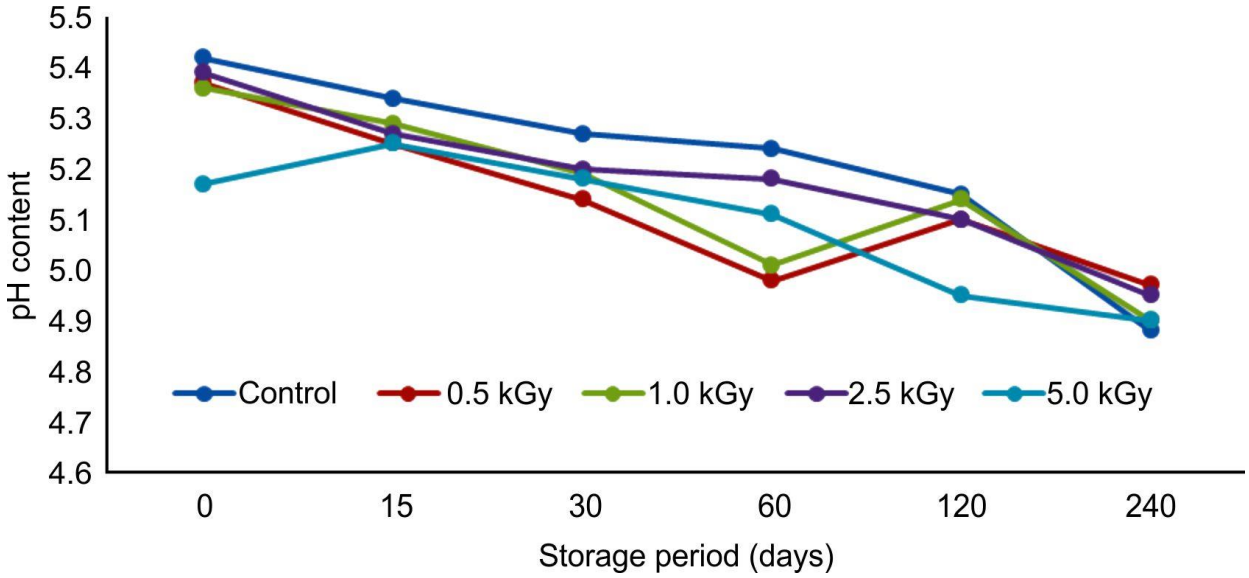

Fig. 3. Effect of γ-radiation treatments on pH value of bamboo shoot during 240 days of storage

TABLE-4
EFFECT OF DIFFERENT DOSES OF γ-IRRADIATION ON pH VALUE OF BAMBOO SHOOT DURING STORAGE PERIOD AT 5 °C IN BRINE

Irradiation dose (kGy)	Storage period (days)					
	0	15	30	60	120	240
Control	5.42 ± 0.01	5.34 ± 0.02	5.27 ± 0.02	5.24 ± 0.04	5.15 ± 0.01	4.88 ± 0.06
0.5	5.37 ± 0.03	5.25 ± 0.03	5.14 ± 0.04	4.98 ± 0.01	5.10 ± 0.03	4.97 ± 0.02
1.0	5.36 ± 0.02	5.29 ± 0.05	5.19 ± 0.03	5.01 ± 0.04	5.14 ± 0.02	4.90 ± 0.03
2.5	5.39 ± 0.01	5.27 ± 0.01	5.20 ± 0.04	5.18 ± 0.01	5.10 ± 0.01	4.95 ± 0.03
5.0	5.17 ± 0.03	5.25 ± 0.01	5.18 ± 0.03	5.11 ± 0.02	4.95 ± 0.02	4.90 ± 0.03
Values are mean ± Standard deviation (n = 3)						

