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MODIFIED ATMOSPHERE PACKAGING WITH GAMMA IRRADIATION EXTENDING SHELF LIFE OF STRAWBERRY 'CV' WINTER DAWN

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Abstract

An experiment was carried out at the Postharvest Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period of February to March, 2023 to find the effects of different postharvest treatments on shelf life and quality of strawberry. The experiment was laid out in completely randomized designs with three replications. There were five treatments, viz. T_0: Control (non-irradiated unwrapped), T_1: 2.0 KGy gamma irradiated fruits held in 25µ polypropylene bag, T_2: 2.0 KGy gamma irradiated fruits held in ambient condition, T_3: 2.0 KGy irradiated fruits wrapped in 25µ low-density poly ethylene bag, T_4: 2.0 KGy irradiated fruits wrapped in 25µ high-density poly ethylene bag. Data were recorded on weight loss, firmness, color, flavor, shrinkage, freshness, appearance, diseases severity and shelf life at different days after storage. The minimum weight loss (0.73%) was found in 2.0 KGy gamma irradiated fruits wrapped in 25µ polypropylene bag and the maximum weight loss (3.44%) in untreated control strawberry. The longest shelf life (4.0 days) was recorded in 2.0 KGy irradiated fruits held in 25µ polypropylene bag, fruits and the shortest shelf life (3.0 days) was found in untreated control fruits. The findings would greatly contribute to reducing postharvest loss of strawberry and maintaining their quality during storage and marketing at ambient conditions.

Key words: Strawberry, Gamma irradiation, MAP, Polypropylene, LDPE, HDPE.

Introduction

Strawberry (*Fragaria ananassa* Duch) is a popular and delicious fruit for its flavor, taste, and fresh use. It is a non-climacteric fruit and highly valued as a dessert fruit, and its production in Bangladesh is increasing gradually day by day. The quality of strawberry fruits is largely dependent on various postharvest treatments, which are principally applied to increase their storability. It is essential to understand the physico-chemical changes of strawberries to improve the postharvest quality of the fruits. Preserving non-climacteric fruits involves understanding the factors influencing softening, browning, and microbial growth and developing appropriate handling, temperature control, and packaging strategies. Climacteric fruits exhibit a distinct increase in ethylene production and respiration upon ripening; non-climacteric fruits do not display this characteristic peak, making their postharvest physiology and preservation requirements unique. Recently in Bangladesh, the postharvest losses of fruits and vegetables have been assessed across marketing channels and

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systems for 17-32% (Hassan *et al.*, 2021). Modified atmosphere packaging of fresh products refers to the technique that prolongs the shelf life by modifying the atmosphere within the package. This can be done by controlling the respiration of the product and the gas permeability. Many research studies have been done on different aspects of strawberries in different parts of the world. Although considerable literature dealing with shelf life extension, postharvest loss reduction, and physico-chemical changes during storage and ripening of fruit is available, little work on these aspects of strawberry has been done in Bangladesh. The shelf life and quality properties of these fresh fruits could potentially be maintained by applying Modified Atmospher Packaging (MAP) and active packaging technologies such as ethylene and moisture absorbers and different types of sanitizers (Zheng *et al.,* 2008). This experiment aims to explore existing research on postharvest behavior, physiological changes, and preservation challenges associated with non-climacteric strawberry.

