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Effect of edible coatings for extending shelf life of fig (*Ficus carica*) Cv. brown Turkey at different storage conditions

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Abstract
The present investigation entitled "Effect of edible coatings for extending shelf life of fig (*Ficus carica* L) Cv. Brown Turkey at different storage conditions". The experiment was laid out in completely randomized design with factorial concept with 14 treatments, 3 replications with two factors *viz.*, factor one consists of 7 treatments C1-Guar gum @ 1%, C2- Guar gum @ 2%, C3-Beewax @ 1%, C4-Beewax @ 2%, C5-Corn starch @ 1%, C6-Corn starch @ 2%, C7-Control (without any surface coatings) and factor two includes two storage conditions *i.e.*, S1-Ambient temperature (25 °C), S2-Cold storage (6 °C). Data pertaining to physical parameters were analysed at two days interval and results were summarized below. Fruits treated with Guar gum 2% recorded significantly lowest PLW (10.34%), spoilage (33.30%) and significantly highest firmness (1.81 kg/cm^2), surface colour measurement (0.88) at the end of storage. Among both storage conditions fruits stored in S2-cold storage (6 °C) gave better results with increase of shelf life. In the interaction effects Guar gum 2%+ cold storage (6 °C) is best of all the treatments with shelf life of 10.80 days followed by guar gum 1%+ cold storage 10 days over control + Ambient temperature 2.50 days.

Keywords: Fig, edible coatings, storage conditions, shelf life, guar gum, bee wax, corn starch

Introduction
Fig (*Ficus carica* L.) is native to western Asia and has been cultivated and consumed in the Mediterranean Basin since the earliest stages of the agricultural civilization. Indeed, Turkey, Egypt, Algeria, and Morocco account for 65 percent of the world production. Turkey is the leading Country with 27 percent of world fresh figs and 53 percent of dry figs, accounting for 51 percent of fig fruit world exports (Yilmaz *et al.*, 2015; Allegra *et al*., 2019) [20, 1]. In India, figs are regarded as a minor fruit crop and commercial production of common (edible) figs is primarily restricted to the western regions of Maharashtra, Gujarat, Uttar Pradesh (Lucknow and Saharanpur), Karnataka (Bellary, Chitradurga, and Srirangapatna), and Tamil Nadu (Coimbatore). Telangana also has some commercial production of figs, but it is in a limited amount.
The family Moraceae includes common fig. In the subtropics, it grows to a huge deciduous tree, but in the tropics, it behaves as an evergreen. The branches are asymmetrical, the shoots emerge from the trunk's base and the large, oval leaves have lengthy stalks. The majority of fruits are long stalked, shaped like pears and have a velvety or glabrous skin that is yellow, brown, purple, or black in colour. The botanical term for the multiple fruit known as the fig is a "syconium," which is made up of a hollow receptacle with a small opening at the tip and a lining with countless tiny, little fruits. Fruits like figs are healthful, nourishing, and delicious. Fresh fruit contains peel (15%) and pulp (85%). Figs have several health benefits, including the ability to treat diabetes, cough, bronchitis, piles, indigestion, piles and sexual dysfunction. Numerous healthy nutrients, such as vitamin-A, vitamin-B1, vitamin-B2, calcium, iron, phosphorus, manganese, salt, potassium and chlorine, are present in them. Fresh figs keep well for a few days at 4 to 6 °C and 75 percent relative humidity, but once taken out of storage, they only last one or two days. In fact, different yeasts, fungi, and bacteria, many of which are transferred to the fruits by insects like wasps and vinegar flies, cause rot and surrounding disease, which are the principal postharvest losses in fig fruits. Additionally, some are able to initiate fermentation processes that change the figs' sensory qualities (Paolucci *et al*., 2020) [12].
The fig is a climacteric fruit, so depending upon the stage of ripeness at which it is harvested,

it displays autocatalytic ethylene synthesis and a respiratory upsurge that affects its commercial quality and promotes senescence with typical effects like an increase in the rate of yellowing, increase in microbial growth, induction of physiological disorders, particularly chilling effects and development of unfavourable flavours (Vieira *et al.,* 2021) [20]. Hydrocolloids (polysaccharides or proteins), hydrophobic substances (lipids or waxes), or a combination of both (composite coatings) make up edible coatings, which may improve the coating's handling characteristics (Espino-Diaz *et al*., 2010) [5]. Edible coatings are a potential substitute because they provide no risks from residue (Ergun and Satici, 2012) [4]. Some of the most widely used edible coatings are guar gum, bee wax, corn starch.