Protein content: Bamboo shoot is a natural source that is abundant in protein for humans, varying in protein content from 21.1 g/100 g to 25.8 g/100 g and 1.49 g/100 g to 4.04 g/100 g based on weight, both dry and wet, respectively. The bamboo species and culm maturity have a significant impact on the amount of protein in bamboo shoots [41]. Table-5 illustrates this; protein was found to be in the range of 3.70 to 2.11 for unirradiated as control sample whereas 3.71 to 2.39 for irradiated samples at various dosage level. The data reveal that the protein content in% in each group of bamboo shoot was significantly ($p \leq 0.05$) impacted after radiation process. On day one of storage, protein value of treated bamboo shoot was just marginally ($p \leq 0.05$) greater than the control sample, all of the treated bamboo culms exhibited a decrease in protein content, while the control sample showed a significantly ($p \leq 0.05$) higher decline. Among treatments, following 30 days of storage; protein content of samples gamma exposed at dose above 2.5 kGy was significantly ($p \leq 0.05$) higher compared to other treated samples including control, on day 60 of storage, samples irradiated at dose of 2.5 kGy recorded highest protein value compared to other treatments. The protein content trend among treatments persisted until the end of the storage. At 240 days of storage, significantly higher protein content was retained in 2.5 kGy sample. When compared to the treatment groups, the

control sample protein content decreased more faster, which exemplified that during storage bamboo shoots protein deterioration rate was slowed down by irradiation. Study outcomes indicates, protein content dropped throughout the storage period and reached at it lowest at end. The lowest protein content 2.80 was determined in untreated bamboo shoots, which was followed by lowest 0.5, 1.0, 2.5, and 5.0 KGy highest dose, respectively (Fig. 4). The highest consistent protein content was observed by the 2.5 kGy group over the storage period. Similar findings were reported that irradiation had no appreciable effect on the amount of protein content. During storage retention period of bamboo shoots, observed faster deterioration in protein content in control unirradiated sample in comparison to those of gamma treated groups, which illustrated γ-radiation exposure decreased the rate at which soluble proteins in bamboo shoots degraded while being stored [42]. These findings showed that a typical tendency of slightly decreasing protein content was seen in edible bamboo shoot variety *Dendrocalamus hamiltonii* with increasing storage retention time period for 240 days at 5 ± 2 °C, While the unirradiated sample showed higher diminution under the same storage circumstances. An earlier study established that the optimal γ-irradiation dose for bamboo shoots to maintain their macronutrients for long-term preservation was 3 kGy, similar observation was reported [42]. Proteins amino acid chains can change in the presence of water owing to electron transfer, which could accelerate the process of denaturation by changing the secondary and tertiary structures before the amino acid chains are destroyed. Denaturation still occurs, albeit less quickly than during a thermal procedure [43].

TABLE-5

EFFECT OF DIFFERENT DOSES OF γ-IRRADIATION ON PROTEIN CONTENT (%) OF BAMBOO SHOOT DURING STORAGE PERIOD AT 5 °C IN BRINE

Irradiation dose (kGy)	Storage period (days)					
	0	15	30	60	120	240
Control	3.70 ± 0.02	3.21 ± 0.01	3.03 ± 0.01	2.69 ± 0.02	2.30 ± 0.03	2.11 ± 0.01
0.5	3.72 ± 0.05	3.32 ± 0.02	3.25 ± 0.02	2..94 ± 0.03	2.63 ± 0.02	2.39 ± 0.03
1.0	3.71 ± 0.03	3.39 ± 0.03	3.31 ± 0.01	3.13 ± 0.02	2.90 ± 0.04	2.73 ± 0.02
2.5	3.73 ± 0.04	3.66 ± 0.03	3.57 ± 0.02	3.48 ± 0.03	3.28 ± 0.03	3.13 ± 0.03
5.0	3.72 ± 0.02	3.63 ± 0.02	3.51 ± 0.04	3.45 ± 0.03	3.29 ± 0.05	3.05 ± 0.02
Values are mean ± Standard deviation (n = 3)						

