Biological Forum – An International Journal 15(8a): 168-176(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Gamma Irradiation on Post-harvest Shelf life and Quality of Aggregatum Onion (*Allium cepa* L. var. aggregatum Don.)

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(Received: 11 June 2023; Revised: 22 June 2023; Accepted: 26 July 2023; Published: 15 August 2023)
(Published by Research Trend)

ABSTRACT: The shelf life of aggregatum onion need to be increased in order to open export opportunities worldwide. To extend the shelf life, research was started with selection of CO4 variety and treated with gamma irradiation of different dosages (0 Gy, 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy) and stored at room conditions. At monthly interval evaluation, it shown significant difference ($p<0.05$) in physiological and biochemical parameters with respect to different doses. After 4 months of storage, it was cleared that treatment of 100 Gy showed less moisture loss, physiological weight loss with high marketable yield and total sugars followed by 150 Gy with less rotting loss and high sulphur content at the end of the storage. However, Marketable bulb (%) determines the profitability of exporting, it is concluded that treatment of 100 Gy extends the shelf life of onion bulbs with less losses and high marketable bulb %. So, this would extend shelf life of onion bulb without disturbing its qualities and its pungency for which its well-known. As it was easy to irradiate tons of bulbs in this advanced world, we hope this would benefit both farmers and consumers.

Keywords: Irradiation, small onions, storage, sprout inhibition, qualities.

INTRODUCTION

Aggregatum onion also known as minor bulb globally is most famous for its unique pungency. While the other vegetable crop grown on a larger scale as a protective food for the increasing demand among people, aggregatum onion competes in that race with its unique flavour and medicinal properties. As the production of aggregatum onion is mostly in southern India, it creates the best export opportunities worldwide. Most varieties of aggregatum onion were released from Tamil Nadu namely CO 1, CO 2, CO 3, CO 4, CO (On) 5 and MDU 1. Although the CO 4 variety is bold in size, appealing to customers, and has a pleasing look, it produces 18.8% less bulbs per plant than the CO (On) 5 variety (Saraswathi *et al.*, 2017). Generally, India ranked 2nd in onion production and many countries depends on India for the import of vegetables. The lean season for onion in India is from May to October, so a certain quantity of onion bulbs was stored both for domestic and export purposes (Sharma *et al.*, 2020). Mostly, Onions are stored at ambient conditions (18-25°C and high relative humidity more than 85%) that forms a catabolism which led to sprouting, transpiration, rotting and microbial spoilage (Benkeblia *et al.*, 2002). Minimizing the post-harvest losses while exporting these onions is a deciding factor for the profit and loss percent. But India recorded 40 - 60 percent of annual storage loss (Maini *et al.*, 1984). The factors responsible for storage quality can be categorized into pre-harvest and post- harvest factors. It is impossible to fully control the pre-harvest factors but we can regulate the factors after harvest while storing. So, there is a need for new technology without affecting biochemical properties of the produce with the increasing demand even though many technologies are already in action but it disturbs the product's properties. For solving these queries, researchers turn their sides towards Gamma irradiation which reduces storage loss without affecting the properties of the produces. Irradiation of onion shows high shelf-life period by controlling sprouting and rotting loss with maintenance of some properties like pyruvic acid content, texture, colour retention and it also has antimicrobial effects (Kallai *et al.*, 2015; Kim *et al.*, 2005). The least amount of weight loss, rotting, and sprouting occurred and the maximum quality was maintained in onion bulbs exposed to 120 Gy of gamma radiation for three months (Sharma *et al.*, 2020). And also, with the increase of dosage, the Vitamin C reduces. So, the standardized of dosage of Gamma irradiation is necessary to prevent those effects and also to avoid the use of high radiation dose

MATERIAL AND METHODS

Raw materials: The CO 4 variety released by the Tamil Nadu Agricultural University in Coimbatore, was the one used in this experiment. They were purchased from the village of Irur in the Perambalur district of Tamil Nadu, and during transportation, the bulbs were wrapped in netting bags for free circulation before being laid out on the floor to reduce heat. Bulbs were cured for almost 2 weeks (14 days) before treatment. A total of 50 kg of onion bulbs were bought, out of 6 kgs were used for each treatment and then it can be divided for observing physiological and biochemical of 1 kg of each with three replications.