Materials and Methods

The experiment was conducted at the Postharvest Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh. The maximum and minimum temperatures of the storage room were 26.0 and 25.3 °C and the maximum and minimum relative humidities were 65 and 50%, respectively. The temperature and relative humidity of the storage room were recorded with a Digital Temperature-Humidity Recorder (Max-Min thermo Hygrometet and clock, Zeal). The experimental materials were mature and fully ripe strawberry fruits (cv. Winter Dawn). The maturity of strawberry was indicated when the fruit was light red color to red in color. Maturity was also judged by the grower's recommendation. This experiment was conducted during the months of February to March 2023. The experiment comprised the following treatments: T_0: Control (Non-irradiated unwrapped), T_1: 2.0 KGy gamma irradiated fruits held in 25µ polypropylene (PP) bag, T_2: 2.0 KGy gamma irradiated fruits held in ambient condition (unwrapped), T_3: 2.0 KGy gamma irradiated fruits wrapped in 25µ low-density polyethylene (LDPE) bag, T_4: 2.0 KGy gamma irradiated fruits were wrapped in 25µ high-density poly ethylene (HDPE) bag. The single-factor experiment was laid out in a completely randomized design with three replications of three fruits per replication. A total of 45 fruits of more or less similar shape and size were used as experimental materials. The postharvest treatments were assigned randomly to the selected fruits. Experimental strawberry fruits were collected from Moumita Nursery, Mawna, Gazipur and the collected fruits were irradiated by ^{60}Co gamma irradiator at Bangladesh Institute of Nuclear Agriculture (BINA) in BAU Campus, Mymensingh. Data were analyzed using analysis of variance (ANOVA) by Statistix 10 (Version 10.0 Analytical Software USA). The mean value for all the treatments were calculated and ANOVA for all parameters was performed by F-test. Statistically significant differences among the different doses were identified by LSD at the 1% and 5% levels of significance as described by Gomez and Gomez (1984).

Parameters investigated

Estimation of total weight loss (%)

The fruits of each treatment were individually weighed using an electric weighing balance and kept for storage. The percent total weight loss was calculated every day during storage by using the following formula:

$$\text{Weigth loss \%} = \frac{\text{IW} - \text{FW}}{1\text{IW}} \times 100$$

Where,

IW = Initial fruit weight (g); FW = Final fruit weight (g)

Firmness

Strawberry firmness is affected by fruit size, stage of maturity (Schmitz and Lenz, 1985) and is composed of two factors: skin toughness and the firmness of the underlying flesh (Büttner *et al*., 1987). Days required to reach the different stages of firmness during storage and ripening were determined objectively using a numerical rating scale of 1-4, where 1 = Firm, 2 = Sprung, 3 = Soft, and 4 = Overripe.

Freshness

Days required to reach different stages of freshness during storage were determined objectively using a numerical rating scale of 1-4, where 1 = Excellent, 2 = Good, 3 = Fare, and 4 = Poor.

Shrinkage

Days required to reach different stages of shrinkage during storage were determined objectively using a numerical rating scale of 1-4, where 1 = no shrinkage, 2 = slightly shrinked, 3 = moderately shrinked, and 4 = shrinked.

Color

Days required to reach the different stages of color during storage and ripening were determined objectively using a numerical rating scale of 1-3, where 1 = Red, 2 = Deep red, 3 = Rotten/Dark purple.

Flavor

Days required to reach different stages of strawberry flavor during storage were determined objectively using a numerical rating scale of 1-4, where 1 = Excellent, 2 = Slightly odor, 3 = Moderately odor, and 4 = Off odor.

Appearance

Days required to reach different stages of freshness during storage were determined objectively using a numerical rating scale of 1-4, where 1 = Excellent, 2 = Good, 3 = Fare, and 4 = Poor.

Disease severity

Disease severity represents the percent diseased portion of the infested fruit. The infected fruits were selected to determine the percentage of the fruit area infected. The percentage of fruit area diseased was measured based on eye estimation.

Estimation of shelf life

Shelf life is the period of time which starts from harvesting and extends up to the start of the rotting of fruits. The shelf life of strawberry as influenced by different postharvest storage treatments was calculated by counting the number of days required to ripe fully so as to retain optimum marketing and eating qualities.

Results and Discussion

Qualitative evaluations of external and internal characteristics of fruits and storage behavior observed during the period of the study. The data were recorded every day during storage on different characteristics and shelf life of strawberry. The results are presented and discussed in the following heads:

Total weight loss

The data pertaining to the total weight loss (%) of strawberry fruits during storage are presented in (Table. 1). The total weight loss (%) differed significantly over the storage period irrespective of postharvest treatment and modified atmosphere packaging. With respect to the postharvest treatments the lowest total weight loss (0.33, 0.34 and 0.73%) was found in the fruits treated with 2.0 KGy irradiated fruits wrapped in 25µ PP bags followed by 2.0 KGy irradiated fruits were wrapped 25µ LDPE bags (0.44, 0.53 and 0.83%) at 2nd, 3rd and 4th days of storage. The highest total weight loss (11.73, 30.08 and 54.26%) was found in control fruits (without any treatment) at 2nd, 3rd and 4th days of storage. These results are in agreement with other studies showing that perforated plastic bags can be used to reduce shriveling of crops sensitive to water loss after harvest by maintaining high relative humidity around the commodity (Freitas *et al*., 2013).