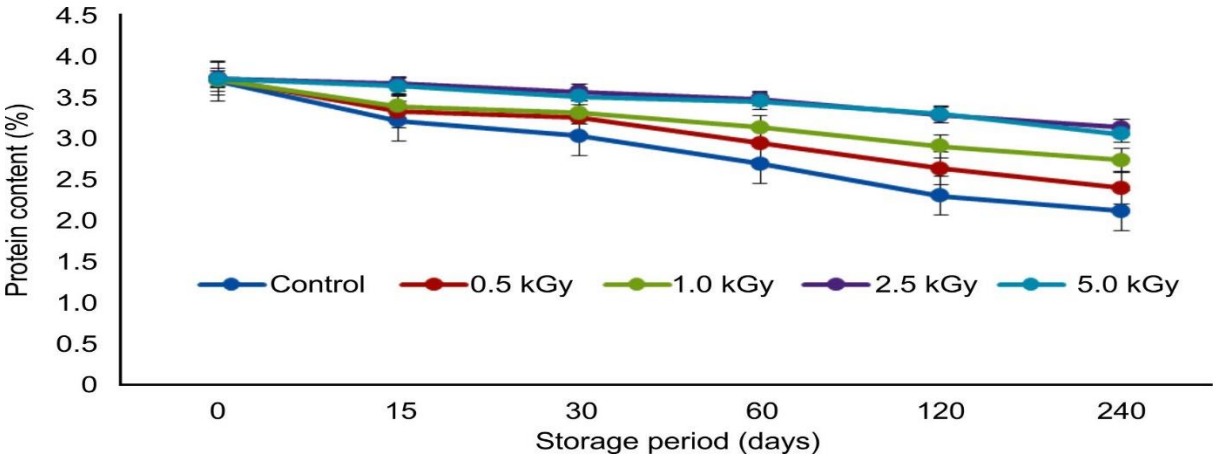

Fig. 4.Effect of γ-radiation treatments on protein content of bamboo shoot during 240 days of storage

Hydrogen cyanide content: The impact of γ-radiation on the hydrogen cyanide concentration of edible bamboo shoots variety *Dendrocalamus hamiltonii* depicted in Table-6. Compared to the control on the first storage day, the bamboo shoots treated with varied dosage of γ-radiation were found a marginally ($p \leq 0.05$) reduced HCN concentration. During storage trivial elevation in HCN content was evident in all treated samples at varied levels of dosage however HCN content was found significantly ($p \leq 0.05$) higher in untreated control samples (Fig. 5). Statistical analysis data also indicated that for all the observations at various storage periods, HCN content of control was found significantly different when compare with gamma treated bamboo samples. Among treatments after 15 days of storage; HCN content of treated bamboo shoot at doses above 1 kGy was significantly ($p \leq 0.05$) lesser compared to lower dose 1 kGy and below including control. However, after 30 days of storage, sample irradiated at dose 2.5 kGy noted lowest HCN content than rest of the treatments. Same trend in content of hydrogen cyanide among treatments sustained till end of the storage. After 240 days of storage, significantly ($p \leq 0.05$) lower HCN content retained in 2.5 kGy sample (Table-6).

TABLE-6

EFFECT OF DIFFERENT DOSES OF γ-IRRADIATION ON HCN CONTENT (mg/kg) OF BAMBOO SHOOT DURING STORAGE PERIOD AT 5 °C IN BRINE

Irradiation dose (kGy)	Storage period (days)					
	0	15	30	60	120	240
Control	23.13 ± 0.2	29.33 ± 0.3	31.50 ± 0.2	34.63 ± 0.4	49.3 ± 0.1	59.63 ± 0.2
0.5	22.80 ± 0.1	22.90 ± 0.3	24.43 ± 0.2	26.50 ± 0.1	27.07 ± 0.3	29.23 ± 0.2
1.0	23.03 ± 0.3	25.20 ± 0.2	27.90 ± 0.1	32.60 ± 0.2	34.77 ± 0.1	37.73 ± 0.3
2.5	22.83 ± 0.2	21.13 ± 0.1	21.43 ± 0.2	23.50 ± 0.1	26.70 ± 0.1	28.0 ± 0.2
5.0	18.80 ± 0.2	19.27 ± 0.1	19.9 ± 0.1	20.40 ± 0.1	20.80 ± 0.1	21.13 ± 0.1
Values are mean ± Standard deviation (n = 3)						

