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Effect of postharvest application of biocontrol agents on quality attributes and shelf-life of papaya (*Carica papaya* L.)

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Abstract
Efficacy of biocontrol control agents such as *Trichoderma harizanum* UHSBTH15, *T. viridae* UHSBTV9, *Bacillus amyloliquefaciens* UHSBBA9, *B. amyloliquefaciens* UHSBBA10, *B. subtilis* UHSBBS1 and *Cryptococcus albidus* UHSBCA7 on quality attributes and shelf life of papaya cv. Red Lady was evaluated. The fruits harvested at mature green stage with 1-2 yellow streaks on the surface, were washed and treated with respective bio-control agents and stored at ambient storage. Further, various physico-chemical parameters are analysed. Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 provided an effective control in reducing physiological weight loss and% disease index delayed changes in the peel colour maintained firmness, titratable acidity, total soluble solids, β carotene content during 9 days of storage. Fruits treated with B. *amyloliquefaciens* UHSBBA9 also confirm the sensory evaluation along with maximum shelf life of 8.00 days.

Keywords: *Cryptococcus albidus*, *Bacillus amyloliquefaciens*, *Trichoderma harizanum*

Introduction
Papaya (*Carica papaya* L.) is an economically important commercial fruit crop widely cultivated and consumed in the tropical and subtropical regions (Gao *et al*., 2020) [9]. It is a typical climacteric fruit exhibit peak in ethylene production coincides with enhanced rate of respiration leading to ripening of fruits. Fruit ripening is accompanied with rapid loss in firmness, deterioration of fruit quality and development of diseases, which dramatically shorten the shelf life (Paull *et al*., 1997) [20]. The causes for postharvest loss are over ripeness (47.40%), soft fruit (16.70%) and bruise damage (14.80%). However, there is a general agreement that postharvest diseases caused by fungi are the most important problem during handling and storage (Singh, 2010) [28]. The major postharvest fungal infections associated with papaya are *Colletotrichum gloeosporioides* (anthracnose), *Fusarium* spp (Fusarium fruit rot disease), *Alternaria solani* (Alternaria fruit spot), *Rhizopus stolonifer* (Rhizopus soft rot), *Penicillium digitatum* (*Penicillium* rot), *Guignardia* spp. (*Guignardia* spot), *Cercospora papayae* (Cercospora black spot) and stem-end rot disease caused by fungi like *Botryodiplodia theobromae*, *Phomopsis caricae-papayae*, *Mycosphaerella* spp. and *Phytophthora palmivora* (Hewajulige and Wilson Wijeratnam, 2010) [11]. With few exceptions fungal disease symptoms are visible externally and on ripe fruits, thereby reducing the marketability. The application of synthetic fungicides is the primary means of controlling these postharvest diseases (Ma *et al*., 2004) [19]. However, use of these fungicides has been progressively restricted, due to increasing concerns on the protection of the environment and human health, together with increased pathogen resistance to fungicides (Rial-Otero *et al*., 2005) [26].
Biological control of postharvest disease has emerged as an effective non-chemical alternative. Which exploits the activities of one microorganism to control the development of a second microorganism (Fravel, 2005) [7]. In the present investigation biocontrol agents such as *Trichoderma* species, *Bacillus* species and *Cryptococcus albidus* were used. *Bacillus* species produce spores that are resistant to various physical and chemical treatments, such as desiccation, heat, UV irradiation and organic solvents (Leelasuphakul *et al*., 2008) [16] and serve as excellent biological control agents against a wide range of plant pathogens by their production of antibiotics (iturin, surfactin, and fengycin), cell wall-degrading enzymes (chitinase and ß-1, 3 glucanase), and antifungal volatiles (Leelasuphakul *et al*., 2006) [16]

Cryptococcus species have several important properties making them useful for biocontrol purposes. For example, they do not produce mycotoxins or allergenic spores and can utilize a broad range of nutrients (Fredlund *et al*., 2002) [8]. The possible mechanisms for the postharvest yeast antagonists involve their competition with pathogens for limiting nutrients and space, the action of lytic enzymes produced by the yeast and induction of the host resistance to pathogens (Janisiewicz and Korsten, 2002) [13]. The biocontrol mechanisms attributed to *Trichoderma* spp., are competition for nutrients, parasitism, antibiosis, secretion of enzymes, and the production of inhibitor compounds. This biocontrol agent attacks and penetrates fungal cells, causing an alteration with the consequent degradation of the cell wall, causing retraction of the plasma membrane and disorganization of the cytoplasm (Guédez *et al*., 2009) [10]. Thus, this study is aimed to determine the efficacy of biocontrol agents *i.e*., *Trichoderma* species, *Bacillus* species and yeast antagonist *Cryptococcus albidus* in terms of postharvest decay management, quality attributes and shelf life of papaya.