Firmness

The firmness of the strawberry fruits differed significantly over the storage period irrespective of the postharvest treatment, packaging and their interactions. This could be due to an increase in the rate of physiological processes like transpiration and respiration. This is mainly attributed to continuous moisture and other nutrient loss as fruits are alive (Pila *et al*., 2010). Among postharvest treatments, the minimum firmness score (2.33) throughout the storage period was found in the fruits treated with 2.0 KGy irradiated fruits were wrapped in 25µ PP bags, followed by 2.0 KGy gamma irradiated fruits were wrapped in 25µ LDPE bags (2.67) and the maximum firmness score (4.00) was found in fruits without control fruits at 4th day of storage (Table 1). Our observation was confirmed by Munir and Manzoor (2018) in tomatoes and Throat *et al.* (2018) in custard apples.

Table 1. Effect of postharvest treatments on percent weight loss and firmness of strawberry at different days after storage

Postharvest treatments	Weight loss (%) of fruits at different days after storage (DAS)			Firmness[a] of fruits at different days after storage (DAS)			
	2	3	4	1	2	3	4
T_0	11.73	30.08	54.26	1.00	1.00	2.00	4.00
T_1	0.33	0.34	0.73	1.00	1.00	1.67	2.33
T_2	11.37	26.57	45.28	1.00	1.00	2.00	3.34
T_3	0.44	0.53	0.83	1.00	1.00	1.33	2.67
T_4	0.59	0.70	0.97	1.00	1.00	1.33	3.00
$LSD_{0.05}$	1.08	5.70	14.96	-	-	0.81	0.81
$LSD_{0.01}$	1.54	8.11	21.27	-	-	1.16	1.16
Level of significance	**	**	**	-	-	NS	**

** = Significant at 1% level of probability; * = Significant at 5% level of probability. NS = Not significant.

T_0: Control (without any treatment); T_1: 2.0 KGy irradiated fruits wrapped in 25μ PP bag; T_2: 2.0 K Gy gamma irradiated fruits held in ambient condition; T_3: 2.0 KGy irradiated fruits wrapped in 25μ LDPE bag, T_4: 2.0 KGy irradiated fruits wrapped in 25μ HDPE bags, [a] = Firm scale: 1 = Firm, 2 = Sprung, 3 = Soft, 4 = Over ripe.

Freshness

Among postharvest treatments, the minimum freshness (score: 2.00) throughout the storage period was found in the fruits treated with 2.0 KGy gamma irradiated fruits were wrapped in 25μ polypropylene bag, followed by a freshness score of 2.67 was found 2.0 KGy gamma irradiated fruits were wrapped in 25μ LDPE and HDPE bags at 4th days of storage. While the maximum freshness score (4.00) was found in control fruits. The high relative humidity inside packages may contribute highly to this positive stalk freshness. Reduced dehydration and better condition of stalks were reported also by Harb *et al.* (2006) with cherries stored in MA up to 42 days.

Table 2. Effect of postharvest treatments on freshness and shrinkage of strawberry at different days after storage

Postharvest treatments	Freshness[b] of fruits at different days after storage (DAS)				Shrinkage[c] of fruits at different days after storage (DAS)			
	1	2	3	4	1	2	3	4
T_0	1.00	1.00	2.00	4.00	1.00	1.00	1.67	3.67
T_1	1.00	1.00	1.00	2.00	1.00	1.00	1.00	2.00
T_2	1.00	1.00	2.00	3.00	1.00	1.00	1.33	2.67
T_3	1.00	1.00	1.33	2.67	1.00	1.00	1.33	2.33
T_4	1.00	1.00	1.33	2.67	1.00	1.00	1.33	2.33
$LSD_{0.05}$	-	-	0.66	1.05	-	-	0.94	0.94
$LSD_{0.01}$	-	-	0.94	1.49	-	-	1.34	1.34
Level of significance	-	-	*	*	-	-	NS	*

** = Significant at 1% level of probability; * = Significant at 5% level of probability. NS = Not significant. T_0: Control (without any treatment); T_1: 2.0 KGy irradiated fruits wrapped in 25μ PP bag; T_2: 2.0 K Gy gamma irradiated fruits held in ambient condition; T_3: 2.0 KGy irradiated fruits wrapped in 25μ LDPE bag, T_4: 2.0 KGy irradiated fruits wrapped in 25μ HDPE bags [b] = Freshness scale: 1 = Excellent, 2 = Good, 3 = Fair and 4 = Poor. [c] = Shrinkage scale: 1 = No shrinkage, 2 = Slightly shrinked, 3 = Moderately and 4 = Shrinked.