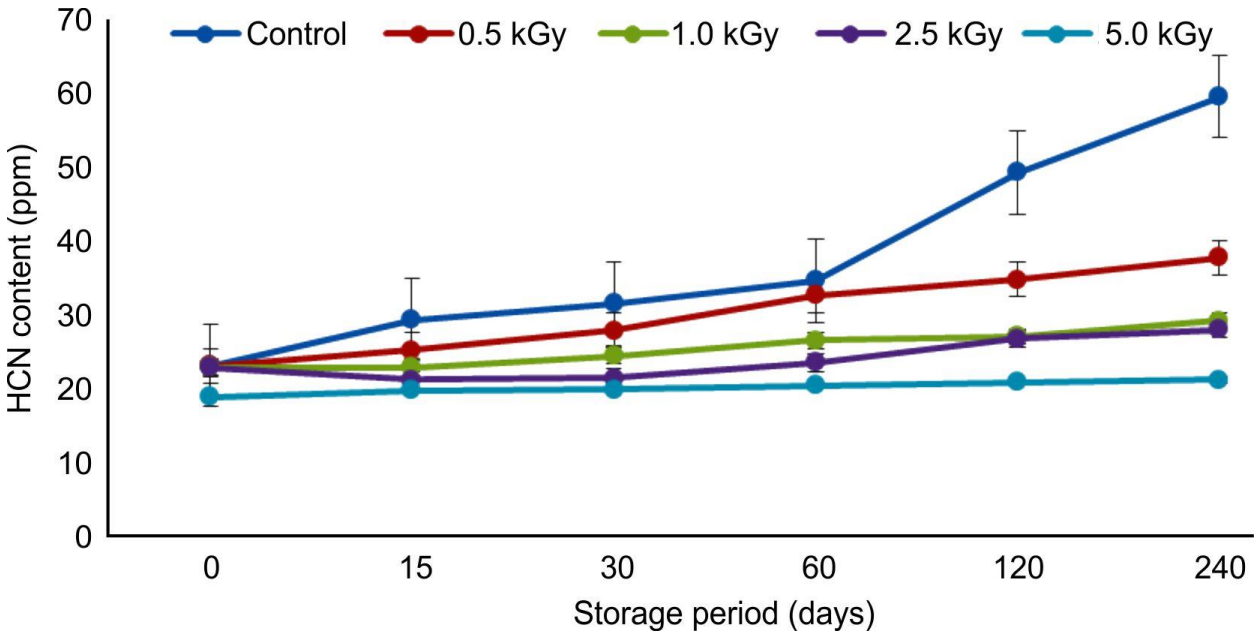

Fig. 5.Effect of γ-radiation treatments on HCN content of bamboo shoot during 240 days of storage

In carrot root tissues, γ-radiation has also been shown to decrease ethylene synthesis [44]. Ethylene has been involved to the lignification of bamboo shoots, according to a previous research report [9]. PAL is an inducible enzyme [45], although postharvest bamboo shoots merely produce low amount of ethylene, this might be sufficient to trigger PAL activity, the present results indicated that γ-radiation could be able to prevent bamboo shoots from lignifying by severely inhibiting the production of ethylene. Former study stated that PAL and POD are a key enzyme in bamboo shoot that promotes the lignification. Over the course of storage, the POD activities of the irradiated groups were continuously lower than those of the control group.[42] This may be due to the pre-treatment cutting process disrupting the bamboo shoot's cell membrane system integrity, which was followed by an increase in POD activity due to oxidative stress. These obtained results are in agreement with those mentioned that 3 kGy dose of radiation effectively inhibit the activity of POD & PAL responsible for lignification of bamboo shoot [42]. Therefore, HCN inhibition in stored radiation processed (2.5 kGy) bamboo shoots were thus proposed to be a synergistic effect of suppressing ethylene synthesis and reduced enzyme (PPO and PAL) activities.

