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Chaudhary AD
Department of Fruit Science, ASPEE College of Horticulture & Forestry Navsari Agricultural University, Navsari, Gujarat, India

Attar Sanjay Kumar
Department of Fruit Science, ASPEE College of Horticulture & Forestry Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
Chaudhary AD
Department of Fruit Science, ASPEE College of Horticulture & Forestry Navsari Agricultural University, Navsari, Gujarat, India

Effect of different edible coating materials on physiological changes and shelf life of guava fruits under ambient and zero energy cool chamber storage

Chaudhary AD and Attar Sanjay Kumar

Abstract
Many techniques have been developed over the years to extend the storage life of fruits there by expanding the marketing distances. One such approach is the use of edible coatings which are environment friendly and relatively inexpensive. Edible coatings delay ripening of climacteric fruit, reduce water loss, decay and improve appearance. In this regard an experiment was laid out in completely randomized design with factorial concept with fourteen treatment combinations of coating materials (A1- wax coating 5%, A2-wax coating 10%, A3-rice starch 5%, A4-rice starch 10%, A5-sago 5%, A6-sago 10%, A7-distilled water) and storage condition (T1-ZECC and T2-ambient) for finding the effect of post-harvest coating (wax, rice starch and sago) along with two storage conditions zero energy cool chamber (14.0-20.0 ^{0}C and 84-94% RH) and ambient (9.8-28.5 ^{0}C and 40-73% RH) on physiological attributes of Sardar Guava. Fruits treated with wax emulsion 10 per cent and stored in ZECC (A2T1) recorded least PLW (6.13 per cent), firmness (5.50 Kg/cm^2) and respiratory activity (51.97 ml $CO_2 kg^{-1} hr^{-1}$) at 15th day and exhibited 13.77 days of shelf life.

Keywords: Edible coating materials, zero energy cool chamber, respiration rate, sardar guava, wax, rice & sago starch

Introduction
Guava (*Psidium guajava* L.) has been aptly called the "Apple of Tropics" and is one of the most important subtropical and tropical fruit crops of the world as well as India. In guava, Cv. 'L-49', also known as Sardar is a seedling selection of Allahabad safeda. Guava is a climacteric fruit with relative short storage/shelf life due its rapid ripening process and chilling sensitive nature (Pantastico, 1975) [13]. Fruits need to be disposed of immediately after harvest, it is common experience that 20-25% of the guava fruit is completely damaged and spoiled before it reaches the consumer (Yadav, 1997) [19]. The loss in appearance, taste and texture of fruits is likely to reduce the consumer's acceptability drastically (Yadav *et al*, 2014) [21]. Many techniques have been developed over the years to extend the storage life of fruits there by expanding the marketing distances. One such approach is the use of edible coatings which are environment friendly and relatively inexpensive. Edible coatings can create a modified atmosphere, similar to that of MAP, which is a function of coating permeability and fruit respiration. Edible coatings delay ripening of climacteric fruit, reduce water loss, decay and improve appearance. Another approach directed towards enhancing shelf life is low temperature storage (Yadav *et al*., 2013) [20]. Temperature control is very important since it can affect the rate of fruit respiration. Higher temperatures increase and lower temperatures decrease fruit respiration rates. Low temperature storage has great importance and applicability in tropical and subtropical India but its installation costs are very heavy which may not be economical to the small and marginal farmers. Therefore, it is necessary to develop less expensive methods of storage which are convenient, economical and within the reach of a common grower or trader. In this direction, zero energy cool chamber (ZECC) can play important role since it is on farm, low cost, environment friendly and rural oriented storage structure which operates on the principle of evaporative cooling. In this paper, the results of studies for standardization of protocol for edible and surface coating materials and storage conditions for guava fruits are presented and discussed.

Materials and Methods
The present research work was carried out at Department of Fruit Science, ASPEE college of Horticulture and Forestry, Navsari Agricultural University, Navsari in the year 2011. The experiment was laid out with three coating materials in different concentrations and two storage conditions *i.e.* ambient and ZECC. The Number of treatment combinations were 14 with 3 repetitions and 4kg fruits per repetition were taken. The treatments consisted of factor – I: Coating material (A1-A7) *i. e.* (wax emulsion 5% and 10%, rice starch 5% and 10% sago (Tapioca starch) 5% and 10% and distilled Water) and factor – II: Storage conditions (T1-T2) *i. e.* Zero energy cool chamber and ambient (room temperature). Wax emulsions were procured from M/s. Navdip industries, Ahmedabad and rice starch was prepared as per method described by Manay and Shadaksharaswamy, 1987 [10]. Sago emulsions were prepared as per method described by Jholgiker and Reddy (2007b) [8]. The anthrone reagent method described by Thimmaiah (2006) [17] was adopted for estimation of starch content in rice and tapioca. The fruits were dipped in different concentrations of rice starch, sago and wax emulsion for one minute, dried and stored. The control fruits were dipped in distilled water, dried and stored.