Irradiation Treatments: The onion bulbs were subjected to gamma irradiation treatment at the Department of Vegetable Science's orchard, Horticultural College and Research Institute, TNAU, Coimbatore, Tamil Nadu. Irradiation treatment was given by using a Gamma irradiator chamber (CG-5000) where ^{60}Co is a source of irradiation. It is approved by Atomic Energy Regulatory Board (AERB) and installed by Board of Radiation & Isotope Technology (BRIT), Mumbai, India. In a gamma irradiation chamber with a capacity to treat 1 kg of bulbs at a time, bulbs were packaged in polyethylene bags and treated. As it was automated, treatments doses of 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy were set and given automatically where non-irradiated bulbs serves as control (0 Gy) (Fig. 1. A and B).

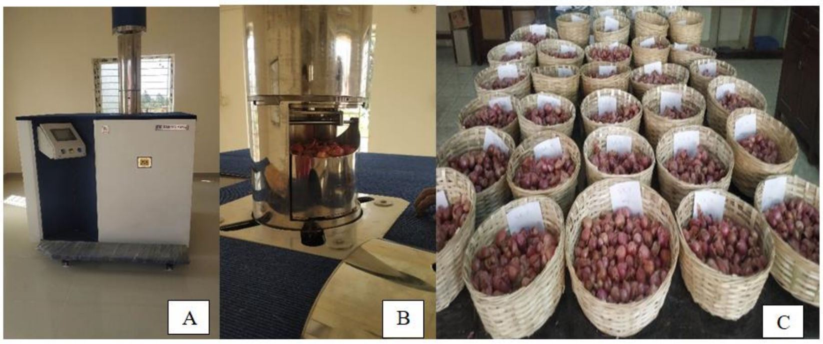

Fig. 1. A) Gamma irradiation chamber B) Irradiation treatment for onion bulbs C) storage of onion bulbs after treatments at ambient storage conditions.

Storage conditions: After receiving radiation treatments, bulbs were moved to a college laboratory and kept there in bamboo baskets (36 baskets were used) under room conditions with temperature (24°C–34°C) and relative humidity (40–75%) (Fig. 1 C). At intervals of 30 days up to 150 days, the physiological, biochemical, and sprouting behaviour of the treated bulbs were examined and documented.

Quality evaluation:

1. Physiological parameters:

Moisture content (%): The oven dry method was used to calculate the moisture content (%) (AOAC, 2000). Using a hot air oven, bulbs chosen were cut into pieces and dried at 105°C for three hours or more to achieve constant weight. This process is repeated up to 120 days in a row at intervals of 30 days.

$$\text{Moisture content (\%)(wet basis)} = \frac{\text{Initial weight} - \text{oven dry weight}}{\text{Initial weight}}$$

Physiological loss in weight (%): The weight of the bulbs was initially recorded on the first day of storage, and then again at intervals of 30, 60, 90 and 120 days (Waghmare & Annapure 2015). The bulbs were kept at room temperature throughout the storage period. The physiological loss of weight was determined using the formula below.

$$\text{Physiological loss of weight (\%)} = \frac{\text{P0} - \text{P1 or P2}}{\text{P0}} \times 100$$

Where P0 – Initial weight, P1 - weight after 30 days, P2 - weight after 60 days, P3 - weight after 90 days and P4 - weight after 120 days.

Per cent dry matter (%): The hot air oven method was used to calculate the dry matter (%). With a sharp knife, the bulbs were cut into small pieces. A known weight of cut-up bulbs was used as the fresh weight, and it was dried using a hot air oven at 60 °C until a constant weight was attained. With 30-day storage breaks, this has to be done for 120 days. Dry matter (%) was computed using the following formula.

