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Waxing, lining and polyethylene packaging on the shelf-life and juice quality of passion fruit during storage

Patel RK*, Singh Akath, Yadav DS, Bhuyan Mousumi, Deka Bidyut C

Division of Horticulture, ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India
*E-mail:patel_rk5@yahoo.co.in

Effect of different combinations of waxing, lining materials and polyethylene packaging on shelf-life and quality attributes of yellow passion fruit (*P. edulis f. flavicarpa* Degener) during storage was studied. Weight loss, decay loss and the chemical changes associated with ripening were monitored during storage for 5 weeks at ambient condition (18-23^{0}C, 58-77% RH). The study revealed that shriveled fruit percentage, physiological weight loss and fruit rotting increased gradually, while juice and ascorbic acid content decreased during storage in all treatments. Paraffin waxed fruits and sealed polyethylene packed fruits had a shelf-life of 5 weeks as compared to 1 week for control (fruits packed in CFB without lining). Decreasing rate in weight loss, rotting percentage and juice content were slow in the fruits coated with solid wax and lined/packed with polyethylene. Acidity decreased during storage in newspaper lining, polyethylene lining and solid wax + polyethylene lining, while other treatments showed the increasing trends. The total soluble solids and ascorbic acid content of juice decreased throughout storage period in all the treatments but the rate of decrease was least in wax coated as well as polyethylene packed fruit. Shriveling was minimum in fruits coated with wax, sealed in polyethylene packaging and the fruits retained the excellent flavour and colour of juice during storage for 5 weeks in the same treatment.

Keywords: Yellow passion fruit, Waxing, Lining, Polyethylene packaging, Shelf-life, Quality

Passion fruit (*Passiflora* sp.) belongs to family Passifloraceae, of which purple (*P. edulis* Sims) and yellow type (*P. edulis f. flavicarpa* Degener) are common. It is a high value crop having export potential due to its juice flavour. This is a native of Brazil and widely cultivated in South Africa, Kenya, East Africa, Australia, New Zealand and Indonesia. In India, it grows wildly in Niligiri Hills, Kodaikanal, Kodagu, Malabar, Kerala and Himachal Pradesh. This crop is gaining popularity in the Northeastern hill States because of its adoptability, easy method of cultivation and higher yield per unit area without much care. Due to its unique and delicate flavour, the fruits are widely used in preparation of beverages, squash and cordials.

Passion fruits are very much prone to shriveling and drying. Fruits start deteriorating immediately after harvest and loose consumer appeal within a short span of 2-3 days of storage. To avoid shriveling and to increase shelf-life, proper packaging is very important. Proper packaging protects the fruit from physical (firmness), physiological (weight) and pathological (decay) deterioration (Zagory and Kader 1988). Out of various packaging materials, use of plastic film is very common for packaging of fruits (Singh Akath et al 2007). Therefore, the present investigation was undertaken to ascertain effectiveness of waxing, lining and polyethylene packaging to enhance the shelf-life of fruit and maintain the juice quality during storage.

Material and methods

The study was conducted in the post-harvest laboratory during 2006. Uniform and well ripened harvested yellow passion fruits were dipped in 500 ppm carbendazim for 2 min to avoid the infection of mould during storage. Surface moisture was removed by keeping the fruits under fan for 30 min. The selected fruits were then subjected to the following treatments.

T1-Newspaper lining, T2 - Solid wax + newspaper lining, T3 - Liquid wax + newspaper lining, T4 - polyethylene trepthalate lining, T5 - Solid wax + polyethylene trepthalate lining, T6 - Liquid wax + polyethylene trepthalate lining, T7 - Sealed polyethylene trepthalate packaging, T8 - Solid wax + sealed polyethylene trepthalate packaging, T9 - Liquid wax + sealed polyethylene trepthalate packaging and T10 - Control.

