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Effect of edible coatings on shelf life of apple ber (*Ziziphus mauritiana* L.) under ambient storage conditions

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Abstract
The present investigation entitled "Effect of edible coatings on shelf life of Apple ber (*Ziziphus mauritiana* L.) under ambient storage conditions" was carried out at College of Horticulture, SKLTSHU, Rajendranagar, Hyderabad during the year 2021-2022. In an attempt to achieve the objective of effect of edible coatings on shelf life of Apple ber (*Ziziphus mauritiana* L.). The experiment was conducted in Completely Randomized Design in four replications with five treatments consisting of three edible coatings *viz*. T_1: *Aloe vera* gel @ 2%, T_2: Chitosan @ 1%, T_3: Guar gum @ 2%, T_4: Garlic extract @ 10% and T_5: Control (without edible coating) in four replications, stored at ambient temperature. The fruits used in all the treatments are stored at ambient conditions and the physical parameters are analyzed daily. Fruits treated with Guar gum @ 2% recorded significantly lowest PLW (13.86%), spoilage (45.72%), and browning score (4.55) and significantly highest fruit firmness (9.51 kg/cm^2), surface colour (1.06) on 12th day, at the end of storage. The highest shelf life (13.08 days) was also seen in fruits treated with Guar gum @ 2% followed by Chitosan @ 1% (12.21 days).

Keywords: Indian mustard, path coefficient analysis

Introduction
Apple ber (*Ziziphus mauritiana*) is a Thailand variety ber and hardy minor tropical fruit, belongs to the family Rhamnaceae. Apple ber is developed by grafting Thailand green apple with Thai local ber. This fruit resembles green apple in its appearance and tastes like ber, hence the name Apple ber. It is also called as Apple plum or Jujube berry. The genus *Ziziphus* comprises about 40 species distributed throughout the tropical and subtropical regions of the world. Among various species, *mauritiana* is commercially cultivated for its nutritive and edible fruits. It is popularly known as poor man's fruit of tropics. In India, Maharashtra was the first state to cultivate Apple ber, later, it was also cultivated in states like Gujarat and Telangana. It is grown commercially in the Telangana districts of Rangareddy, Mahbubnagar, Medak, Warangal, and Khammam. Each fruit weighs between 60 to 150 g. It has an attractive colour and is sweet, crunchy, and juicy. Due to its distinct qualities, such as its thorn less nature, high yield, early crop, ease of cultivation in terms of harvesting, and wider adaptability to grow in any type of soil with less water consumption, farmers are currently showing interest in the cultivation of Apple ber when compared to ber. It can resist harsh summers, heavy rains, strong winds, and harsh winters. The yielding of the plant starts in nine months. Fruits are produced mainly from November to March, with a first crop of 20 to 25 kg per tree, a second crop of about 50 kg per tree, and a yield of 100 to 200 kg per tree produced from third year onwards. The term "edible or surface coatings" refers to a thin layer of substance that covers the fruit's surface and can be consumed along with the fruit as a whole. By acting as a barrier between the fruit surface and the atmosphere, the surface coatings used on fruits helps in increasing their shelf life. *Aloe vera*, Chitosan, Guar gum, and Garlic extract are some of the most widely used edible coatings.

Material and Methods
The experiment was conducted at PG Laboratory, College of Horticulture, SKLTSHU, Rajendranagar, Hyderabad during the year 2021-2022. Rajendranagar falls under arid sub-tropical climatic zone with an average rainfall of 800 mm at an altitude of 542.3 m above mean sea level on 17°20.092' N latitude and 78°24.5144' E longitude.

The experiment was conducted in Completely Randomized Design in four replications with five treatments consisting of three edible coatings *viz*. T_1: *Aloe vera* gel @ 2%, T_2: Chitosan @ 1%, T_3: Guar gum @ 2%, T_4: Garlic extract @ 10% and T_5: Control (without edible coating) in four replications, stored at ambient temperature. Fruits used for research were procured from the orchard in Gudeppad Village Warangal district of Telangana.