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Rotting loss (%): The weight of the rotten onion bulbs was assessed at various storage intervals of 30, 60, 90 and 120 days after the onion bulbs that exhibit soft or mould rot symptoms were separated (Sharma *et al.*, 2020). The following formula was used to compute the Rotting loss (%).

$$\text{Rotting loss (\%)} = \frac{\text{Weight of the rotten bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

Marketable bulb (%): At the end of the storage period (30, 60, 90 and 120 days after storing), the rotten and sprouting bulbs were separated from the lot, and the weight of the remaining healthy bulbs was recorded. The following formula was used to determine the Marketable bulb (%).

$$\text{Marketable bulb (\%)} = \frac{\text{Weight of the healty bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

2. Biochemical parameters:

Soluble protein (mg g^{-1}): The Soluble Protein estimation was carried out by using Lowry *et al.* (1951) method. Take 0.5 g of the stored bulb's sample. Use distilled water or a buffer to make a sample extract. Pipette 0.1 and 0.2 millilitres of the sample extracts into two test tubes after collecting the supernatant. With distilled water, fill each test tube to a volume of 1 ml. Add 5 ml of solution C, thoroughly mix together, and incubate10 minutes at room temperature. Then, add 0.5 ml of FCR, mix well, and incubate for 30 minutes at room temperature in the dark. Measure the absorbance at 660 nm. The concentrations of proteins were calculated against the working standard using a standard curve and represented as mg/g, mg/100g of sample, or as a percentage.

Sulphur content (%): (Chopra & Kanwar 1982) method with little modifications was used to estimate the sample's sulphur concentration. First, a sample of plants weighing 10g was extracted using a solution of magnesium nitrate. After 30 minutes of heating to 180° Celsius, it was chilled. The resulting ash was wet with distilled water and HCl in a ratio of 1:1, then allowed to dry off. Once more moistened with distilled water and HCl (1:1), the mixture was left in the sand bath till it reached clearness. Then it was cleaned, filtered, and mixed with distilled water to make a volume of 100 ml. A conical flask was filled with 10 ml of an aliquot (extract). Add 1g of 30–60 mesh barium chloride crystals and shaken vigorously for one minute. Then 1 ml of gum acacia was added and with distilled water, increased the volume to 25 ml, and then shaked it once more for a minute. Then, within 5 to 30 minutes, turbidity readings at 420 nm were taken using a photoelectric calorimeter. The concentration of the Sulphur content was determined using the standard curve and represented as a percentage on a dry weight basis.

Total sugar (%): The anthrone method was used to estimate the percentage of total sugars (Hedge & Hofreiter 1962). 100 mg of the sample should be taken in a boiling tube with 5 ml of 2.5 N HCl and heated for 3 hours and then cooled immediately. By using solid sodium carbonate, neutralise it until the effervescence stops, then 100 ml of distilled water were added, and centrifuged. Pipetting out 0.5 and 1 ml of aliquots into separate test tubes from the supernatant after centrifugation. Distilled water was added to make each test tube to a volume of 1 ml. Then, 4 ml of the anthrone reagent was added, and it was heated for 8 minutes in a water bath before being cooled. In the end, measure the absorbance at 630 nm. The total sugar concentration was computed against Glucose standard curve and expressed it as a percentage (%).

Ascorbic acid (mg g^{-1}): Ascorbic acid content was estimated by using Horwitz (1975) method. 5 ml of the working standard solution should be transferred into a 100 ml conical flask. After adding 10ml of 4% oxalic acid, titrate against the dye and determines the titre value of V1 ml. The end point is the appearance of a pink colour, and the amount of ascorbic acid present is equal to the amount of dye consumed. The sample should be extracted (0.5–5g, depending on the sample) in 4% oxalic acid, diluted to a specified volume (100ml), and then centrifuged. Take the supernatant and pipette out 5 ml into a conical flask. Add 10 ml of 4% oxalic acid and titrate against the dye and entered the titre value as V2 ml. The amount of ascorbic acid present in 100 mg sample was calculated by the following formula.

Titrable acidity (%): Titrable acidity is the acidity of the predominant acid present in the sample juice (i.e.) citric acid. Titrable acidity was measured by using the method of (Ranganna, 1986). Samples were collected, ground up, and then transferred to volumetric flasks. Made up a volume that was ten times the sample's weight and passed through glass wool. Indicator phenolphthalein of few drops was added to 5 ml of the sample before being titrated against 0.1N NaOH. The following formula was used to compute the Titrable acidity and express it as a percentage (%).

Statistical Analysis: The experiment was laid out in a Completely Randomized Design (CRD) with three replications (wooden basket with 1 kg of bulb for each replication). Statistically significant differences among the different doses and shelf life were identified at a 5% level of significance.