Polyethylene used for lining and packaging was 0.03 mm thickness. In sealed packing treatments, fruits were kept in each polyethylene trepthalate bags (30 x15 cm) with 6 perforations of 3 mm diameter/bag. In all the treatments, fruits were packed in perforated (6 perforations, 10 mm diameter) corrugated fiberboard boxes (CFB) (40 x 30 x 20 cm) in two rows and 3 layers. CFB boxes were sealed and kept at ambient condition (18-23^{0}C, 58-77% RH). Control fruits were packed in CFB boxes without lining.

The cumulative physiological loss in weight (PLW) of the fruit was determined, on the basis of initial and final weight of the fruit. Cumulative fruit rotting was also recorded, on the basis of initial quantity of the fruits and the number of fruits rotted at periodical interval. Fruits from different treatments were weighed, cut and juice was extracted from the pulp by squeezing and straining through muslin cloth under aseptic condition. The juice obtained was weighed and then measured and the density of the juice was determined from the weight divided by volume of the juice. The total soluble solids (TSS) content was determined with Erma hand refractometer (0-32^{o}Brix). The tritratable acidity, sugar (reducing, sucrose and total sugars) and ascorbic acid content of juice were estimated as per AOAC (2000). The pH of fruit juice was determined by using the pocket pH meter (pH Scan 1, Eutech Instrument, Singapore). TSS/acid ratio was calculated by dividing the TSS value with acidity. The changes in physical appearance of fruit (shriveled fruit %), flavour

and juice colour were determined by visual and sensory evaluation using 10 - point scale.

The experiment was carried out in completely randomized design and each treatment was replicated thrice. Five fruits per treatment were used for estimations and observations were recorded at weekly interval up to 5 weeks of storage. The data were subjected to statistical analysis as per the method of Gomez and Gomez (1984). Least significant difference at 5% level was used for finding the significant differences if any, between the treatment means.

Results and discussion

PLW of fruit gradually increased during storage in all the treatments (Table 1). This could be mainly due to continuous transpiration of moisture from the fruit and respiration. The maximum weight loss (7.1-43.5%) was noticed in T10 (control) followed by T1 (6.3-34.8%) and T3 (4.8-31.9%) during storage. However, it was lower in T8 (3.4%), T5 (6.0%), T7 (6.1%) and T9 (6.8%). Weight loss was negligible in T2, T7, T8 and T9 up to 2 weeks. Minimum weight loss in wax treated as well as polyethylene packed fruits could be due to controlling the moisture loss from the fruit surface by retardation of the process of transpiration and respiration. The present findings are in agreement with the observations by Venkatesha and Reddy (1994) in guava and Joshua and Sathiamoorthy (1993) in sapota.

Fruit rotting also increased during storage (Table 1). This might be due to anaerobic condition, which helped in multiplication of microflora. None of the treatments showed the fruit rotting in the 1st week. However, it was observed in 2nd week in T3 (7.1%), T9 (7.2%) and T6 (14.3%) treatments. No fruit rotting was noticed in T4, T5 and T7 at 3rd week and in T4 even up to 4th week. Minimum cumulative fruit rotting was recorded in T4 (10%), T7 (16.7%) and T5 (23.1%), while it was maximum in T1 (100%) followed by T3, T6 (64.3%) and T10 (53.9%) at the end of storage study. The reduced fruit rotting might be attributed to limited permeability of gases (CO_2 and O_2) and water vapour, which can interplay with physiological processes of fruit (Singh Akath et al 2007). The results of this finding are in consonance with reports of Ben-Yehoshua et al (1999).

Juice content in fruit gradually decreased during storage of fruits in all treatments (Table 2). The maximum loss in juice content was in T1 (16.8%), whereas minimum juice loss was in T4 (6.2%). Wax coating, use of polyethylene lining and packaging reduced moisture loss in fruits due to slowing down of evapo-transpiration rate. Juice density did not differ significantly in the treatments during storage except 2 and 3 weeks (Table 2).