Material and methods

An experiment on effect of postharvest application of biocontrol agents on quality attributes and shelf-life of papaya (*Carica papaya* L.) was carried out at Department of Post-Harvest Technology, College of Horticulture, Bagalkot (UHS, Bagalkot), Karnataka.

Plant material

Mature-green papaya fruit (green with 1 or 2 yellow streaks) were obtained from a local commercial field of Bagalkot district, Karnataka. The cultivar 'Red Lady' fruit of uniform size, shape and maturity and free from any indication of mechanical injury, insect or pathogenic infection were selected for the conducting experiment.

Method of preparation of biocontrol agents

The cultures of biocontrol agents *Trichoderma harzianum* UHSBTH15, *T. viride* UHSBTV9, *Bacillus amyloliquefaciens* UHSBBA9, *B. amyloliquefaciens* UHSBBA9, *B. subtilis* UHSBBS1 and *Cryptococcus albidus* UHSBCA7 were obtained from the Department of Agriculture Microbiology, College of Horticulture, Bagalkot. Further these biocontrol agents were sub-cultured on nutrient agar (NA) and potato dextrose agar (PDA) for bacterial and fungal cultures respectively.

To prepare the aqueous suspension of the antagonist's overnight grown cultures of bacterial antagonists which were grown on NA at 30 °C and the fungus and yeasts cultures grown on PDA at 25 °C for 7 days were used. In case of bacterial isolates 2 loops of each culture were inoculated to 250 ml of nutrient broth in 500 ml conical flasks and incubated on a rotary shaker at 150 rpm for 48 hours and used. Similarly fungal and yeast cultures were grown for 7 days in a BOD incubator at 25±1 °C in potato dextrose broth by inoculation of 5 mm disc of fungi and 2 loop full culture of yeast culture respectively.

Application of treatments

The papaya fruits were treated with respective biocontrol agent's solution supplemented with 0.01% (v/v) Tween 80 sticker solution using a hand sprayer until fruit were wet to runoff. After treatment the fruits were air-dried for 30 minutes at room temperature and stored under ambient condition for further analysis of physico-chemical properties.

Treatment details

T_1	-	Control
T_2	-	*Trichoderma harizanum* UHSBTH15
T_3	-	*T. viridae* UHSBTV9
T_4	-	*Bacillus amyloliquefaciens* UHSBBA9
T_5	-	*B. amyloliquefaciens* UHSBBA10
T_6	-	*B. subtilis* UHSBBS1
T_7	-	*Cryptococcus albidus* UHSBCA7

Determination of physical attributes

Physiological weight loss

For determining the physiological weight loss four fruits in each replication for each treatment were marked before storage, and weighed using an electronic balance. The same fruits were weighed at the beginning of the experiment and at subsequent storage interval. The physiological loss in weight (PLW) and was calculated using formula and results were expressed as the% loss of initial weight.

$$PLW = \frac{\text{Initial weight (g)} - \text{Final weight (g)} \times 100}{\text{Initial weight (g)}}$$

Fruit firmness

The fruit firmness was measured by the TAXT plus texture analyzer (Make: Stable Micro System, Model: Texture Export Version 1.22). Four fruits in each replication were measured. The compression force was measured at the maximum peak of the recorded force on the chart and expressed in Newton (N).

Peel colour

The peel colour of the fruit was determined using a Lovibond colour meter. The peel colour determination was expressed in chromaticity values of L*, a* and b*.

% disease index (PDI)

Disease intensity in different treatments was scored using a 0-4 scale (Pramod *et al.*, 2007) [22].