Results and Discussion

1. Physiological loss in weight (PLW) (%)

The effect of edible coatings on physiological loss in weight of Apple ber fruits stored at ambient storage conditions at different intervals is presented in the Table 1. The percent PLW values showed an increasing trend from 3rd day to 12 th day during storage. There was a significant difference observed among the treatments with respect to PLW at ambient storage conditions. However, the increase was at a reduced rate in the treated fruits compared to control. On 3rd day, T_3 - Guar gum @ 2% recorded lowest PLW (5.56) followed by T_2 - Chitosan @ 1% (5.92) which was on par with T_4 - Garlic extract @ 10% (6.07) and the highest PLW was recorded in T_5 –Control (8.02). On 6th day, lowest PLW was recorded in T_3 - Guar gum @ 2% (7.85) followed by T_2 - Chitosan @ 1% (8.68) and the highest PLW was recorded in T_5 – Control (11.20). On 9th day, T_5 - Control have shown the end of shelf life and lowest PLW was recorded in T_3 - Guar gum @ 2% (10.18) followed T_2 - Chitosan @ 1% (11.34), while highest PLW was recorded in T_1 -*Aloe vera* gel @ 2% (13.55).On 12th day, T_1 - *Aloe vera* gel @ 2% and T_4 - Garlic extract @ 10% have shown the end of shelf life and among the other treatments, T_3 - Guar gum @ 2% and T_2 - Chitosan @ 1% recorded PLW (13.86) and (14.24) respectively.

Fruits treated with T_3 - Guar gum @ 2% showed the least physiological weight loss during storage when compared to other treatments. This is because guar gum coating lowers the rate of fruit respiration and water loss while acting as a barrier between the fruit surface and the atmosphere. The results of the present study closely resemble those of Ghosh *et al*. (2014) [3], Dutta *et al*. (2016) [2], Bhavana *et al*. (2018) [1], and Shivani *et al*. (2022) [10].

2. Firmness (kg/cm^2)

The data related to the firmness of Apple ber fruits as influenced by the application of edible coatings is presented in Table 2. Firmness of Apple ber fruits showed a decreasing tendency with increase in storage period at ambient conditions. On 3rd day, fruits treated with T_3-Guar gum @ 2% recorded highest firmness (12.52) and followed by T_2 - Chitosan @ 1% (12.03) which was on par with T_4- Garlic extract @ 10% (11.95) and lowest firmness was recorded in T5-Control (10.15). Similar trend was observed on 6th day. On 9th day, T_5 - Control showed end of shelf life and among the other treatments, T_3 -Guar gum @ 2% recorded highest firmness (10.40) followed by T_2 - Chitosan @ 1% (10.07), while least firmness was recorded in T_4 - *Aloe vera* gel @ 2% (9.56). On 12th day, T_1 - *Aloe vera* gel @ 2% and T_4 - Garlic extract @ 10% have shown the end of shelf life and among the other treatments, T_3 -Guar gum @ 2% and T_2 - Chitosan @ 1% were recorded (9.51) and (8.60) respectively. The rate of firmness decreased in treated fruits was slower when compared with control fruits which indicating that the ripening process was hindered. The fruits with the highest firmness may have a low rate of respiration as a result of edible coatings that slowed down the metabolic activity of the fruits, retaining the fruits firmness. The results are in accordance with Bhavana *et al*. (2018) [1] in Apple beras well as those of Sharvani *et al*. (2021) [12] in papaya and Prashanth *et al*. (2022) [7] in dragon fruit.

3. Spoilage (%)

The data pertaining to the spoilage of Apple ber fruits as affected using edible coatings is reported in Table 3. On 3rd day, there was no spoilage observed in T_2 and T_3,while the least spoilage recorded in T_4 - Garlic extract @ 10% followed by T_1 -*Aloe vera* gel @ 2% (8.51) and highest spoilage was recorded in T5- Control (without edible coating) (23.52). On 6th day, lowest soilage was recorded in T_3 - Guar gum @ 2% (8.52) followed by T_2 - Chitosan @ 1% (15.03), while highest spoilage recorded in T_5 - Control (48.26).On 9th day, T_5 - Control have shown the end of shelf life and among the other treatments, lowest spoilage was recorded in T_3 - Guar gum @ 2% (28.32) followed by T_2 - Chitosan @ 1% (35.61), while highest spoilage recorded in T_1 - *Aloe vera* gel @ 2% (48.58) followed by T_4 - Garlic extract @ 10% (45.07).On 12th day, T_1 - *Aloe vera* gel @ 2% and T_4 - Garlic extract @ 10% have shown end of shelf life and among the other treatments, T_3 - Guar gum @ 2% and T_2 - Chitosan @ 1% recorded spoilage (45.72) and (50.21) respectively. The skin of the fruits got affected by the action of bacteria and insect pests, resulting in the decay or spoilage of the fruits, due to the lack of an insulating coating or the ineffective protection by the coatings. Guar gum @ 2% in treatment T_3 was more effective because it maintained a balance between permeability and insulation. Similar outcomes were reported by Mani *et al*. (2017) [4]. The formation of a barrier between the surface of the fruit and the outer atmosphere is aided by edible coating. The results from the current study are closely similar to those from Bhavana *et al*. (2018) [1] in Apple ber, Shivani *et al*. (2022) [10] in guava, and Prashanth *et al*. (2022) [7] in dragon fruit.