RESULTS AND DISCUSSION

Moisture content (%): Moisture content is one of the deciding factors to the market value of the onion bulb where higher the moisture content, higher the market value. There was a significant difference in a moisture content at a different dosages of gamma irradiation. The moisture content after 120 days of storage period for 0 Gy, 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy gamma irradiated were 76.62, 77.56, 77.67, 79.33, 78.67 and 76.96% respectively in these 100 Gy shows higher moisture content of 79.33 % at the end of storage period (Table 1). It was observed that after 120 days of storage period, moisture loss was more in radiated bulbs at 30^{th} and 60^{th} days of storage. But after that radiated bulbs maintain higher moisture content than the control in following months. These are in accordance with Balakrishnan *et al.* (2021), radiation may soften and release water more easily because it causes depolymerization of polysaccharides, which can result in major alterations in the cell membrane and connective tissues. At 90^{th} and 120^{th} day of storage period, unirradiated bulbs show high moisture loss due to initiation of sprouting than the radiated bulbs in which sprouting is completely ceased. From these results, it was cleared that moisture content was higher in irradiated bulbs than the nonradiated bulbs over the entire period of storage. This is agreed with the findings of (Vethamoni & Gomathi 2018), moisture content decreases with the increasing storage life due to continuous respiration process which reduces moisture content in the form of water vapour. Mazumder & Misran (2022) reported that gamma irradiation reduces respiration rate in tomato which results in less moisture loss with increased storage life and these research findings supports our results.

Table 1: Effect of different doses of irradiation on moisture content of bulbs during storage.

Treatments	Days after storage at ambient conditions			
	30 DAS	60 DAS	90 DAS	120 DAS
T_1	84.33	83.00	79.78	76.62
T_2	83.67	82.67	80.69	77.56
T_3	83.33	82.33	81.87	77.67
T_4	82.67	81.50	80.29	79.33
T_5	82.17	81.33	80.18	78.67
T_6	81.83	81.00	80.16	76.96
SE(d)	0.67	0.73	0.64	0.60
CD (0.05)	1.45*	1.58*	1.39*	1.31*

NS = Not Significant; *= Significantly difference at 5% level i.e. ($p < 0.05$), DAS= Days After Storage.

Physiological loss in weight (PLW): The factors responsible for physiological weight losses are moisture loss, sprouting and respiration. It was observed that there was a significant difference in a physiological weight loss at a different dosages of gamma irradiation and storage period. It was found that radiated bulbs show less physiological weight loss than the non-radiated bulbs after 120 days of storage period. The Physiological weight loss of 0 Gy, 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy gamma irradiated bulbs after 120 days of storage were 66.23, 64.37, 62.80, 60.48, 57.07 and 59.72 % respectively (Table 2). The PLW of 100 Gy radiated bulbs showed lesser than control and any other dosage at 90^{th} and 120^{th} day of storage as it controls moisture loss by controlling respiration rate while other treatments show losses due to respiration and other volatile compounds. These findings are in line with (Abdullah *et al.*, 2018), minimum weight loss was observed in onion when treated with 150 Gy. The Bulbs radiated with 200 Gy showed higher physiological weight loss similar to non-radiated ones which matches the findings of (Sharma *et al.*, 2020), that higher PLW in bulbs exposed to 200 Gy of radiation may be related to a decrease in the concentration of allyl propyl sulfite content, which led to increased rotting.

Dry matter content: Usually, dry matter content of onion increases with the increased storage period due to reduction of moisture content. It was observed that there was a significant difference in dry matter content of the bulbs at a different dosages of gamma irradiation and storage period. The Dry matter content of 0 Gy, 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy gamma irradiated bulbs after 120 days of storage were 23.38, 22.44, 22.33, 20.67, 21.33 and 23.04% respectively (Table 3). It was found that bulbs irradiated with 200 Gy and non- radiated bulbs show similar results at 90^{th} and 120^{th} day of storage period. The moisture loss in control is due to high respiration rate and in treatments with higher doses by radiolysis of water molecules. This is similar to the findings of (Croci *et al.*, 1995), dry matter percent was similar in irradiated and non-irradiated bulbs during storage and (Ahmadi, 2020), dosages of 90 and 120 Gy produced the highest dry matter results (12.45%) in onion bulbs due to reduced moisture content. Onion keeping quality and dry matter content are directly correlated; the higher the dry matter content of the bulb, the better it will hold up during the cold period.