Extent of infection	Severity grade
No infection	0
0.10-25.0% fruit surface infected	1
25.10-50.0% fruit surface infected	2
50.10-75.0% fruit surface infected	3

% disease index was calculated by using the formula given by Wheeler (1969) [30]

$$PDI = \frac{\text{Sum of all disease rating X 100}}{\text{Total number of ratings X Maximum disease grade}}$$

Shelf life

The shelf life of treated fruits was determined based on visual appearance and the extent of ripening. The over ripen, soft and rotten fruits were considered to be the end shelf life and is expressed in days.

Sensory evaluation

The sensory evaluation was done for the ripe fruits using nine-point hedonic scale for colour and colour and appearance of the fruit surface, pulp colour, texture, taste and flavor and overall acceptability of chemical elicitor treated papaya fruit was determined. The sensory evaluation panel consist of semi-trained judges *i.e*. teachers and post-graduate students of College of Horticulture, Bagalkot.

Determination of chemical attributes

The total soluble solid was measured by using digital refractrometer. Titratable acidity (%) was determined by the titration method (Ranganna, 1986) [24]. Beta carotene (mg/100 gm) was determined by method followed by Ranganna (1986) [24].

Statistical analysis

The data obtained in this experiment was subjected to statistical analysis by ANOVA for a completely randomized design (CRD) with 3 replications. Statistical analysis was performed using Web Agri Stat Package (WASP) Version 2 (Jangam and Thali, 2010) [12]. The level of significance used in the F and t-test was p=0.01.

Results and discussion

Effect of post-harvest application of biocontrol agents on physical attributes of papaya Physiological loss in weight

Physiological loss in weight appeared to be the major determinant of storage life and quality of papaya fruit. With advancement in storage duration the weight loss of fruits increased (Table 1). Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (15.93%), *B. amyloliquefaciens* UHSBBA10 (T_5) (15.97%) and *B. subtilis* UHSBBS1 (T_6) (16.04%) exhibited a declined in PLW compared to untreated fruits (T_1) (20.02%). This was possibly due to decline in ethylene production, respiration rate and maintenance of turgor pressure in *Bacillus* species (Wang *et al*., 2010) [29] treated fruits. The increased PLW of control (T_1) fruits might possibly due to the active metabolism in terms of respiration and transpiration.

Fruit firmness

Fruit firmness is a major attribute that dictates the postharvest life and quality of fruit. Papaya fruit softening occurred with advanced storage duration regardless of treatment. Fruit ripening is a highly coordinated, genetically programmed and an irreversible phenomenon involving a series of physico-chemical changes leading fruit softening (Kaur *et al*. 2014). *Bacillus* species treated fruits *i.e*., *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (26.30 N), *B. amyloliquefaciens* UHSBBA10 (T_5) (24.72 N), and *B. subtilis* UHSBBS1 (T_6) (24.34 N) had recorded maximum fruit firmness in comparison to control (T_1) fruits (10.07 N) at 9 DAS (Table 1). This might possibly due to delayed ethylene synthesis, resulting in delayed rate of ripening and softening (Wang *et al*., 2010) [29]. Similar results are found in papaya (Reshma *et al*., 2018) [25], peach (Arrebola *et al*., 2009) [1]. The enhanced rate of respiration and transpiration could be possible cause for decline in fruit firmness of control (T_1) fruits.

Peel colour (L*, a*, b*)

Colour is one of the major visual attributes of papaya. The change in colour from green to yellow continued with prolonged storage duration.

L* value

The lower L* value was observed in papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (57.45) was significantly on par with fruits treated with *B. amyloliquefaciens* UHSBBA10 (T_5) (57.63), *Trichoderma harizanum* UHSBTH15 (T_2) (58.17), *T. viridae* UHSBTV9 (T_3) (58.28) and *B. subtilis* UHSBBS1 (T_6) (58.88) in comparison to fruits treated with *C. albidus* UHSBCA7 (T_7) (60.94) and control (T_1) (60.60) at 9 DAS (Table 2).

a* value

Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) was found to exhibit minimum a* value with 17.03 was statistically on par with fruits treated with *T. harizanum* UHSBTH15 (T_2) (17.19) and *T. viridae* UHSBTV9 (T_3) (17.94) in comparison to fruits treated with *C. albidus* UHSBCA7 (T_7) (19.34) and untreated fruits (T_1) (20.86) at 9 DAS (Table 2).

b* value

Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (50.41) exhibited minimum b* value was followed by fruits treated with *T. harizanum* UHSBTH15 (T_2) (50.47), *B. subtilis* UHSBBS1 (T_6) (50.89), *B. amyloliquefaciens* UHSBBA10 (T_5) (51.20) and *T. viridae* UHSBTV9 (T_3) (51.30) in comparison to untreated (T_1) fruits (55.46) (Table 2).