Materials and Methods

The experiment was conducted at college of horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendra Nagar, Hyderabad during the year 2021-2022. Fig fruits used for research were procured from the orchard in sangareddy district, Hyderabad. The experiment was laid out in completely randomized design with factorial concept with 14 treatments, 3 replications with two factors *viz.*, factor one consists of 7 treatments C1-Guar gum @ 1%, C2-Guar gum @ 2%, C3-Beewax @ 1%, C4-Beewax @ 2%, C5-Corn starch @ 1%, C6-Corn starch @ 2%, C7-Control (without any surface coatings) and factor two includes two storage conditions *i.e.,* S1-Ambient temperature (25 °C), S2-Cold storage (6 °C).

Results and Discussion

Physiological loss in weight

The data pertaining to physiological loss in weight at different storage conditions as influenced by edible coatings is presented in Table 1. The percent PLW values showed an increasing trend at different storage conditions. There was significant difference observed among the treatments with respect to PLW. The lowest PLW values was recorded in C2-guar gum 2% (5.46%), (9.83%), (6.25%), (8.94%), (10.34%) on 2nd, 4th, 6th, 8th and 10th day of storage respectively. Among the storage conditions S2- cold storage recorded the lowest PLW (3.12%), (6.20%) and highest PLW was recorded in S1-ambient conditions (14.19%), (18.68%) on 2nd and 4th day, respectively. With respect to interactions, lowest PLW was recorded in C2S2 - Guar gum @ 2% + cold storage (1.07%), (3.01%) on 2nd and 4th day respectively. Among all the treatments, guar gum 2% + cold storage showed the minimum loss of physiological weight in fruits during storage compared to other treatments. The reduction in weight loss was probably due to effect of guar gum coating formed as a semipermeable layer, which allows passage of certain small molecules and acting as a barrier to others, and acted as protective barrier to reduce respiration and transpiration on the fruit surface and conferred a physical barrier against O2, CO_2, moisture, and solute movement there by reducing water loss (Ruelas-Chacon *et al*., 2017) [16]. A significant delay in change of weight in tomato fruits by using guar gum as an edible coating was reported by (Ghosh *et al.,* 2014) [6] and Marpudi *et al.* (2013) [9] in fig fruit.

Firmness (kg/cm²)

The results on firmness of fig stored at both cold storage and ambient temperature as affected by edible coatings is depicted in the Table 2. Firmness of fig fruits showed decreasing tendency with increase in storage period. There was significant difference was observed among the treatments with respect to firmness. The highest firmness values was recorded in C2- guar gum 2% (3.40 kg/cm^2), (2.83 kg/cm^2), (2.60 kg/cm^2),(2.25 kg/cm^2),(1.81 kg/cm^2) on 2nd, 4th, 6th, 8th and 10th day of storage respectively. Among the storage conditions S2-cold storage recorded the highest firmness (3.32 kg/cm^2), (2.84 kg/cm^2) and lowest firmness was observed in S1-ambient conditions (2.67 kg/cm^2), (2.12 kg/cm^2) on 2nd day and 4th day of storage respectively. With respect to interactions C2S2 guar gum @ 2% + cold storage recorded significantly highest firmness (3.50 kg/cm^2), (3.20 kg/cm^2) on 2nd and 4th day of storage respectively. Highest firmness was recorded in fruits treated with guar gum (2%). The rate of decline in firmness in coated fruits was slow when compared to control fruits which indicates that the hinderance of ripening process. The decline of hardness was mainly due to the disintegration of the polysaccharides like xyloglucan, cellulose and pectic substances in the cell wall's middle lamella. Guar gum significantly slowed respiration and delayed transpiration (Mani *et al*., 2018) [8]. Low temperatures slow down the metabolic activity of fruits which may leads to highest firmness in fruits. Similar results were obtained by Sophia *et al.* (2015) [18] in mango fruits and Bhowmick *et al.* (2015) [2] in ber fruits.