Table 2: Effect of different doses of irradiation on PLW of bulbs during storage.

Treatments	Days after storage at ambient conditions			
	30 DAS	60 DAS	90 DAS	120 DAS
T_1	15.90	24.60	47.43	66.23
T_2	14.27	21.57	44.50	64.37
T_3	13.93	18.20	40.85	62.80
T_4	13.40	17.13	35.97	57.07
T_5	11.23	12.67	38.80	60.48
T_6	12.60	15.70	40.73	59.72
SE(d)	0.36	1.61	1.67	1.64
CD (0.05)	0.78*	3.50*	3.64*	3.58*

NS = Not Significant; *= Significantly difference at 5% level i.e. ($p < 0.05$), DAS= Days After Storage

Table 3: Effect of different doses of irradiation on Dry matter (%) of bulbs during storage.

Treatments	Days after storage at ambient conditions			
	30 DAS	60 DAS	90 DAS	120 DAS
T_1	15.67	17.00	20.22	23.38
T_2	16.33	17.33	19.31	22.44
T_3	16.67	17.67	18.13	22.33
T_4	17.33	18.50	19.71	20.67
T_5	17.83	18.67	19.82	21.33
T_6	18.17	19.00	19.84	23.04
SE(d)	0.67	0.73	0.63	0.60
CD (0.05)	1.45*	NS	NS	1.31*

NS = Not Significant; *= Significantly difference at 5% level i.e. ($p < 0.05$), DAS= Days After Storage.

Rotting loss (%): Rotting of bulbs is generally occurs due to pathogens (*Aspergillus* sp. and *Erwinia* sp.), mechanical damage during handling and so on. It couldn't be controlled completely by post- harvest treatments where it only reduces the loss percent. It was recorded that there was a significance difference in the rotting loss among the treatments. In every 30 days interval, non-radiated bulbs show higher rotting loss than the treated ones. After 120 days of storage period, rotting loss (%) of bulbs treated with 0 Gy, 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy gamma irradiation were 4.50, 2.47, 2.22, 2.03, 1.83 and 3.16% respectively (Table 4). Among different dosage of gamma irradiation treatments, treatment with 150 Gy showed lesser rotting loss of 1.83 % at 120th day of storage period. This is due to radiolysis of water by gamma irradiation, which releases reactive oxygen species (ROS) where it damages microorganism DNA and other macromolecules and ultimately cause them death. It satisfies the findings of Akhther *et al.* (2022) that onion treated with gamma irradiation of 100 Gy showed minimum rotting loss of 4.01% at 180th day which 3 times lesser than the untreated ones. This is also in accordance with Sumalatha and Maheshwar (2022), fungus incidence on onion samples treated with 0.15 KGy decreased from 31.8 to 26.1% without compromising its nutritional value.

Marketability (%): The highest percent of marketable bulb was obtained by less physiological weight loss, sprouting loss and rotting loss. During storage period of 120 days, different dosage of gamma irradiation treatment showed significance different to a non-irradiated bulbs in marketable bulb (%). At 30th and 60th days of storage, bulbs treated with 150 Gy gave high marketable bulb (%) of 88.90 and 86.17% respectively than any other treatment dosage followed by 200 Gy treatment with 87.40 and 83.33% respectively (Table 5). It is suggested that higher dosage of gamma irradiation control microbial load and prevent rotting loss. At 90th and 120th day of storage, treatment with 100 Gy showed high marketable bulbs with 62.23 and 40.90 % respectively followed by 150 Gy with 59.43 and 37.68% of marketable bulbs respectively. This is in favour of (Sharma *et al.*, 2020) that higher dosage led to decrease in the concentration of allyl propyl sulfite content which slowly increase rotting loss at few months later after treatment. It was found that these results are in accordance with findings of recent researches that Gamma irradiated bulbs show high shelf life with increased marketability than the non-irradiated bulbs by reduced PLW, sprouting and rotting and also higher dosages of gamma irradiation would affect marketable bulb by radiolysis of water molecules which leads to dried scales of bulb while it directly affects the marketable bulb (%), 100 Gy should give the maximum marketable bulb at the end of the storage period which also open the chances of long distance export.

Table 4: Effect of different doses of irradiation on rotting loss (%) of bulbs during storage.