The decreasing trend in acidity was observed during storage in T1, T4 and T5, while other treatments like T2, T3 and T9 up to 4 week, T6 and T7 up to 3 week and T10 up to 2 week showed increasing trends (Table 3). The decrease in acidity might be due to the utilization of available organic acids at faster rate in the respiration during ripening and conversion of acid into sugar. This finding is in accordance with the findings of Gama et al (1991). The increased acidity might be due to slow conversion of sugar into acids or transpiration rate, which increased the concentration of acids. Maximum acid content in passion fruit juice was recorded in T8 (4.5%) and minimum in T4 (3.2%) at the end of storage study (Table 3). Increase in acidity values corresponded with decrease in pH values (Table 3).

TSS content decreased during storage in most of the treatments except T4, T5, T8 and T9, where, TSS was slightly increased up to 2 weeks and decreased subsequently (Table 4). Maximum TSS (15%) was recorded in T9 and minimum (11.8%) in T7 on 5th week. The slight increase in TSS of polyethylene and wax treated fruit could be the reason of sudden influx of C_2H_4, which might have hydrolyzed the starch and other polysac-

Table 1. Effect of wax coating, lining and polyethylene packaging on physiological loss in weight (PLW) and rotting of passion fruit during storage

	PLW, %					Fruit rotting, %				
	Storage period, week					Storage period, week				
	1	2	3	4	5	1	2	3	4	5
T1	6.3	12.5	17.9	28.6	34.8	0	0	46.2	61.5	100
T2	0	0	1.4	2.7	12.5	0	0	16.7	33.3	41.7
T3	4.8	11.1	19.4	31.4	31.9	0	7.1	35.7	50.0	64.3
T4	2.4	4.9	6.3	9.8	13.4	0	0	0	0	10.0
T5	3.6	4.8	4.8	6.0	6.0	0	0	0	7.7	23.1
T6	4.6	7.1	9.3	11.9	21.9	0	14.3	50.0	57.1	64.3
T7	0	0	3.0	6.1	6.1	0	0	0	8.3	16.7
T8	0	0	1.5	1.5	3.4	0	0	7.7	15.4	30.8
T9	0	0	2.8	2.8	6.8	0	7.2	21.5	21.5	35.8
T10	7.1	14.3	21.4	31.9	43.5	0	0	38.5	38.5	53.9
SEm ±	0.84	1.68	2.35	3.71	4.26	0.0	1.57	5.54	6.48	8.15
CD (0.05) (n=3)	2.49	4.99	6.99	11.02	12.66	NS	4.67	16.48	19.26	24.22

NS: Not significant, T1: Newspaper lining, T2: Solid wax + newspaper lining, T3: Liquid wax + newspaper lining, T4: Polyethylene trepthalate lining, T5: Solid wax + polyethylene trepthalate lining, T6: Liquid wax + polyethylene trepthalate lining, T7: Sealed polyethylene trepthalate packaging, T8: Solid wax + sealed polyethylene trepthalate packaging, T9: Liquid wax + sealed polyethylene trepthalate packaging, T10: Control

Table 2. Effect of wax coating, lining and polyethylene packaging on juice content and juice density of passion fruit during storage

Treatment	Juice, %					Juice density, g/cc				
	Storage period, week					Storage period, week				
	1	2	3	4	5	1	2	3	4	5
			36.5*					0.9*		
T1	38.6	37.7	36.4	33.8	21.8	1.0	1.0	1.0	1.0	1.0
T2	38.2	34.5	33.6	29.4	25.2	1.0	1.0	1.0	1.0	1.0
T3	38.3	33.2	33.0	30.5	30.3	1.0	0.9	1.0	1.0	1.0
T4	39.8	35.6	33.7	33.7	33.6	1.0	0.9	1.0	1.0	1.0
T5	40.3	38.2	34.4	32.3	32.1	1.0	1.0	1.0	1.0	1.0
T6	50.7	44.7	42.6	39.3	38.3	1.0	0.9	0.9	1.0	1.0
T7	41.4	39.5	38.0	37.9	28.0	1.0	0.9	1.0	1.0	1.0
T8	43.0	38.3	35.3	33.3	28.7	1.0	0.9	0.9	1.0	1.0
T9	40.7	37.0	35.1	35.1	32.7	1.0	1.0	1.0	1.0	1.0
T10	45.1	40.2	37.3	34.6	28.7	1.1	1.0	1.0	1.0	1.0
SEm ±	1.16	0.97	0.51	0.57	1.07	0.02	0.01	0.02	0.00	0.00
CD (0.05) (n=3)	3.45	2.88	1.49	1.70	3.19	NS	0.03	0.05	NS	NS