Sensory analysis: The 9-point hedonic scale test was acquired to evaluate customer acceptability and determine the impact of γ-irradiation on stored *Dendrocalamus hamiltonii* bamboo shoots. Overall acceptability, taste, colour and texture were evaluated. The results of overall acceptability based on hedonic scale test for the edible bamboo shoot are portrayed in Table-7. It can be observed that on day zero, there was no significant difference ($p \leq 0.05$) among unirradiated control and treated shoot samples up to a dosage level of 1.0 kGy. The shoot was hardly affected by γ-radiation doses at initial stage with overall acceptability lies like very much score (7.5 points). During storage colour, texture, taste even overall acceptability of control sample was decreased. However, the sensory quality attributes of the group treated with 2.5 kGy or more showing consistency in score value at hedonic scale. The control sample was found deteriorated before 120 days of storage. Though, the overall acceptability of the samples decreased but not deteriorated for radiation doses of 0.5–1.5 kGy. Whereas, at 2.5 and 5.0 kGy, throughout storage, it remained unchanged. Remarkably, at all storage phases, samples at 2.5 kGy were more acceptable than those at 5.0 kGy. These samples also scored better in colour and texture attributes making them more acceptable compared to the other samples on the ono twenty day. Therefore, it is inferred that radiation processed samples of edible bamboo shoot at dosage of 2.5 kGy had the highest scores retained in hedonic scale analysis for overall acceptability and same perceived by the colour and texture throughout the storage period as depicted in Table-7.

TABLE-7

EFFECT OF DIFFERENT DOSES OF γ-IRRADIATION ON ORGANOLEPTIC EVALUATION OF BAMBOO SHOOT DURING STORAGE PERIOD AT 5 °C IN BRINE

Day	Dose (kGy)	Colour	Texture	Taste	Over all acceptability
0	Control	7.8 ± 0.5	7.4 ± 0.5	7.3 ± 0.7	7.5 ± 0.3
	0.5	7.8 ± 0.4	7.4 ± 0.6	7.3 ± 0.5	7.5 ± 0.3
	1.0	7.7 ± 0.2	7.3 ± 0.3	7.6 ± 0.5	7.5 ± 0.2
	2.5	7.7 ± 0.3	7.6 ± 0.3	7.6 ± 0.4	7.6 ± 0.3
	5.0	7.6 ± 0.2	7.7 ± 0.2	7.5 ± 0.3	7.6 ± 0.2
15	Control	6.8 ± 0.5	6.7 ± 0.4	6.6 ± 0.4	6.7 ± 0.4
	0.5	7.1 ± 0.3	7.0 ± 0.5	7.2 ± 0.3	7.2 ± 0.3
	1.0	7.4 ± 0.3	7.1 ± 0.2	7.2 ± 0.2	7.2 ± 0.2