4. Shelf life (days)

The data related to the Shelf life of Apple ber fruits treated with edible coatings is presented in the Table 4. Highest shelf life was recorded in T_3 - Guar gum @ 2% (13.08) followed by T_2 - Chitosan @ 1% (12.21), T_4 - Garlic extract @ 10% (11.28) and T_1 - Aloe vera gel @ 2%, (10.52) and lowest shelf life was recorded in T_5 – Control (6.82). Fruits treated with guar gum (2%) had observed highest shelf life because edible coatings reduced shrinkage and retained the freshness of the fruit by reducing moisture, transpiration, and respiration losses. The current findings are in accordance with those of Sandeep and Bal (2003) [9] in ber, Ghosh *et al*. (2014) [3] in tomato, Bhavana *et al*. (2018) [1] in Apple ber, and Sharvani *et al*. (2021) [12] in papaya.

5. Browning (days)

The data related to browning of Apple ber fruits at ambient storage conditions influenced by edible coatings presented in Table 5. Browning score was given according to a scale from 1-5. Browning increased significantly along with the storage period. Lowest browning was recorded in T_3 - Guar gum @ 2%, followed by T_2 - Chitosan @ 1%, and highest browning was recorded in Control, there after shelf life of control fruits ended on 6th day. Browning of fruits was started on 3rd day

stored at ambient temperature. On 3rd day, no browning was recorded in T_2 (0) and T_3 (0) and significantly lowest browning was recorded in T_4 - Garlic extract @ 10% (0.68) which was on par with T_1 - *Aloe vera* gel @ 2% (0.79), while highest browning was recorded in T_5 - Control (2.01). On 6th day, lowest browning was recorded in T_3 - Guar gum @ 2% (0.81) and which was on par with T_2 - Chitosan @ 1% (0.95), while highest browning recorded in T_5 - Control (4.25). On 9th day, T_5 - Control have shown the end of shelf life and among the other treatments, lowest browning was recorded in T_3 - Guar gum @ 2% (2.83) followed by T_2 - Chitosan @ 1% (3.12) and highest browning recorded in T_1 *Aloe vera* gel @ 2% (4.52). On 12th day, T_4 - Garlic extract @ 10% and T_1 - *Aloe vera* gel @ 2% have shown the end of the shelf life and among the other treatments, browning recorded in T_3 - Guar gum @ 2% and T_2 - Chitosan @ 1% was (4.55) and (4.82) respectively. Fruits treated with T_3 - Guar gum @ 2% showed least amount of browning in fruits during storage compared to other treatments. Browning of fruits was little more in *Aloe vera* gel coated fruits compared to other treatments this may be due to *Aloe vera* gel turns brown when kept exposed and even though pectin is added in *Aloe vera* gel it may limit browning only to some extent. Similar findings were observed by Bhavana *et al*. (2018) [1] in Apple ber fruits.

6. Surface colour measurement (DA index)

The effect of edible coatings on surface colour measurement of Apple ber fruits stored at ambient temperature is presented in the Table 6. The surface colour values showed a decreasing trend from 3rd day to12th day at ambient storage conditions. On 3rd day, fruits treated with T_3 -Guar gum @ 2% recorded highest surface colour (1.77) followed by T_2 - Chitosan @ 1% (1.64), while lowest surface colour recorded in T_5 -Control (1.20). Similar trend was observed on 6th day. On 9th day, T_5 - Control have shown the end of shelf life and fruits treated with T_3 -Guar gum @ 2% recorded highest value of surface colour (1.27) followed by T_2 - Chitosan @ 1% (1.15) which was on par with T4 - Garlic extract @ 10% (1.07) and lowest surface colour was recorded in T_1 - *Aloe vera* gel @ 2% (0.86). On 12th day, T_4 - Garlic extract @ 10% and T_1 - *Aloe vera* gel @ 2% have shown the end of shelf life and among the other treatments, T_3 -Guar gum@ 2% and T_2
Chitosan @ 1% recorded surface colour (1.06) and (0.94) respectively. DA metre measures the amount of chlorophyll in a fruit, which in turn determines how ripe it is. As a result of the fruit's absorbent characteristics, the index of absorbance difference (IAD) loses value as the fruit ripens, eventually reaching a very low value. Each cultivar and fruit type has a unique DA value based on the various stages of development Ziosi *et al*. (2008) [11]. According to Medlicott *et al*. (1990) [5], noticed that the decreasing trend in surface colour (DA reading) with the advancement of fruit ripening which may be attributed to decrease in chlorophyll concentration, while carotenoids concentrations increased during fruit ripening. The similar findings with decreasing trend in DA reading with degradation of chlorophyll content was observed in apple by Peter (2011) [6], and in guava fruits by Saharika *et al*. (2021) [8] and Shivani *et al*. (2022) [10].