Spoilage (%)

The Table 3 depicts the results of spoilage of fig fruits as influenced by the edible coatings at different storage conditions. Initially none of the treatments have shown spoilage symptoms except C5–Corn starch 1% and C7-Control shown spoilage symptoms in cold storage-S1, while all the treatments in S1-ambient condition showed spoilage symptoms. Among the storage conditions S2- cold storage recorded the least spoilage (1.98%), (17.46%) while highest spoilage was observed in S1-ambient conditions (29.20%), (39.48%) on 2nd day and 4th day respectively. With respect to interactions least spoilage was noticed in C2S2 -Guar gum @ 2% + cold storage (0), (10.00%), on 2nd and 4th day of storage respectively. Fruits treated with guar gum (2%) and kept in cold storage exhibited the least amount of spoilage during storage compared to other treatments. This may be because of low temperatures cause low ethylene synthesis and respiration rates, and the guar gum coating helps to create a barrier between the fruit's surface and the atmosphere outside. Present results are in close conformity with the findings of Mani *et al*. (2018) [8] in ber fruits. A similar observation was conferred by Marpudi *et al.* (2013) [9] in fig and Prashanth *et al*. (2022) [14] in Dragon fruit.

Surface colour measurement (DA meter)

The data pertaining to the surface colour measurement as influenced by the edible coatings at different storage conditions is presented in the Table 4. DA meter values showed decreasing tendency throughout the storage period. There was significant difference observed among all the treatments with respect to surface colour measurement. The highest surface colour values was recorded in C2- guar gum 2% (1.56), (1.36), (1.35), (1.14), (0.88) on 2nd, 4th, 6th, 8th and 10th day of storage respectively. With respect to the storage conditions S2- cold storage recorded the highest surface colour (1.45), (1.34) and lowest surface colour was observed in S1-ambient conditions (1.14), (0.97) on 2nd day and 4th day respectively. Among interactions C2S2 -Guar gum @ 2% + cold storage recorded significantly highest surface colour (1.68), (1.58) on 2nd and 4th day of storage respectively. The loss of chlorophyll during maturation and ripening is measured with a Differential absorbance metre (Costa *et al*., 2009) [3]. The index of absorbance difference (IAD) decreases in value during ripening by absorbency properties of the fruit, until it reaches very low value, when ripening was complete. According to the various maturation stages, each type of fruit and cultivar has a unique Differential absorbance value (Ziosi *et al*., 2008) [21]. The decreasing trend in Differential absorbance reading with the advancement of ripening may be attributed to the reason that during fruit ripening, chlorophyll concentration decreased significantly, while carotenoids concentration increased (Medlocott *et al*., 1990) [10]. Peter (2011) [13] noticed that decreasing trend in Differential absorbance reading with degradation of chlorophyll content in apple. The results obtained by Lorenzo *et al*. (1999) [7] revealed that the Differential absorbance index allows separation of the fruits in different categories of maturation in Mango. Similar results were demonstrated by Noferini *et al*. (2008) [11] who reported that in Apple, the Differential absorbance was found to be a reliable parameter for monitoring tree apple ripening decreasing index ranges corresponded to increasingly advanced stages of ripening. These findings are in conformity with Prashanth *et al*. (2022) [14] in Dragon fruit.

Shelf life (days)

Shelf life days of fig fruits treated as influenced by edible coatings and different storage conditions is presented in Table 5. C2-Guar gum @ 2% recorded significantly highest shelf life (8.32 days) followed by C1-Guar gum @ 1% (7.72 days) while the lowest shelf life was recorded in C7 Control (3.67 days). Fig fruits treated with Guar gum @ 2% stored in cold storage-C2S2 recorded the highest shelf life of (10.80 days) followed by C1S2-Guar gum 1% +cold storage (10.00 days) and lowest shelf life was recorded in C7S1 -Control + ambient conditions (2.50 days). Among the storage conditions S2- cold storage recorded the highest shelf life (8.21 days) and the lowest shelf life was recorded in S1- ambient conditions (4.76 days). Guar gum 2% coating recorded superior results in maintaining highest shelf life. Guar gum coating retarded transpiration, reduced respiration rate and their by retains freshness of fruits. Sable and Waskar (2020) [17] reported that fig fruits can be stored for 2 days at ambient conditions and Reyes Avalos *et al.* (2019) [15] reported storage period of 15 days at low temperature in fig fruits.