* Initial value, NS: Not significant, T1-T10: As in Table 1.

Table 3. Effect of wax coating, lining and polyethylene packaging on acidity and pH of passion fruit juice during storage

Treatment	Acidity, %					pH				
	Storage period, week					Storage period, week				
	1	2	3	4	5	1	2	3	4	5
			5.2*					4.0*		
T1	4.1	4.1	4.0	3.5	3.5	4.5	4.0	4.0	4.1	4.2
T2	3.7	4.4	4.6	4.6	4.4	4.5	3.8	4.0	4.1	4.1
T3	3.1	4.4	5.3	5.3	4.0	4.4	3.8	3.9	4.0	4.1
T4	4.1	3.9	3.5	3.3	3.2	4.4	3.9	4.2	4.2	4.1
T5	5.7	4.6	4.2	4.2	4.1	4.4	3.7	4.1	4.2	3.9
T6	3.3	4.0	4.9	3.8	3.6	4.3	4.0	4.1	4.2	4.0
T7	4.0	4.0	4.2	3.9	3.5	4.3	3.9	4.0	4.3	4.2
T8	3.5	3.7	4.3	4.4	4.5	4.4	3.8	4.1	4.3	4.2
T9	4.0	4.2	4.7	5.1	3.8	4.3	3.9	4.0	4.3	4.2
T10	3.9	4.4	4.0	3.9	3.5	4.2	3.9	4.0	4.4	4.3
SEm ±	0.21	0.08	0.15	0.21	0.13	0.03	0.02	0.02	0.04	0.03
CD (0.05) (n=3)	0.63	0.25	0.46	0.62	0.39	0.09	0.08	0.08	0.11	0.10

* Initial value, T1-T10: As in Table 1

charides such as pectin into simple sugars. Decrease in TSS after 2nd week might be due to utilization of sugars in the process of respiration. TSS to acid ratio of juice decreased during storage (Table 4). Maximum TSS to acid ratio was recorded in T3 (5.2) at one week and maximum in T9 (4.0) at 5th week.

Ascorbic acid content decreased throughout storage period in all the treatments (Table 5). Wax treated as well as polyethylene packed fruits maintained higher ascorbic acid content than untreated fruits. Higher ascorbic acid in wax and polyethylene packed fruits might be due to low rate of physiological process accompanied by lower respiration and transpiration losses. These findings are also in accordance with the findings of Rao and Murthy (1983) in Coorg mandarin and Cereda et al (1984) in passion fruit.

Slight increase in reducing sugar content of fruit was noticed up to 2nd week and later on continuous reduction up to 5th week in all treatments except T2, T3, T7 and T8 (Table 5) where, it gradually increased in T2 and decreased in T3, T7 and T8 since Ist to 5th week. The maximum reducing sugar content was in T2 (5.9%) and minimum in T1 (2%) at 5th week after storage. The increase in reducing sugar might be due to hydrolysis of polysaccharides. Slight decline in sucrose content was observed during storage in all treatments (Table 6). However, it was found maximum in T2 (7.3%) and minimum in control T10 (4.3%) at 5th week. Decline in sucrose content during storage might be due to conversion of non reducing sugar into reducing sugar. The maximum total sugars content was in T2 (13.2%) and minimum in T10 (7.1%) at the end of storage (Table 6).