Shrinkage

The analyses revealed that, among postharvest treatments, the minimum shrinkage score (2.00) throughout the storage period was found in the fruits treated with 2.0 KGy gamma irradiated fruits were wrapped in 25µ PP bag, followed by 2.0 KGy gamma irradiated fruits were wrapped in 25µ LDPE bags at 4^{th} day of storage. While the maximum shrinkage score (3.67) was found in fruits without any treatment at 4^{th} day of storage. Respiration rate increased progressively in individually wrapped fruits while at a higher rate in control fruits, thereafter progressive decline occurred. The higher respiration rate detected in control fruits is in accordance to the results of Mahajan and Brar (2010) could be due to post climacteric decline and skin dryness preventing the exchange of gases. Reduced respiration rate observed in polythene packed fruit, as per previous study could be consequence of O_2 depletion and CO_2 accumulation in pack as polythene prevented the moisture loss, maintained the shrinkage and modified the atmosphere around the fruit (Rana *et al*. 2018).

Flavor

Flavor changes were found to be faster in fruits of the control treatment and also 2 KGy gamma irradiated fruits without bagging. On the other hand, color changes were slower in the fruits treated with 2 KGy gamma radiated fruits were kept in 25µ polypropylene bag. The highest rate of flavor changes was found in the control fruits, also 2 KGy gamma irradiated fruits without bagging (3.00) and slowest rate of flavor changes occurred in fruits under T_1 (1.00), T_3 (1.67) and T_4 (2.00) at the 4^{th} day of storage, respectively. Fruit flavor is mainly represented by the balance between the content of sugars and organic acids (Medlicott & Thompson, 1985), quantified through Soluble Solids/ Titrable Acidity (SS/TA) ratio. The SS/TA ratio increased over storage in all treatments, more markedly in unbagged fruit. These results corroborate with the delayed increase in SS/TA ratio found in mangoes (Vilvert *et al.,* 2022).

Appearance

The external appearance of a fruit is one of its main quality attributes since it plays an important role in the consumer's decision by visual attraction. At 56 days of storage, un-bagged fruit showed the lowest external appearance (4.0), resulting in fruit unacceptable for marketing due to the high presence of decay spots. On the same day, bagged fruit had a very good external appearance. Several factors are associated with changes in the appearance of straeberry after harvest. Among them are the weight loss with consequent wilting and the microbial infection, which results in the early loss of good visual appearance of the fruit (Ricardo *et al*., 2023; Srivastava *et al.*, 2023; Wu *et al*., 2010).

Fruit appearance trended upward with the progress of storage duration. Appearance changes were found to be faster in the fruits of the control treatment. On the other hand, appearance changes were slower in the fruits treated with 2 KGy gamma irradiated fruits kept in a 25µ polypropylene bag. The highest rate of appearance changes was found in the control fruits (4.00) and slowest rate of appearance changes occurred in fruits under T_1 (2.00), T_3 & T_4 (2.67) and T_2 (3.00) at the 4^{th} day of storage, respectively (Table 3).

Table 3. Effect of postharvest treatments on flavor and appearanc of strawberry at different days after storage

Postharvest treatments	Flavor[d] of fruits at different days after storage (DAS)				Appearance[e] of fruits at different days after storage (DAS)			
	1	2	3	4	1	2	3	4
T_0	1.00	1.00	1.67	3.67	1.00	1.00	2.00	4.00
T_1	1.00	1.00	1.00	2.00	1.00	1.00	1.00	2.00
T_2	1.00	1.00	1.67	3.67	1.00	1.00	2.00	3.00
T_3	1.00	1.00	1.33	2.33	1.00	1.00	1.33	2.67
T_4	1.00	1.00	1.33	2.67	1.00	1.00	1.33	2.67
$LSD_{0.05}$	-	-	0.94	0.94	-	-	0.66	1.05
$LSD_{0.01}$	-	-	1.34	1.34	-	-	0.94	1.49
Level of significance	-	-	NS	**	-	-	*	*