Table 1: Effect of edible coatings on Physiological Loss in Weight (%) of fig (*Ficus carica* L.) Cv. Brown Turkey at different storage conditions

Edible coatings (C)	Physiological loss in weight (%)											
	Storage conditions (S)											
	2nd day			4th day			6th day		8th day		10th day	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	S_1	S_2	S_1	S_2
C1-Guar gum (1%)	10.55	1.25	5.90	16.95	3.95	10.45	*	7.18	*	9.16	*	11.06
C2-Guar gum (2%)	9.85	1.07	5.46	16.64	3.01	9.83	*	6.25	*	8.94	*	10.34
C3-Beewax (1%)	12.72	2.90	7.81	20.04	4.85	12.45	*	10.35	*	11.27	*	*
C4-Beewax (2%)	12.60	2.75	7.68	19.15	4.07	11.61	*	9.44	*	10.55	*	*
C5-Corn starch (1%)	18.56	4.65	10.11	*	10.11	-	*	*	*	*	*	*
C6-Corn starch (2%)	16.14	3.50	9.82	20.66	7.08	13.87	*	10.66	*	*	*	*
C7-Control	18.90	5.75	12.33	*	10.34	-	*	*	*	*	*	*
Mean	14.19	3.12		18.68	6.20			8.77		9.98		10.07

	2nd day		4th day		6th day		8th day		10th day	
	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Factor-1(C)	0.13	0.38	0.16	0.45	0.07	0.19	0.06	0.19	0.04	0.13
Factor 2 (S)	0.07	0.21	0.08	0.24	0.04	0.10	0.03	0.10	0.02	0.07
C×S	0.19	0.54	0.22	0.64	0.09	0.27	0.09	0.26	0.06	0.18

*-End of shelf life S1- Ambient temperature (25 °C) S2-Cold storage (6 °C)

Table 2: Effect of edible coatings on firmness (kg/cm^2) of fig (*Ficus carica* L.) Cv. Brown Turkey at different storage conditions

Edible coatings (C)	Firmness (kg/cm2)											
	Storage conditions (S)											
	2nd day			4th day			6th day		8th day		10th day	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	S_1	S_2	S_1	S_2
C1-Guar gum (1%)	3.12	3.46	3.29	2.37	3.15	2.76	*	2.51	*	2.15	*	1.74
C2-Guar gum (2%)	3.30	3.50	3.40	2.45	3.20	2.83	*	2.60	*	2.25	*	1.81
C3-Beewax (1%)	2.79	3.33	3.06	1.86	2.85	2.36	*	2.34	*	1.87	*	*
C4-Beewax (2%)	2.85	3.41	3.13	2.31	3.04	2.68	*	2.44	*	2.04	*	*
C5-Corn starch (1%)	2.05	3.19	2.62	*	2.51	-	*	*	*	*	*	*
C6-Corn starch (2%)	2.70	3.30	3.00	1.64	2.70	2.17	*	2.09	*	*	*	*
C7-Control	1.86	3.02	2.44	*	2.40	-	*	*	*	*	*	*
Mean	2.67	3.32		2.12	2.84			2.39		2.07		1.77

	2nd day		4th day		6th day		8th day		10th day	
	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Factor-1 (C)	0.033	0.096	0.026	0.075	0.015	0.044	0.004	0.013	0.004	0.014
Factor 2 (S)	0.018	0.051	0.013	0.040	0.008	0.024	0.002	0.007	0.002	0.008
C×S	0.047	0.135	0.036	0.106	0.021	0.062	0.006	0.018	0.007	0.020

Table 3: Effect of edible coatings on spoilage (%) of fig (*Ficus carica* L.) Cv. Brown Turkey at different storage conditions