Treatments	Days after storage at ambient conditions			
	30 DAS	60 DAS	90 DAS	120 DAS
T_1	0	2.53	3.43	4.50
T_2	0	1.65	2.27	2.47
T_3	0	1.62	1.88	2.22
T_4	0	1.67	1.80	2.03
T_5	0	1.00	1.77	1.83
T_6	0	0.97	1.43	3.16
SE(d)	-	0.33	0.32	0.55
CD (0.05)	-	0.72*	0.69*	1.20*

NS = Not Significant; *= Significantly difference at 5% level i.e. ($p < 0.05$), DAS= Days After Storage.

Table 5: Effect of different doses of irradiation on marketability (%) of bulbs during storage.

Treatments	Days after storage at ambient conditions			
	30 DAS	60 DAS	90 DAS	120 DAS
T_1	84.10	72.87	49.13	29.26
T_2	85.73	76.78	53.23	33.17
T_3	86.07	79.25	57.27	34.98
T_4	86.60	81.20	62.23	40.90
T_5	88.90	86.17	59.43	37.68
T_6	87.40	83.33	57.83	37.13
SE(d)	0.35	1.53	1.73	1.50
CD (0.05)	0.76*	3.34*	3.78*	3.28*

NS = Not Significant; *= Significantly difference at 5% level i.e. ($p < 0.05$), DAS= Days After Storage.

Ascorbic acid (mg g^{-1}): After 120 days of storage, there was a significance difference between bulbs with different treatment and storage period. During the storage period of 120 days, unirradiated bulbs show high ascorbic content than the irradiated bulbs at every 30 days interval of 30th, 60th, 90 th and 120th day of storage with 9.36, 8.69, 8.18 and 7.72 mg g^{-1} respectively. At the end of storage period of 120 days, the ascorbic content of 0 Gy, 10 Gy, 50 Gy, 100 Gy, 150 Gy and 200 Gy gamma irradiated bulbs were 7.72, 7.10, 6.85, 6.06, 6.00 and 5.75 mg g^{-1} respectively (Fig. 2). This may be in accordance with Lester *et al.* (2010), that the increasing amount of irradiation produced oxidative radicals, which then caused the ascorbic acid level to drop and this may be due to an increase in the metabolism of ascorbic acid and the synthesis of carbohydrates or by its oxidation to dehydroascorbic acid (Rezaee *et al.*, 2013). Also there was a findings which support this results (Sharma *et al.*, 2020), that the ascorbic acid content of bulbs exposed to gamma rays at 120 and 200 Gy decreased to lower values of 6.12 and 6.02 mg/100 g, respectively than the control at 144 days of storage where ascorbic acid is sensitive to irradiation and also the sensitivity increases with increasing doses of levels.

Soluble Protein (mg g^{-1}): It was observed that there was no significance difference in the soluble protein content among treatments up to 90 days of storage while bulbs treated with 10 Gy shows little higher protein value at each monthly interval. After 120 th day of storage, bulbs treated with gamma radiation of 10 Gy significantly had higher protein content with 16.63 mg g^{-1} respectively where unirradiated bulbs show lesser value of 16.40 mg g^{-1} (Fig. 3). This may be suggested that radiation enhance the production of sulphur containing amino acids which leads to higher protein content in low dose of radiated samples. Totally, the results were in accordance with findings of (Vethamoni & Gomathi 2018), that the protein content increased with increase in storage period and also in agreement with (Neelma *et al.*, 2017), irradiation causes deamination and scission of peptide and disulphide bonds which leads to reduction of protein content in irradiated bulbs.

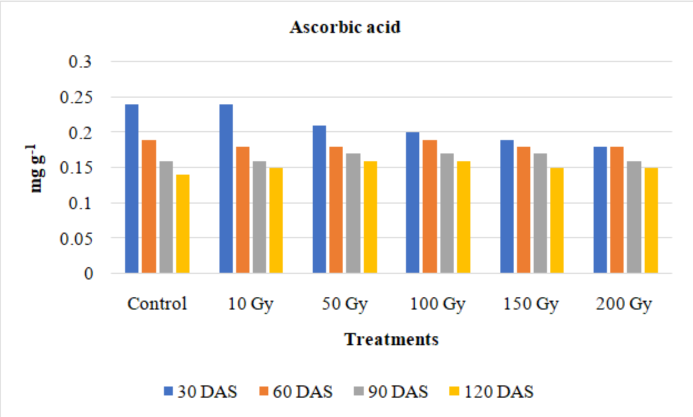

Fig. 2. Effect of different doses of irradiation on ascorbic acid of bulbs during storage.