Fruits treated with *Bacillus* species and *Trichoderma* species recorded minimum L*, a* and b* value compared to the control (T_1) fruits. This might possibly due to declined ethylene biosynthesis (Wang *et al*., 2010) [29] and consequently delayed ripening and the subsequent colour change. The uncontrolled ripening of control (T_1) fruits might be the possible cause for maximum L*, a* and b* value. Our results are in line with Kavya *et al*. (2018) [15] in papaya fruits.

% disease index

Minimum% disease index (PDI) was observed in fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (13.33%) was followed by *Trichoderma harizanum* UHSBTH15 (T_2) (26.67%) in comparison to control (T_1) (100.00%) (Table 3). The decreased PDI in *Bacillus* species treated fruits might possibly due to competition for space, nutrients and production of antagonistic protein (Qi *et al*., 2005) [23] and induction of defense response against pathogenic micro-organism (Chebotar *et al*., 2015) [4]. The *Trichoderma* species might possibly had promoted the expression of genes *i.e*., chit36, chit42, agn13.1 and gluc78 which correspond to defense enzymes against cellular attack (Singh *et al*., 2018) [28]. In addition, they might possibly had increased the activity of enzymes peroxidase, catalase, β-1,3-glucanase and the concentration of phenolic compounds, related as defense mechanisms against pathogens (Bordbar *et al*., 2010) [3]. Our results are in line with the findings of Prabakar *et al*. (2008) [21] in mango, Reshma *et al*. (2018) [25] in papaya. Maximum PDI of control (T_1) papaya fruits might possibly due to reduced natural defense response.

Shelf life

The shelf life of papaya fruits was significantly influenced by postharvest application of biocontrol agents. Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) recorded maximum shelf life of 8.00 days in comparison to control (T_{10}) (6.00 days) fruits (Table 3). This might possibly due reduced rate of respiration and ethylene production (Wang *et al*., 2010) [29]. Which in turn might had delayed the rate of ripening, lowers the PLW and retains the fruit firmness and in turn enhances the shelf life. On contrary, minimum shelf life observed in control (T_1) fruits might possibly due to the uncontrolled ripening and enhanced rate of senescence.

Sensory evaluation

The papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) had a gloss and no wrinkles, therefore had scored highest of 6.67 for colour and appearance of the fruit surface, 6.60 for pulp colour, 6.70 for texture, 6.50 for taste-flavor and 6.58 for overall acceptability at 9 DAS (Table 4). This may be due to the effect of *B. amyloliquefaciens* UHSBBA9 on retaining the colour (L*, a*, b*), firmness, TA, TSS *etc*. quality attributes with minimum decay incidence. The untreated fruits (T_1) had lost their shelf life of 6 days and thereafter begin to decompose. Therefore these fruits were not presented to the panelists for sensory evaluation. Similar results were reported in peach (Arrebola *et al.*, 2009) [1], papaya (Yadav *et al.*, 2014) [31] and litchi (Jiang *et al.*, 2001) [14].

Effect of post-harvest application of biocontrol agents on chemical attributes of papaya

Titratable acidity

Titratable acidity declined with advancement in storage duration (Table 5). Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (0.21%), *B. amyloliquefaciens* UHSBBA10 (T_5) (0.20%) and *Trichoderma harizanum* UHSBTH15 (T_2) (0.20%) recorded higher TA compared to control (T_1) (0.10%). This might possibly due to reduced respiration and ethylene production (Wang *et al.*, 2010) [29] in these fruits. The results are in line with work of Reshma *et al.* (2018) [25] in papaya, Luo *et al.* (2015) [18] in mango, Chiradej *et al.* (2010) [5] in rambutan. The active metabolic activities and enhanced rate of respiration in control (T_1) fruits might be the possible cause for decline TA.