Method of storage
The coated guava fruits were stored in plastic crates in two different storage conditions *i.e.* ambient (room temperature) and zero energy cool chamber (ZECC). The construction of ZECC was made according to method described by Kalia (2006) [9]. The sand was kept moist during the duration of experiment by saturating it four times a day. During the storage period, the following observations were recorded: physiological loss in weight (%) on the first day of treatment and subsequently at alternate days and the loss in weight was expressed as percentage over the initial weight, ripening (%) the fruits showing a colour change from greenish yellow to yellow, having a soft and mealy texture and exhibiting a eating ripeness were counted at alternate day interval and expressed in percentage, decay loss (%) decayed fruits were counted at alternate days of storage and expressed in percentage. Firmness of fruits (Kg/cm^2), the hardness of the fruit was tested by a pocket penetrometer (Italy made, fruit tester, model FT 327), respiration rate (ml $CO_2 kg^{-1} hr^{-1}$) for respiration rate fruits were placed in perplex chamber of known volume connected to Gaspace advance 3 infrared gas analyser (Systech Instruments, Thame, UK). The concentration of CO_2 in the perplex chamber at start and after 1hr was recorded and respiration rate was expressed in ml CO_2 kg^{-1}hr^{-1} and shelf life of fruits (days) the shelf-life was recorded as the days from harvest to a stage when fruits had reached optimum eating stage and after which spoilage was inevitable. The data collected were analyzed statistically by completely randomized design with factorial concept (FCRD) as suggested by Panse and Sukhatme (1967) [12] where the treatment means were compared by means of critical differences at 5% level of probability. The interaction between different coating and storage was also worked out. Depending on the nature of the data the data was transformed in certain instances and then analyzed statistically.

Results and discussion
The suitability period of guava fruits for consumption is reduced due to rapid modifications in their appearance, resulting from intense shrivelling. One of the mechanisms utilized to reduce water loss and increase the storage period of guava is the use of a modified atmosphere by means of adequate packaging or hydrophobic additives on the fruit surface, such as waxes and starches, thus reducing transpiration and respiration rates. Fruits and vegetables coated with wax look better and exhibit improved shriveling control. The physiological loss in weight (%) was measured at alternate day up to the end of shelf life of fruits and data have been presented in table 1 and 2 where significantly minimum physiological loss in fruit weight (%) was observed in treatment wax coating 10% at 3rd and 5th day of fruit storage (0.80 and 2.10%, respectively) which was at par with treatment wax coating 5% at 3rd day and at 5th day of fruit storage (*i.e.* 0.90 and 2.44%, respectively). The highest physiological loss in weight was observed in treatment distilled water at 3th and 5th day of fruit storage (4.39 and 8.34%, respectively). As well as, significantly minimum physiological loss in weight (%) was observed in storage treatment ZECC at 3th and 5th day of fruit storage (1.36 and 2.28%, respectively) than the ambient storage where physiological loss in weight (%) was maximum (2.14 and 5.12%, respectively). In this investigation, treatments having wax coating 10% and ZECC storage condition recorded significantly lower physiological loss in weight up to 13th day of fruits storage constantly (Table 2). This was probably due to the fact that wax seals the stomata on the fruit surface and controls transpiration, respiration and build up a modified atmosphere around the fruits (Dalal *et al*., 1971) [2] and fairly high relative humidity and reduced temperatures prevailing inside the cool chamber (Ganesan *et al.*, 2004) [4] which minimized the process of enzymatic activation, rate of respiration and transpiration from fruit surface (Singh *et al*. 2010) [17]. Similar results were obtained by Thangraj and Irulappan (1988) [16], and Waskar and Gaikwad (2005) [18] with wax coating and ZECC storage in mango, Jat *et al*. (2010) [6] with oil coating in Guava. The highest physiological loss in weight (%) was recorded under treatment combination distilled water + ambient over rest of the treatments during storage. This might be due to water vapour deficit being greater at higher temperatures (Hardenburg *et al*., 1990) [5] thereby, causing more loss of moisture from the epidermal cells through transpiration. These results are in confermity with Jholgiker and Reddy (2007a) [7] with distilled water dip and ambient storage in custard apple. The per cent ripening was observed at alternate day upto the ending of shelf life of fruits and data have been presented in table 1 and 2, where significantly minimum ripening per cent (0.00%) was observed in treatment wax coating 5%, wax coating 10% and sago 10% at 3rd day of fruit storage. Whereas, at 5th day of fruit storage treatment wax coating 10% recorded lowest per cent ripening (6.57%) which was followed by treatment wax coating 5% *i.e.* 14.01% while the highest per cent ripening was observed in treatment distilled water dip at 3th and 5th day of fruit storage (30.15 and 64.60%, respectively). The significantly lower per cent ripening was observed in treatment ZECC at 3th and 5th day of fruit storage (3.17 and 17.42%, respectively) than ambient storage where per cent ripening was higher (11.86 and 33.02%, respectively). Fruits in all treatments ripened in 15 days storage period but ripening was delayed in coated fruits with wax coating 10% and stored in ZECC storage. The lowest ripening rate in wax coating 10% + ZECC might be due to decreased ethylene evolution and reduction in hydrolysis of starch to sugars in fruit tissues by modified atmosphere created with the layer of wax and reduction in evaporation due to low temperature and