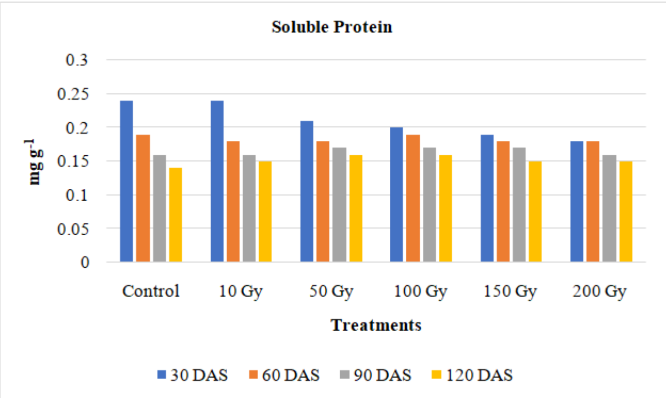

Fig. 3. Effect of different doses of irradiation on soluble protein of bulbs during storage.

Sulphur content (%): Sulphur is a flavour compound formed by being uptaken from the soil during growth period (Ma *et al.*, 2010). During the storage period for the first two months, there was no significance difference among the treatments in sulphur content. But treatment 100 Gy and 150 Gy showed significantly higher sulphur content with 0.514% equally at 90 th day and treatment 150 Gy show significantly higher sulphur content with 0.561% at 120 th day of storage followed by 100 Gy with 0.553% of sulphur content (Fig. 4). Normally as storage life increases, sulphur containing compounds like thiosulfinates and sulfides decreases as it is volatile, it will easily evaporate and these losses can be reduced by gamma irradiation where it increases the sulphur containing compounds. Our result agreed with sayings of Gyawali *et al.* (2006), that the radiation increases the volatile organic compound as dosage increases but only to a certain threshold limit because high dose rate of irradiation splits the chemical bond of molecules which leads to formation of free radicals and these radicals combine to form a radiolytic products. (Fan, 2004) also reported that radiation up to 3 kGy increased the number of sulphurs containing compounds in fresh orange juice which leads to increase of sulphur content.

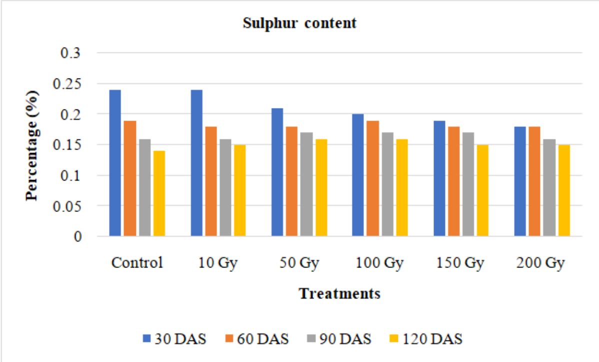

Fig. 4. Effect of different doses of irradiation on sulphur content (%) of bulbs during storage.

Total Sugars (%): During the storage period of 120 days, it was observed that in the first month of storage, there was no much differences in sugars among the treatments but after continuous storage period there was a significance difference from the 2nd month between irradiated and unirradiated bulbs. At 30th, 60 th, 90 th and 120 th day of storage, unirradiated bulbs show 5.15, 5.25, 5.43 and 5.45% of total sugars respectively where one of the treatment doses of 100 Gy show 5.26, 5.28, 5.35 and 5.45% of total sugars (Fig. 5). From these results, it was found that sugars increase with increasing storage period in all treatments and irradiated bulbs show higher sugars content immediately after treatment than the unirradiated bulbs. Our results support the findings of Akhther *et al.* (2022), TSS levels gradually increased over time in both the control and the irradiation bulbs, probably as a result of starch breaking down into sugars and (Nouri & Toofanian 2001), that the irradiation actually increases the reducing and non-reducing sugars by increasing the activity of enzyme responsible for conversion of starch into glucose, fructose and sucrose than the unirradiated ones.