Data presented in Table 7 reveal that none of the fruits shriveled in T9 (Liquid wax + Sealed polyethylene packaging) till end of storage, whereas, in other treatments the % shriveled fruits increased

Table 4. Effect of wax coating, lining and polyethylene packaging on total soluble solids (TSS) and TSS: acid ratio of passion fruit juice during storage

Treatment	TSS, %					TSS: Acid ratio				
	Storage period, week					Storage period, week				
	1	2	3	4	5	1	2	3	4	5
			15.8*					3.1*		
T1	16.0	15.6	15.5	14.8	12.2	3.9	3.8	3.9	4.2	3.5
T2	16.0	15.9	15.8	14.0	13.8	4.4	3.7	3.4	3.0	3.0
T3	16.4	16.0	15.8	14.6	14.0	5.2	3.6	3.0	2.8	3.5
T4	15.8	16.3	14.0	14.0	12.2	3.9	4.2	4.0	4.3	3.8
T5	15.0	16.7	14.2	14.2	13.8	2.6	3.6	3.4	3.4	3.4
T6	15.6	15.6	14.6	13.8	12.8	4.8	3.9	3.0	3.7	3.6
T7	15.0	14.0	13.4	13.0	11.8	3.8	3.5	3.2	3.6	3.3
T8	15.6	16.0	15.6	15.0	14.0	4.4	4.3	3.6	3.4	3.1
T9	15.0	16.5	15.4	15.4	15.0	3.7	3.9	3.3	3.0	4.0
T10	15.0	14.8	14.8	13.2	12.1	3.9	3.4	3.7	3.4	3.4
SEm ±	0.15	0.32	0.25	0.23	0.32	0.21	0.09	0.10	0.15	0.09
CD (0.05) (n=3)	0.46	0.94	0.76	0.68	0.97	0.63	0.26	0.31	0.44	0.27

* Initial value, T1-T10: As in Table 1

Table 5. Effect of wax coating, lining and polyethylene packaging on ascorbic acid and reducing sugar of passion fruit juice during storage

Treatment	Ascorbic acid, mg/100 ml juice					Reducing sugar, %				
	Storage period, week					Storage period, week				
	1	2	3	4	5	1	2	3	4	5
			28.5*					5.5*		
T1	26.2	18.1	16.2	10.2	7.2	4.6	5.1	4.3	3.6	2.0
T2	27.9	17.6	12.2	12.5	10.2	4.2	4.4	4.9	5.3	5.9
T3	27.9	18.1	17.9	16.2	12.2	6.7	6.0	5.0	4.8	3.9
T4	21.3	15.3	15.2	14.1	11.8	5.6	6.8	4.8	4.6	4.2
T5	32.8	22.2	21.3	17.6	9.0	4.8	5.2	5.2	4.8	4.3
T6	20.9	19.7	16.2	15.4	10.4	5.2	5.4	4.8	4.8	3.4
T7	19.8	18.0	11.8	11.1	9.0	6.0	4.6	4.6	4.4	4.4
T8	23.0	19.1	18.2	17.9	12.5	6.0	5.6	5.5	5.5	3.9
T9	24.6	21.3	17.9	15.3	13.2	5.8	5.9	5.7	5.4	4.1
T10	16.6	16.4	13.2	9.7	7.2	5.1	5.2	4.4	4.0	2.8
SEm ±	1.43	0.63	0.90	0.89	0.65	0.23	0.21	0.13	0.19	0.31
CD (0.05) (n=3)	4.24	1.87	2.68	2.65	1.92	0.67	0.63	0.40	0.55	0.91

* Initial value, T1-T10: As in Table 1

Table 6. Effect of wax coating, lining and polyethylene packaging on sucrose and total sugars content of passion fruit juice during storage.