high humidity inside the ZECC. These results are in agreement with those of Patel *et al*. (1993) [15] with wax coating in guava and Jholgiker and Reddy (2007a) [7] with wax emulsion and ZECC storage in custard apple. The per cent decay loss was measured at alternate day up to the end of shelf life and data have been presented in table 1 and 2, where per cent decay loss was significantly influenced by various treatments of coating materials. At 3rd day of fruit storage nil/no per cent decay loss was observed in all six treatments of coating material than treatment distilled water dip which shows 15.29 per cent decay loss. At 5th day of storage there was no decay loss in the treatment wax coating 5%, and 10% and sago 10%. While 28.43% fruits decayed in distilled water dip treatment. Besides, significantly lower decay loss was observed in treatment ZECC at 3th and 5th day of fruit storage (*i.e.* 1.80 and 2.97%, respectively) than treatment ambient temperature where per cent decay loss was higher (2.57 and 11.56%, respectively). The minimum decay loss was observed in treatment combination wax coating 10% + ZECC at 15 days of storage (Table 2), which may be due to higher concentration of wax emulsion which prohibited the entry of decay causing organisms and ZECC low temperature which inhibited the occurrence of disease in fruits (Dhaka *et al.*, 2001) [3]. These findings are in accordance with the observation recorded by Jholgiker and Reddy (2007a) [7] with wax emulsion and zero energy cool chamber in custard apple. The higher percentage of decay loss (%) was recorded in distilled water treated fruits at both storage conditions due to direct exposure of fruits to pathogens. The data pertaining to firmness of fruits (Kg/cm^2) are presented in table 1 and 2 where at 3rd day of fruit storage significantly highest firmness was observed in treatment wax emulsion 10%, 11.73 Kg/cm^2 which was followed by wax emulsion 5% (11.15 Kg/cm^2). At 5th day of fruit storage significantly highest firmness was observed in wax emulsion 10% (10.50 Kg/cm^2) which was followed by wax emulsion 5% (9.77 Kg/cm^2). The lowest firmness was observed in distilled water at 3rd and 5th day of fruit storage (8.93 and 6.08 Kg/cm^2, respectively). Significantly higher firmness was observed in ZECC storage at 3th and 5th day (*i.e.* 11.38 and 9.62 Kg/cm^2, respectively) than treatment ambient storage where lowest firmness (*i.e.* 10.09 and 8.19 Kg/cm^2, respectively) was observed. As regard to treatment combinations, the highest firmness was recorded under treatment combination wax coating 10% + ZECC at 15th day of storage. Control of cell wall degradation through retardation of bio-chemical changes and enzymatic activities by higher concentration of wax emulsion and low temperature and high humidity prevailing in ZECC slowed fruit softening, solubilization of cell wall and senescence of fruits. These findings are in conformity with the results obtained by Ahlawat *et al*. (1980) [1] with wax coating in guava and Mann and Randhawa (1978) [11] with wax emulsion in Kinnow mandarin. The data on respiration rate are presented in table 1 and 2, where at 3rd and 5th day of fruit storage significantly minimum respiration rate (ml $CO_2kg^{-1}hr^{-1}$) in fruits was observed in wax emulsion 10% *i.e.