	2.5	7.4 ± 0.2	7.2 ± 0.4	7.3 ± 0.2	7.3 ± 0.4
	5.0	7.2 ± 0.2	7.3 ± 0.2	7.1 ± 0.3	7.2 ± 0.2
30	Control	5.7 ± 0.6	5.7 ± 0.4	5.9 ± 0.3	5.8 ± 0.2
	0.5	6.7 ± 0.5	6.6 ± 0.5	6.8 ± 0.2	6.7 ± 0.4
	1.0	6.8 ± 0.4	6.7 ± 0.2	6.8 ± 0.3	6.7 ± 0.2
	2.5	7.0 ± 0.2	7.0 ± 0.5	6.9 ± 0.4	6.9 ± 0.3
	5.0	6.9 ± 0.2	6.9 ± 0.3	6.8 ± 0.4	6.9 ± 0.3
60	Control	4.5 ± 0.5	4.7 ± 0.4	4.8 ± 0.5	4.7 ± 0.3
	0.5	6.0 ± 0.4	6.0 ± 0.3	5.9 ± 0.2	6.0 ± 0.2
	1.0	6.0 ± 0.3	6.3 ± 0.2	6.4 ± 0.3	6.2 ± 0.2
	2.5	6.7 ± 0.5	6.6 ± 0.4	6.6 ± 0.5	6.6 ± 0.3
	5.0	6.5 ± 0.5	6.6 ± 0.4	6.5 ± 0.4	6.5 ± 0.4
120	Control	3.5 ± 0.5	3.6 ± 0.4	NA	3.5 ± 0.3
	0.5	4.5 ± 0.5	4.3 ± 0.4	3.9 ± 0.4	4.3 ± 0.3
	1.0	4.9 ± 0.3	4.9 ± 0.4	4.9 ± 0.3	4.9 ± 0.2
	2.5	6.3 ± 0.3	6.4 ± 0.4	6.4 ± 0.4	6.3 ± 0.3
	5.0	6.0 ± 0.3	6.0 ± 0.3	5.9 ± 0.3	6.0 ± 0.3
240	Control	1.5 ± 0.4	1.4 ± 0.6	NA	1.5 ± 0.3
	0.5	3.1 ± 0.5	3.0 ± 0.4	NA	2.1 ± 0.1
	1.0	3.4 ± 0.5	3.4 ± 0.2	3.1 ± 0.2	3.3 ± 0.3
	2.5	5.9 ± 0.2	5.8 ± 0.2	5.5 ± 0.4	5.7 ± 0.4
	5.0	5.4 ± 0.5	5.5 ± 0.3	5.3 ± 0.4	5.4 ± 0.4
Data are expressed as mean ± standard deviation (n = 10); NA = Not applicable					

Similarly, the γ-irradiated grains, nuts, vegetables, green tea and fresh and dried fruits (such as carrots, spinach leaves, lettuce, broccoli, red kidney beans, pistachios, raisins dried figs, apricots, pears, apples, fresh strawberries, pineapples and mangoes) was also shown to lead to good sensory and organoleptic quality acceptance [46-50]. One study demonstrated how γ-radiation affected the storage quality of bamboo shoots by inhibiting enzyme activity during storage [42]. Additionally, in rare situations, irradiation of fruits and vegetables also results in an increase in their nutritional value, including their phenolic and vitamin C content [51-53]

Induced radioactivity assessment: Amount of induced radioactivity (a metric for safety of food) using the data gathered from all the samples, the preserved samples of bamboo shoots were found to have no evidence of net induced radioactivity. The fact that there may not have been a nuclear reaction due to the bamboo shoots extremely low metal ion concentration is one possible explanation. Therefore, a consumption prospective the cut *Dendrocalamus hamiltonii* bamboo shoots had no harmful residual radiation.

Conclusion

The present study has demonstrated that a minimum 2.5 kGy γ-radiation dose is adequate for long time storage of bamboo shoots of *Dendrocalamus hamiltonii* without any adverse effect was observed in our results. Food processing method known as γ-irradiation was revealed to be a very effective and cutting-edge research tool for prolonging the retention of storage quality of post-harvested bamboo shoot. Due to microbial deterioration during storage and transit, there is a significant loss of shoots. as presently there is no effective method for prevent edible shoots from microbial decay.

The optimum γ-radiation dosage for the bamboo shoots was 2.5 kGy during the 240 days of storage at $5 \pm 2\ ^0$C temperature, this dosage was considerably helpful in preserving its storage quality, including nutritional and organoleptic properties and reducing the microbial load. The irradiated shoots exhibited no induced radioactivity. Therefore, γ-radiation processing had efficient non-chemical method for protection of postharvest deterioration of edible bamboo shoots and extension their shelf -life, provides an improved benefits in term of food safety and quality.

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Conflict of Interest

No conflicts of interest exist, according to the authors, with the publishing of this work.

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