Treatment	Sucrose, %					Total sugars, %				
	Storage period, week					Storage period, week				
	1	2	3	4	5	1	2	3	4	5
	6.7*	12.2*								
T1	8.0	7.9	6.1	3.5	7.0	12.5	13.0	10.4	7.0	9.0
T2	7.1	5.4	5.3	5.6	7.3	11.3	9.8	10.2	10.9	13.2
T3	7.7	5.2	7.7	6.6	4.8	14.4	11.2	12.6	11.3	8.6
T4	5.9	7.2	6.8	6.3	5.3	11.5	14.0	11.6	10.8	9.5
T5	6.9	6.8	6.8	6.3	5.3	11.7	11.9	11.8	11.0	9.6
T6	6.8	6.0	5.4	5.4	4.4	11.9	11.4	10.2	10.2	7.8
T7	6.3	5.8	5.7	4.4	5.1	12.2	10.4	10.3	8.8	9.4
T8	6.3	6.4	6.2	6.1	5.2	12.3	11.9	11.7	11.6	9.2
T9	6.2	5.4	7.6	4.4	5.8	12.0	11.2	13.3	9.9	9.9
T10	6.7	5.1	5.8	5.0	4.3	11.8	10.3	10.1	9.0	7.1
SEm ±	0.19	0.28	0.26	0.30	0.29	0.26	0.38	0.35	0.43	0.48
CD (0.05) (n=3)	0.59	1.86	0.76	0.90	0.89	0.76	1.13	1.03	1.27	1.42

* Initial values, T1-T10: As in Table 1

Table 7. Effect of wax coating, lining and polyethylene packaging on physical appearance, juice colour and flavour of passion fruit during storage

Treatment	Storage period, week														
	1			2			3			4			5		
	SH, %	JC	JF	SH, %	JC	JF	SH, %	JC	JF	SH, %	JC	JF	SH, %	JC	JF
T1	43.8	Orange	10	87.5	Orange	10	100	Orange	9	100	L.orange	6	100	L.orange	6
T2	6.7	Orange	9	6.7	Orange	9	6.7	Orange	9	8.3	L.orange	9	15	L.orange	8
T3	25	Orange	10	68.8	Orange	10	100	Orange	9	100	Orange	8	100	L.orange	7
T4	6.3	Orange	10	25	Orange	10	35.7	Orange	9	46.2	Orange	9	90.9	Orange	9
T5	0	Orange	9	0	Orange	9	0	Orange	9	8.5	Orange	8	15.4	Yellow	7
T6	0	Orange	10	6.3	Orange	10	28.6	Orange	9	50	Orange	8	55.0	L.orange	8
T7		Orange	10		Orange	10	6.7	Orange	9	8.3	Orange	9	12.5	Orange	8
T8	0	Orange	10	0	L.orange	10	0	L.orange	10	6.5	Yellow	9	10	Yellow	8
T9	0	L.orange	9	0	Orange	9	0	Orange	9	0	Orange	9	0	L.orange	8
T10	43.8	L.orange	9	87.5	Orange	9	100	L.orange	7	100	L.orange	7	100	Yellow	6

SH: Shriveled fruits, JC: Juice colour, JF: Juice flavour scores, L.orange : Light orange T1-T10: As in Table 1

during storage. Fruits treated with wax, sealed polyethylene packaging with and without wax showed minimum shriveled fruits (0-15%). This might be due to less loss of moisture from fruit surface through transpiration. Newspaper lining (T1) and control (T10) showed 100% shriveling at the end of 5 weeks storage. Initially, all the treatments retained the orange colour in juice but later on juice became light orange and yellow in colour at the end of storage. Fruits treated with T4 and T7 retained orange colour till the end of the storage, whereas, T1, T2, T3, T6 and T9 had light orange and T5, T9 and T10 had yellow colour at the end of storage. Under all treatments juice retained good flavour during storage and secured points > 9 except T10 (control) that got 7 point up to 3rd week and then decreased till the end of storage (Table 7).

It can be concluded that shelf-life of yellow passion fruit may be extended up to 5 weeks with good colour, appearance and quality by treating the fruit with wax and packaging in perforated polyethylene (0.03 mm).

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