** = Significant at 1% level of probability, * = Significant at 5% level of probability;NS = Not significant.

T_0: Control (without any treatment); T_1: 2.0 KGy irradiated fruits wrapped in 25µ PP bag; T_2: 2.0 K Gy gamma irradiated fruits held in ambient condition; T_3: 2.0 KGy irradiated fruits wrapped in 25µ LDPE bag, T_4: 2.0 KGy irradiated fruits wrapped in 25µ HDPE bags[d] = Flavor scale: 1= Excellent, 2 = Good, 3 = Fair and 4 = Poor. [e] = Appearance scale: 1 = Excellent, 2 = Good, 3 = Moderate and 4 = Poor.

Color

Color of strawberry is one of the most important criteria to the consumer for buying the fruits in the markets. During storage period, the color of strawberry changes from light red to dark red. The light red color scores increased as the duration of storage progressed at ambient condition. The fastest rate of color changes was observed in the control treatment, whereas fruits under 25µ polypropylene bag, treatment greatly arrested the color changes from light red to dark red or very dark red color and this result could be attributed to the reduction of physiological processes (ethylene production), an ethylene scavenging compound. The fastest rate of color changes was found in the control fruits, color score (3.0 at day 4) and the slowest rate of color changes occurred in fruits under 25µ poly propylene bag and low density polyethylene bags (2.67) at the 4^{th} day of storage (Table 4). The results are in conformity with the findings by Nunes *et al.* (2006) in strawberry during storage. Similarly, Afifi (2016) found that the color development rate of strawberry increased with increasing maturation but rate of color changes occurred slowly in both MAP and air packaging during storage.

Disease severity

The disease severity of strawberry fruits differed significantly to postharvest treatment, packaging and their interaction during the storage period. Disease severity changes were found to be faster in the fruits of the control treatment. On the other hand, disease severity changes were slower in the fruits treated with 2.0 KGy gamma irradiated fruits kept in a 25µ polypropylene bag. The highest rate of disease severity changes was found in the control fruits (58.33) and slowest rate of color changes occurred in fruits under T_1 (11.67), T_3 (30.0), T_4 (40.0) and T_2 (80.0) at the 4th day of storage, respectively (Table 4). Modified atmosphere packaging (MAP) has been shown to fungal decay in several crops like beans, ponted gourd, bitter gourd (Yahia, 2006). Disease severity in banana fruit was significantly reduced by hot water treatment (50 ± 2°C for 5 min) and fungicide application (prochloraz 250 ppm), and the latter treatment also reduced disease incidence (Hassan *et al.*, 2004). These beneficial effects can be explained by the modified atmosphere created inside the package as well as the reduction in water loss. However, controlled or modified atmosphere storage has not yet been successfully practiced for commercial use with papaya (Ghebrelassie, 2003). The use of modified atmosphere packaging or enhanced CO_2 atmospheres (9-12%) can also maintain the visual quality of rambutans and postharvest diseases also limit the successful marketing and export of this specialty fruit (Yahia *et al.*, 2011).

Table 4. Effect of postharvest treatments on colour and disease severity of strawberry at different days after storage

Postharvest treatments	Color^f of fruits at different days after storage (DAS)				Disease severity (%) of fruits at different days after storage (DAS)			
	1	2	3	4	1	2	3	4
T_0	1.00	2.00	2.00	3.00	0.00	1.67	16.67	58.33
T_1	1.00	1.00	1.00	1.00	0.00	0.00	4.00	11.67
T_2	1.00	1.00	1.00	2.33	0.00	3.00	15.00	80.00
T_3	1.00	1.00	1.00	1.00	0.00	1.33	8.33	30.00
T_4	1.00	1.00	1.00	1.67	0.00	0.00	2.33	40.00
$LSD_{0.05}$	-	0.006	0.006	1.33	-	2.90	10.79	15.04
$LSD_{0.01}$	-	0.008	0.008	1.89	-	4.12	15.35	21.39
Level of significance	-	**	**	*	-	*	*	**

** = Significant at 1% level of probability, * = Significant at 5% level of probability; NS = Not significant.

T_0: Control (without any treatment); T_1: 2.0 KGy irradiated fruits wrapped in 25µ PP bag; T_2: 2.0 K Gy gamma irradiated fruits held in ambient condition; T_3: 2.0 KGy irradiated fruits wrapped in 25µ LDPE bag, T_4: 2.0 KGy irradiated fruits wrapped in 25µ HDPE bags ^{f} = Color scale: 1= Red, 2 = Purple brown, 3 = Dark purple red, 4 = Dark purple brown.