Total soluble solids

Total soluble solids of papaya fruits enhanced with advancement in storage duration reached peak followed by slight decline (Table 5). This might possibly due to the conversion of starch into soluble forms of sugars and the subsequent decline in TSS is due to rapid utilization of sugars and other organic metabolites during fruit respiration (Reshma *et al.*, 2018) [25]. Similar results were recorded in mango (Barman, 2013) [2]. The fruits treated with *Trichoderma harizanum* UHSBTH15 (T_2) (11.73%), *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (11.67%) and *B. amyloliquefaciens* UHSBBA10 (T_5) (11.63%) had recorded higher TSS in comparison to control (T_1) (10.67%) fruits at 9 DAS. This might possibly due to decline in rate of respiration and ethylene production in the biocontrol agents treated fruits (Wang *et al.*, 2010) [29]. The enhanced rate of respiration of control (T_1) fruits may be the possible cause for lower TSS.

β carotene

The effect of different biocontrol agents on β carotene content papaya fruits was presented in Table 5. Papaya fruits treated with *Bacillus amyloliquefaciens* UHSBBA9 (T_4) (1.67 mg/100 g), *B. amyloliquefaciens* UHSBBA10 (T_5) (1.61 mg/100 g), *B.* subtilis UHSBBS1 (T_6) (1.60 mg/100 g) and *Trichoderma harizanum* UHSBTH15 (T_2) (1.58 mg/100 g) exhibited higher β carotene content compared to control (T_1) (1.05 mg/100 g) at 9 DAS (Table 5). This might possibly due to enhanced carotenoids content during the last phase of the ripening process in biocontrol agents treated papaya (Reshma *et al*., 2018) [25]. The enhanced rate of senescence might had caused tissue disintegration by causing lipid peroxidation at the cellular level, which in turn might had damaged the cell wall leading to oxidation of cell wall constituents and may possibly the cause for minimum β carotene content in the control (T_1) fruits. Similar results were observed in Ekssotika papaya (Rohani and Zaipun, 2001) [27], papaya (Reshma *et al.*, 2018) [25].

Table 1: Effect of biocontrol agent's treatment on changes in physiological loss in weight and fruit firmness of papaya under ambient storage condition

Treatment details	Physiological loss in weight (%)				Fruit firmness (N)			
	1 DAS	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS
T_1- Control	2.56	8.65	13.47	20.02	93.33	61.81	45.98	10.07
T_2 - *T. harizanum* UHSBTH15	1.81	7.76	10.88	18.45	94.36	74.57	54.53	23.05
T_3 - *T. viridae* UHSBTV9	2.11	7.87	11.48	18.77	94.40	72.79	51.74	22.52
T_4 - *B. amyloliquefaciens* UHSBBA9	1.62	6.09	10.21	15.93	93.57	75.23	57.22	26.30
T_5 - *B. amyloliquefaciens* UHSBBA10	1.83	6.45	10.54	15.97	94.28	73.65	50.84	24.72
T_6- *B. subtilis* UHSBBS1	1.85	7.59	10.62	16.04	93.68	73.23	54.35	24.34
T_7 - *C. albidus* UHSBCA7	2.20	8.53	12.66	18.88	93.57	67.58	54.15	15.93
Mean	2.00	7.56	11.41	17.72	93.88	71.27	52.69	20.99
SEm±	0.02	0.08	0.05	0.04	0.16	0.70	0.44	0.37
CD@1%	0.13	0.59	0.39	0.30	NS	5.13	3.23	2.73

Table 2: Effect of biocontrol agents treatment on changes in peel colour (L*, a*, b*) of papaya under ambient storage condition