* 40.15 and 42.51, respectively amongst all the treatments which was exceeded by treatment wax emulsion 5% *i.e.* 41.37 and 44.08 ml $CO_2kg^{-1}hr^{-1}$). The highest respiration rate (ml $CO_2kg^{-1}hr^{-1}$) was observed in distilled water at 3rd and 5th day of fruit storage (59.10 and 58.82 ml $CO_2kg^{-1}hr^{-1}$, respectively). The resulting data in table 1 indicates that respiration rate was significantly influenced by storage conditions. Significantly minimum respiration rate (ml $CO_2kg^{-1}hr^{-1}$) in fruits was observed in treatment ZECC, *i.e.* 43.43 and 48.99 ml $CO_2kg^{-1}hr^{-1}$, respectively) at 3rd and 5th day of fruit storage and the maximum respiration rate was observed in ambient temperature *i.e.* 47.66 and 52.43 ml $CO_2kg^{-1}hr^{-1}$, respectively. In the present study, higher concentrations of wax emulsion (10%) + ZECC storage reduced the respiration rate in guava fruits. Young *et al.* (1962) [23] speculated that the reduced O_2 might delay the induction of the climacteric by decreasing the available ATP for synthesis. The increased concentration of CO_2 might delay the formation of a particular amino acid necessary for the synthesis of specific enzymes such as polygalacturonose, cellulose, pectin methyl esterase and endo-β-mannanase or might delay the decomposition of an enzyme inhibitor. Similar results were reported by Singh *et al*. (2010) [15] with ZECC storage in ber. The, treatment distilled water dip + ambient storage recorded highest rate of respiration during storage as the water deficit in tissues stimulated ethylene production; as a consequence there was an increase of tissue respiration (Yang and Pratt, 1978) [22]. The data on shelf life of guava fruits are presented in table 1 and 2, where, shelf life was observed significant higher in treatment wax coating 10% (12.83 days) which was followed by treatment wax coating 5% (12.00 days). In distilled water treatment minimum shelf life (7.00 days) of fruits was observed. Consistently, shelf life was significantly higher in ZECC storage, (11.38 days) while the minimum shelf life (9.52 days) was observed in ambient storage. The shelf life was observed significantly maximum in treatment combination wax coating 10% + ZECC storage *i.e.*13.67 days while the water dipped fruits ripened earlier (Table 2). This was a consequence of slow ripening changes like reduced weight loss and other physiological processes. Higher concentration wax emulsion covered the stomatal apertures on the fruit surface and formed a physical barrier to the internal gaseous diffusion into the external atmosphere which prevented transpiration, suppressed initial respiration and decreased the rate of ethylene production. Low temperature with high humidity maintains quality of fruits which leads to prolonged shelf-life in ZECC (Waskar and Gaikwad 2005) [18]. These findings confirm with Thangaraj and Irulappan (1988) [16] and Dhaka *et al.* (2001) [3] with wax coating and ZECC storage in mango and Jholgiker and Reddy (2007a) [7] in custard apple with wax emulsion and ZECC storage treatment.