Edible coatings (C)	Spoilage (%)											
	Storage conditions (S)											
	2nd day			4th day			6th day		8th day		10th day	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	S_1	S_2	S_1	S_2
C1-Guar gum (1%)	18.65	0	9.33	38.16	10.54	24.35	*	17.55	*	29.06	*	39.50
C2-Guar gum (2%)	18.04	0	9.02	35.09	10.00	22.55	*	17.11	*	28.10	*	33.30
C3-Beewax (1%)	33.13	0	16.57	42.17	13.45	27.81	*	29.25	*	36.23	*	*
C4-Beewax (2%)	25.19	0	12.60	38.85	11.33	25.09	*	25.33	*	35.09	*	*
C5-Corn starch (1%)	35.55	0	17.78	*	15.66	-	*	*	*	*	*	*
C6-Corn starch (2%)	33.90	6.66	20.28	43.16	30.33	36.75	*	36.15	*	*	*	*
C7-Control	39.95	7.19	23.57	*	30.94	-	*	*	*	*	*	*
Mean	29.20	1.98		39.48	17.46			25.07		32.12		36.40
	2nd day		4th day		6th day		8th day		10th day			
	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%		
Factor 1(C)	0.22	0.65	0.22	0.65	0.11	0.33	0.21	0.63	0.14	0.41		
Factor 2 (S)	0.12	0.35	0.12	0.35	0.06	0.17	0.11	0.33	0.07	0.21		
C×S	0.32	0.92	0.32	0.93	0.16	0.47	0.31	0.89	0.20	0.58		

Table 4: Effect of edible coatings on surface colour measurement of fig (*Ficus carica* L.) Cv. Brown Turkey at different storage conditions

Edible coatings (C)	Surface colour measurement											
	Storage conditions (S)											
	2nd day			4th day			6th day		8th day		10th day	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	S_1	S_2	S_1	S_2
C1-Guar gum (1%)	1.40	1.64	1.52	1.09	1.53	1.31	*	1.29	*	1.11	*	0.75
C2-Guar gum (2%)	1.43	1.68	1.56	1.14	1.58	1.36	*	1.35	*	1.14	*	0.88
C3-Beewax (1%)	1.27	1.51	1.39	0.88	1.40	1.14	*	1.01	*	0.91	*	*
C4-Beewax (2%)	1.35	1.54	1.45	0.89	1.41	1.15	*	1.15	*	1.05	*	*
C5-Corn starch (1%)	0.82	1.20	1.01	*	1.09	-	*	*	*	*	*	*
C6-Corn starch (2%)	1.02	1.41	1.22	0.85	1.33	1.09	*	0.95	*	*	*	*
C7-Control	0.71	1.15	0.93	*	1.06	-	*	*	*	*	*	*
Mean	1.14	1.45		0.97	1.34			1.15		1.05		0.81
	2nd day		4th day		6th day		8th day		10th day			
	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%		
Factor-1 (C)	0.010	0.030	0.013	0.040	0.006	0.018	0.006	0.019	0.004	0.012		
Factor 2 (S)	0.005	0.016	0.007	0.021	0.003	0.009	0.003	0.010	0.002	0.006		
C×S	0.014	0.042	0.019	0.056	0.009	0.026	0.009	0.027	0.005	0.017		

*-End of shelf life S_1- Ambient temperature (25 °C) S_2-Cold storage (6 °C)

Table 5: Effect of edible coatings on shelf life (days) of fig (*Ficus carica* L.) Cv. Brown Turkey at different storage conditions

Edible coatings (C)	Storage conditions (S)		Mean
	S1- Ambient temperature (25 °C)	S2- Cold storage (6 °C)	
C1-Guar gum (1%)	5.45	10.00	7.72
C2-Guar gum (2%)	5.85	10.80	8.32
C3-Beewax (1%)	5.32	8.32	6.82
C4-Beewax (2%)	5.65	9.50	7.58
C5-Corn starch (1%)	3.05	5.50	4.27
C6-Corn starch (2%)	4.05	8.65	6.35
C7-Control	2.50	4.85	3.99
Mean	4.76	8.21	
	S.Em±	CD at 5%	
Factor 1 (C)	0.07	0.20	
Factor 2 (S)	0.04	0.11	
C × S	0.10	0.28	

Conclusion

From the results it can be concluded that edible coatings and storage conditions had influence on shelf life of fig. Among the treatments C2- guar gum @ 2% was best in terms of shelf life followed by C1-guar gum @ 1%. Among the storage conditions fruits stored in cold storage gave better results with increase in shelf life of fig fruits In interactions C2S_2- guar gum @ 2% + cold storage was best of all the treatments with shelf life 10.80 days followed by C1S_2-guar gum @ 1% + cold storage 10.00 days over C7+S_1-control + ambient temperature (2.50 days).

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