Treatment details	L*				a*				b*			
	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS
T_1- Control	41.78	50.75	55.19	60.60	-10.86	-6.15	6.29	20.86	21.24	43.88	45.71	55.46
T_2 - *T. harizanum* UHSBTH15	42.22	48.16	49.89	58.17	-10.91	-6.83	5.93	17.19	20.72	41.97	43.30	50.47
T_3 - *T. viridae* UHSBTV9	42.41	49.20	50.92	58.28	-10.89	-6.37	4.31	17.94	20.69	41.15	43.85	51.30
T_4 - *B. amyloliquefaciens* UHSBBA9	41.70	46.67	48.72	57.45	-10.93	-7.01	2.35	17.03	20.17	40.33	41.58	50.41
T_5 - *B. amyloliquefaciens* UHSBBA10	41.43	45.79	49.97	57.63	-10.83	-4.55	3.41	18.57	21.89	41.05	42.16	51.20
T_6- *B. subtilis* UHSBBS1	41.81	46.65	50.55	58.88	-10.85	-4.92	4.60	18.82	21.70	41.83	42.97	50.89
T_7 - *C. albidus* UHSBCA7	42.37	50.96	54.05	60.94	-10.78	-1.64	5.70	19.34	21.89	40.76	42.79	51.69
Mean	41.96	48.31	51.33	58.85	-10.86	-5.35	4.66	18.54	21.19	41.57	43.20	51.63
SEm±	0.18	0.20	0.15	0.22	0.03	0.45	0.12	0.16	0.20	0.26	0.19	0.27
CD@1%	NS	1.48	1.13	1.58	NS	3.28	0.86	1.19	NS	1.93	1.36	1.98

Table 3: Effect of biocontrol agent treatment on changes in% disease index and shelf-life of papaya under ambient storage condition

Treatment details	% disease index (%)	Shelf-life (Days)
T_1- Control	100.00	6.00
T_2 - *T. harizanum* UHSBTH15	26.67	7.67
T_3 - *T. viridae* UHSBTV9	46.67	7.00
T_4 - *B. amyloliquefaciens* UHSBBA9	13.33	8.00
T_5 - *B. amyloliquefaciens* UHSBBA10	30.00	7.67
T_6- *B. subtilis* UHSBBS1	53.33	7.33
T_7 - *C. albidus* UHSBCA7	86.67	6.67
Mean	50.95	7.19
SEm±	3.92	0.15
CD@1%	28.56	1.06

Table 5: Effect of biocontrol agent's treatment on changes in titrable acidity, total soluble solids and β carotene content of papaya under ambient storage condition

Treatment details	Titrable acidity (%)				Total soluble solids (%)				β carotene (mg/100 g)			
	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS
T_1- Control	0.43	0.24	0.21	0.10	7.30	11.50	12.07	10.67	0.46	1.56	2.01	1.05
T_2 - *T. harizanum* UHSBTH15	0.45	0.38	0.35	0.20	7.17	11.40	12.30	11.73	0.47	1.61	1.86	1.58
T_3 - *T. viridae* UHSBTV9	0.43	0.34	0.31	0.15	7.23	11.20	12.23	11.50	0.44	1.58	1.95	1.50
T_4 - *B. amyloliquefaciens* UHSBBA9	0.45	0.39	0.35	0.21	7.20	10.80	12.03	11.67	0.45	1.04	1.80	1.67
T_5 - *B. amyloliquefaciens* UHSBBA10	0.45	0.35	0.34	0.20	7.40	11.00	12.10	11.63	0.44	1.10	1.81	1.61
T_6- *B. subtilis* UHSBBS1	0.43	0.34	0.32	0.13	7.33	11.50	12.00	11.53	0.46	1.06	1.86	1.60
T_7 - *C. albidus* UHSBCA7	0.43	0.30	0.29	0.12	7.40	11.40	12.10	11.20	0.45	1.54	2.00	1.18
Mean	0.44	0.34	0.31	0.16	7.29	11.26	12.12	11.42	0.45	1.36	1.90	1.45
SEm±	0.01	0.01	0.01	0.01	0.08	0.06	0.03	0.08	0.01	0.01	0.02	0.01
CD@1%	NS	0.04	0.04	0.04	NS	0.47	0.18	0.60	NS	0.11	0.17	0.12

Conclusion

It is concluded that the post-harvest application of *Bacillus amyloliquefaciens* UHSBBA9 can extend the shelf life of papaya fruits with better quality traits. The papaya fruits treated with *B. amyloliquefaciens* UHSBBA9 can reduce the physiological loss in weight,% disease index, along with retention of quality parameters such as fruit firmness, total soluble solids, titratable acidity, β carotene content, peel colour (L*, a*, b*) with good score for sensory attributes.

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