Table 1: Effect of surface coating materials and storage conditions on physiological attributes of Sardar Guava.

Treatments	PLW (%) on storage days		Ripening (%) on storage days		Decay loss (%) on storage days		Firmness (Kg/cm^2)		Respiration rate (ml $CO_2Kg^{-1}hr^{-1}$)		Shelf life (Days)
	3rd	5th	3rd	5th	3rd	5th	3rd day	5th day	3rd day	5th day	
Coating material (A)											
A1- Wax emulsion 5%	0.90	2.44	0.00 (0.00)	14.01 (5.96)	0.00 (0.00)	0.00 (0.00)	11.15	9.77	41.37	44.08	12.00
A2- Wax emulsion 10%	0.80	2.10	0.00 (0.00)	6.57 (2.59)	0.00 (0.00)	0.00 (0.00)	11.73	10.50	40.15	42.50	12.83
A3- Rice starch 5%	1.64	3.97	8.98 (4.76)*	28.77 (23.73)	0.00 (0.00)	9.28 (5.09)	10.72	8.35	47.63	56.20	9.17
A4- Rice starch 10%	1.61	3.16	7.19 (3.17)	25.22 (18.99)	0.00 (0.00)	6.57 (2.59)	10.83	8.88	44.69	55.54	9.83
A5- Sago 5%	1.50	3.06	6.30 (2.38)	21. 53 (14.56)	0.00 (0.00)	6.57 (2.59)	10.82	9.15	43.57	51.09	10.67
A6- Sago 10%	1.37	2.81	0.00 (0.00)	15.87 (7.68)	0.00 (0.00)	0.00 (0.00)	10.98	9.62	42.31	46.76	11.67
A7 Distilled water	4.39	8.38	30.15(26.20)	64.60 (69.98)	15.29 (7.14)	28.43(23.70)	8.93	6.08	59.10	58.82	6.33
S. Em. ±	0.036	0.052	0.338	0.595	0.000	0.321	0.070	0.069	0.337	0.359	0.178
C. D. At 5%	0.10	0.15	0.98	1.72	0.00	0.93	0.20	0.20	0.98	1.04	0.52
Storage condition (T)											
T1-ZECC	1.36	2.25	3.17 (2.04)	17.42 (11.80)	1.80 (0.68)	2.97 (1.82)	11.38	9.62	43.43	48.99	11.38
T2- Ambient	2.14	5.12	11.86 (8.39)	33.08 (29.20)	2.57 (1.36)	11.56 (7.88)	10.09	8.19	47.66	52.43	9.33
S. Em. ±	0.019	0.028	0.181	0.318	0.00	0.172	0.037	0.037	0.180	0.191	0.095
C. D. At 5%	0.06	0.08	0.52	0.92	0.00	0.50	0.11	0.11	0.52	0.55	0.28
Interaction effect (AxT)											
S. Em. ±	0.050	0.074	0.478	0.842	0.000	0.450	0.099	0.098	0.476	0.506	0.252
C. D. At 5%	0.15	0.21	1.39	2.44	0.00	1.32	0.29	0.28	1.38	1.47	0.73

figures in parentheses are arc sine transformation value.

Table 2: Interaction effect of surface coating materials and storage conditions on physiological attributes of Sardar Guava.

Treatments	PLW (%) on storage days		Ripening (%) on storage days		Decay loss (%) on storage days		Firmness (Kg/cm^2)		Respiration rate (ml $CO_2Kg^{-1}hr^{-1}$)		Shelf life (Days)
	13th*	15th	13th*	15th	13th*	15th	13th*	15th	13th*	15th	
ZECC											
A_1T_1	6.79	**	90.00 (100.0)#	**	36.14 (34.92)	**	5.57	**	52.36	**	12.67
A_2T_1)	4.85	6.13	69.52 (87.74)	90.00 (100.0)	33.58 (30.63)	46.90 (53.33)	6.30	5.50	55.42	51.97	13.67
A_3T_1	**	**	**	**	**	**	**	**	**	**	10.33
A_4T_1	**	**	**	**	**	**	**	**	**	**	11.00
A_5T_1	7.32	**	90.00 (100.0)	**	40.37 (42.06)	**	4.50	**	46.38	**	12.00
A_6T_1	7.16	**	90.00 (100.0)	**	39.00 (39.68)	**	5.43	**	47.43	**	12.33
A_7T_1	**	**	**	**	**	**	**	**	**	**	7.67
Ambient											
A_1T_2	12.37	**	90.00 (100.0)	**	46.90 (53.33)	**	4.17	**	49.15	**	11.33
A_2T_2	11.87	**	90.00 (100.0)	**	42.50 (45.71)	**	5.40	**	52.86	**	12.00
A_3T_2	**	**	**	**	**	**	**	**	**	**	8.00
A_4T_2	**	**	**	**	**	**	**	**	**	**	8.67
A_5T_2	**	**	**	**	**	**	**	**	**	**	9.33
A_6T_2	**	**	**	**	**	**	**	**	**	**	11.00
A_7T_2	**	**	**	**	**	**	**	**	**	**	5.00
S. Em.±	0.123	-	0.448	-	2.349	-	0.047	-	0.334	-	0.252
C. D. at 5%	0.38	-	1.39	-	7.32	-	0.15	-	1.03	-	0.73

***** = Data were analyzed using Complete Randomized Design (CRD).

****** = The fruits were not available for analysis due to complete spoilage.

figures in parentheses are arc sine transformation value.

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