Shelf life

Postharvest treatments exerted significant effects in extending shelf life of strawberry. Among the postharvest treatments, 2.0 KGy gamma irradiated fruits were kept in 25µ polypropylene bag, showed the longest shelf life (4 days) followed by 2.0 kGy gamma irradiated fruits were kept in 25µ low density poly ethylene bag, (3.66 days). However, the shortest shelf life of fruits was recorded in fruits without any treatment and 2.0 kG gamma radiated fruits without bagging (3 days) (Figure 1). The most striking result of the present study was that dramatic extension of shelf life of strawberry, a highly perishable fruit, was achieved at ambient condition when treated with 2.0 KGy gamma irradiation and kept in 25µ poly propylene bag. This could be attributed to lower rate of metabolic activities as polyethylene cover creates modified atmosphere condition and delaying ripening due to irradiation. 25µ polypropylene bag maintains fruit firmness, reduces biochemical changes, delays changes associated with softening, reduces rate of respiration respiratory substrate, and reduces catabolic processes related to senescence (Banothu, 2020). Similar results were also reported by Duan *et al*. (2007). It was observed that untreated fruits kept at ambient condition ripen rapidly within 3 days as compared to all the other treatments. The finding was in conformity with observation by Runkua (2016), Gharezi *et al*. (2012), Atukuri (2017) and Khedkar (1997). Different doses of gamma irradiation (0, 200, 400, and 600 Gy) were applied, and the irradiated mangoes were wrapped in polypropylene (PP) bags of 35µ thickness along with a control treatment to evaluate shelf life and quality at ambient condition observed by Akhther *et al*. (2023).

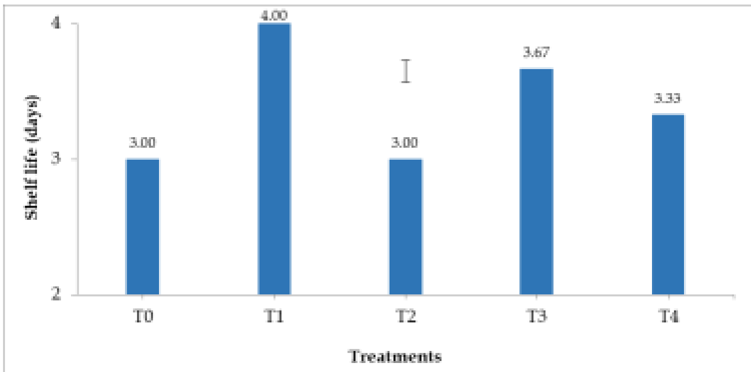

Fig. 1. Effect of postharvest treatments on shelf life of strawberry. The LSD bar represents at 5% level of significance.

T_0: Control (without any treatment); T_1: 2.0 KGy irradiated fruits wrapped in 25µ PP bag; T_2: 2.0 K Gy gamma irradiated fruits held in ambient condition;T_3: 2.0 KGy irradiated fruits wrapped in 25µ LDPE bag, T_4: 2.0 KGy irradiated fruits wrapped in 25µ HDPE bags.

Conclusion

It can be concluded that the result of this experiment will be useful with particular reference to prolong shelf life and maintain better quality of strawberry. Rapid quality deterioration is a major problem in strawberry transport and marketing. And since refrigerators are not available in all the households, especially in the rural and urban areas of Bangladesh, 2.0 KGy gamma irradiated fruits were kept in 25µ polypropylene bags, gave the best result, especially in relation to the reduction of weight loss, disease severity as compared to other treatments and thus ultimately resulted in significantly prolonged shelf life of strawberry. Further studies may be suggested to carry out for further refinement of the technology.

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