Table 1: Effect of edible coatings on physiological loss in weight (%) of Apple ber under ambient conditions

Treatment	PLW (%)			
	Days after storage			
	3rd Day	6th Day	9th Day	12th Day
T_1: *Aloe vera* gel (2%)	6.45	10.02	13.55	*
T_2: Chitosan (1%)	5.92	8.68	11.34	14.24
T_3: Guar gum (2%)	5.56	7.85	10.18	13.86
T_4: Garlic extract (10%)	6.07	9.43	12.53	*
T_5: Control (without edible coating)	8.02	11.20	*	*
S.Em±	0.11	0.23	0.26	0.18
CD at 5%	0.33	0.69	0.78	0.56

End of shelf life

Table 2: Effect of edible coatings on firmness (kg/cm^2) of Apple ber under ambient conditions

Treatment	Firmness (kg/cm^2)			
	Days after storage			
	3rd Day	6th Day	9th Day	12th Day
T_1: *Aloe vera* gel (2%)	11.53	10.41	9.56	*
T_2: Chitosan (1%)	12.03	11.10	10.07	8.60
T_3: Guar gum (2%)	12.52	11.58	10.4	9.51
T_4: Garlic extract (10%)	11.95	10.80	9.72	*
T_5: Control (without edible coating)	10.15	8.23	*	*
S.Em±	0.12	0.13	0.11	0.19
CD at 5%	0.37	0.38	0.32	0.56

End of shelf life

Table 3: Effect of edible coatings on spoilage (%) of Apple ber under ambient conditions

Treatment	Spoilage (%)			
	Days after storage			
	3rd Day	6th Day	9th Day	12th Day
T1: *Aloe vera* gel (2%)	8.51	25.02	48.58	*
T2: Chitosan (1%)	0.00	15.03	35.61	50.21
T3: Guar gum (2%)	0.00	8.52	28.32	45.72
T4: Garlic extract (10%)	7.25	22.15	45.07	*
T5: Control (without edible coating)	23.52	48.26	*	*
S.Em±	0.29	0.33	0.34	0.41
CD at 5%	0.88	0.99	1.04	1.25

Table 4: Effect of edible coatings on shelf life (days) of Apple ber under ambient conditions

Treatment	Shelf life (days)
T1: *Aloe vera* gel (2%)	10.52
T2: Chitosan (1%)	12.21
T3: Guar gum (2%)	13.08
T4: Garlic extract (10%)	11.28
T5: Control (without edible coating)	6.82
S.Em±	0.12
CD at 5%	0.37

Table 5: Effect of edible coatings on browning (days) of Apple ber under ambient conditions

Treatment	Browning (days)			
	Days after storage			
	3rd Day	6th Day	9th Day	12th Day
T1: *Aloe vera* gel (2%)	0.79	1.75	4.52	*
T2: Chitosan (1%)	0.00	0.95	3.12	4.82
T3: Guar gum (2%)	0.00	0.81	2.83	4.55
T4: Garlic extract (10%)	0.68	1.52	4.08	*
T5: Control (without edible coating)	2.01	4.25	*	*
S.Em±	0.04	0.06	0.07	0.04
CD at 5%	0.12	0.19	0.21	0.11

End of shelf life

Table 6: Effect of edible coatings on surface colour measurement of Apple ber under ambient conditions

Treatment	Surface colour measurement (DA index)			
	Days after storage			
	3rd Day	6th Day	9th Day	12th Day
T1: *Aloe vera* gel (2%)	1.43	1.17	0.86	*
T2: Chitosan (1%)	1.64	1.44	1.15	0.94
T3: Guar gum (2%)	1.77	1.51	1.27	1.06
T4: Garlic extract (10%)	1.53	1.35	1.07	*
T5: Control (without edible coating)	1.20	0.91	*	*
S.Em±	0.027	0.023	0.032	0.037
CD at 5%	0.081	0.070	0.096	0.112

End of shelf life

Conclusion

On the basis of results observed from the experiment it was concluded that different edible coatings significantly affected the shelf life of Apple ber fruit. T_1: Aloe vera gel @ 2%, T_2: Chitosan @ 1%, T_3: Guar gum @ 2%, T_4: Garlic extract @ 10% and T_5 was taken as Control (without edible coating), stored at ambient temperature. Fruits treated with Guar gum @ 2% recorded significantly lowest PLW (13.86%), spoilage (45.72%), and browning score (4.55) and significantly highest fruit firmness (9.51 kg/cm^2), surface colour (1.06). With respect to experiment, among the different edible coatings, Guar gum (2%) was best in terms of extending shelf life.

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