Titrable acidity (%): During storage, Titrable acidity decreases as the storage time increases. It was found that there was no much changes in the Titrable acidity of different treatments for the first two months, after that it start to show significance difference in Titrable acidity. There was a decrease in Titrable acidity immediately after irradiation followed by maintenance of that TA through the storage period. At 30th, 60 th, 90 th and 120 th day of storage, unirradiated bulbs show 0.24, 0.19, 0.16 and 0.14% of Titrable acidity respectively (Fig. 6). The unirradiated bulbs show rapid decrease in TA from 2nd month where other treated bulbs show lesser TA in the first month and followed by stable decrease through the storage period. Our results agreed with (Singh *et al.,* 2016), Gamma-irradiated tomatoes (0.75 to 2.0 kGy) showed a decrease in TA in comparison to the control. But at the end of the storage period of 120th day, radiated bulbs show higher TA than the unirradiated bulbs and the dosage of gamma irradiation doesn't create any significant changes in TA among the different treatments. Decreased acidity might be due to acidic hydrolysis of polysaccharides where acid is utilized for converting non-RS into RS (Bhardwaj & Pandey 2011).

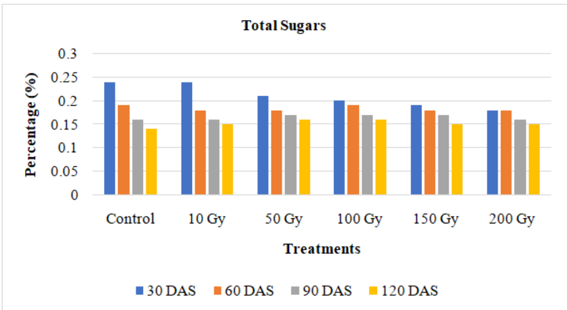

Fig. 5. Effect of different doses of irradiation on total sugars of bulbs during storage.

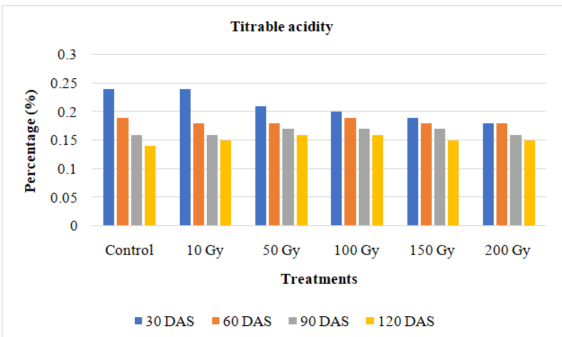

Fig. 6. Effect of different doses of irradiation on Titrable acidity of bulbs during storage.

CONCLUSIONS

It is well known that the gamma irradiation extends shelf life by controlling the sprouting and rotting without affecting its nutritional value. Basically, it controls sprout in onion by inhibiting the synthesis of endogenous growth promoting hormones. In this study, onion bulbs treated with different dosages of gamma irradiation reveals that the gamma irradiation of 100 Gy shows less moisture loss, physiological weight loss with high marketable yield and total sugars followed by 150 Gy which shows less rotting loss with high sulphur content. Ascorbic acid content which is sensitive to radiation is lesser in irradiated bulbs than the unirradiated bulbs and the protein content was moreover similar in all bulbs at the end of the storage period. From these results, it was confirmed that the Gamma irradiation of 100 Gy should be the best treatment to extend shelf life of onion than the other treatments up to 4 months under ambient conditions with high marketable bulb and minor biochemical changes which does not affect its nutritional qualities.

FUTURE SCOPE

The identified standard dose of Gamma irradiation (100 Gy) in extending shelf life of aggregatum onion may also be used to increase the storage life of other vegetables which may develop the export opportunities in wide range.

Acknowledgement. I extend my sincere thanks to (Dr.) P. Irene Vethamoni and to my advisory committee members for giving me proper guidance throughout the course of study. I also sincerely thank my friends for their support and help through this study.
Conflict of Interest: None.

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How to cite this article: K.R. Krishna Kumar, P. Irene Vethamoni, A. Senthil and H. Usha Nandhini Devi (2023). Effect of Gamma Irradiation on Post-harvest Shelf life and Quality of Aggregatum Onion (*Allium cepa* L. var. aggregatum Don.). *Biological Forum – An International Journal*, *15*(8a): 168-176.