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Influence of coating and packaging material on physicho-chemical characters and shelf life of custard apple (*Annona squamosa* L.)

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Abstract
Present investigation to study the influence of coating and packaging material on physico-chemical characters and shelf life of custard apple (*Annona squamosa* L.) cv. Balanagarframed in Factorial Completely Randomized Design (FCRD) with twelve treatments and three replications was during conducted during 2018. The experiment comprised of two factors namely coating (with and without wax coating) and 50 µ low density polyethylene bags (with 0.5%, 1%, 1.3% and 2% perforation, without perforation) and Punnet box. Matured fruits of uniform size, firm, free from pest, diseases and injuries were selected. For coating, fruits were dipped in aqueous solutions of bees wax for 5 minutes and dried for 30 minutes at room temperature. According to the treatment, fruits were packed in polyethylene bags and punnet and observation on changes in physic-chemical characters during storage on2nd, 4th, 6th, and 8th day and shelf life were recorded. Results revealed that there was significant impact of interaction among wax coating and packaging material on all parameters studied. When considered interaction, the treatment C_2P_5i.e. fruits coated with wax and packed in 50 µ low density polyethylene bags without perforation, had maximum TSS, total sugars, and minimum reduction of moisture per cent. This treatment registered the highest TSS (25.05 ^{0}Brix), total sugar (22.24%), least reduction in moisture (77.26%) and shelf life of 8 days. Overall results indicated the wax coating and packaging of custard apple fruits in 50 µ polyethylene bags (without perforations) improved the shelf life and at the same retained quality of fruits and the treatment combination C_2P_5i.e. fruits coated with wax and packed in 50 µ low density polyethylene bags without perforation was found to be promising.

Keywords: Custard apple, wax coating, packaging materials, punnet, shelf life

Introduction
Custard apple is one of the most delicious and highly perishable fruit. It has its delightful taste, flavour, moderate price in markets and a high nutritional status. Being climacteric fruit, ripening of custard appleis characterized by high respiration and high ethylene production rates which makes it highly perishable (Pareek *et al.* 2011) [18]. Extension of shelf life in custard apple would make its handling easy and will reduce losses after harvesting. As custard apple cannot be stored in cold storage, coating and packaging seems to be more promising options to retain its quality as well as increase shelf life. Use of coating has gained importance in reducing the moisture loss and maintaining firmness (Farooqi *et al.* 1988; Chauhan *et al.* 2005) [8, 3]. In many fruits, packaging with the polyethylene is found promising (Rao and Chundawat, 1987) [20]. Apart from being economical, polyethylene packages also fulfill all the functions necessary for protection and distribution (Rana, 2006) [19].

Material and Methods
The experiment was conducted with Factorial Completely Randomized Design (FCRD) with twelve treatments and three replications. There were two factors viz. Factor I was Coating (C_1- without wax and C_2- with wax) and Factor II was Packaging consisting of treatments namely P_1 – 50 µ LDPE bags with 0.5% perforation, P_2– 50 µ LDPE bags with 1% perforation, P_3– 50 µ LDPE bags with 1.3% perforation, P_4 – 50 µ LDPE bags with 2% perforation, P_5– 50 µ LDPE bags without perforation and P_6 – Punnet box. Matured fruits of uniform size, firm, free from pest, diseases and injuries were selected. Such fruits were coated with bee wax. For applying wax treatment, fruits were dipped in aqueous solutions of bees wax for 5 minutes and dried for 30 minutes at room temperature. According to the treatment, fruits then were packed in 50 µ low density polyethylene bags and Punnet box.

The observations were recorded on TSS, total sugars, reducing sugars, moisture per cent and Postharvest loss in weight (%) 2nd, 4th, 6th and 8th day of storage.

Results and Discussions

Fruit weight (g)

Wax coating and packaging materials had a significant effect on fruit weight and a gradual reduction in fruit weight was observed with the advancement of storage in all the treatments. As regards the wax coating, though non-significant results were observed during initial day of storage, coating significantly influenced fruit weight on 2nd, 4th, 6 th and 8th day of storage. The minimum reduction in fruit weight was found in C_2**(**wax coating) *i.e.* 164.96, 161.29, 157.84 and 151.35 g on the initial, 2nd, 4th, 6th and 8th day, respectively, while maximum reduction in weight was observed in C_1 (without coating) and it was163.32, 159.23, 156.56 and 148.64 g on the 2nd, 4th, 6thand 8th day, respectively. As regards the packaging materials, the minimum fruit weight reduction was observed in the treatment P_5 in (50 µ LDPE bags without perforations) and it was 169.74, 166.21, 162.40, 159.58 and 154.26 g, whereas maximum in P_4 (50 µ LDPE bags with 2% perforation) which was 163.12, 161.27, 157.95, 154.73 and 145.03 g on the initial, 2nd, 4th, 6th and 8th day of storage, respectively.

The interaction effect of wax coating and packaging materials on fruit weight of custardapple was found to be non-significant on initial day of storage, but on 2nd, 4th, 6th and 8th day of storage, the interaction effects were significant. The minimum fruit weight reduction wasobserved in C_2P_5(Fruit treated with wax coating and packed in 50 µ LDPE bags without perforation) which was 166.61, 163.67, 160.19 and 155.58 g on the initial, 2nd, 4th, 6th and 8th day of storage, respectively. The maximum fruit weight reduction was recorded in C_1P_4(without wax coating and packed in 50 µ LDPE bags with 2% perforation) and was 160.81, 156.25, 153.94 and 142.55 g on the 2nd, 4th, 6th and 8th day of storage, respectively. Per cent reduction of fruit weight was less in the treatment C_2P_5 (92.00%) and more per cent reduction was observed in C_1P_4 (88.07%). Results are in agreement with Patel *et al.* (2011) [17] and Masalkar and Garande (2005) [14] in custard apple. Similar results were also reported by Nuzba *et al.* (2006) [16] in mango. Maximum loss of fruit weight in untreated fruits may be due to metabolic changes occurring which affect the transpiration and respiration rate of fruit as compared to treated fruits. Minimum loss in treated fruits due to the slower the rate of ripening due to coating and packaging materials.

Total Soluble Solid (TSS) (^{0} Brix)

As revealed from Table 1, maximum TSS was recorded in the treatment combination C_2P_5 (fruit treated with wax coating and packed in 50 µ LDPE bags without perforation) and it was 25.07, 26.03, 27.47 and 28.23 ^{0}Brix, followed by fruit treated with wax coating on 2nd, 4th, 6th and 8th day of storage, respectively. It was followed by the treatment combination C_2P_6 (Punnet box) recording 24.90, 25.77, 27.13 and 28.07 ^{0}Brix TSS on the 2nd, 4th, 6th and 8th day of storage, respectively. On 2nd day C_2P_5 and C_2P_6 were at par with each other than rest of the treatments. On 4th and 6th day $C_2P_5$was superior to other treatments. On 8th day C_2P_5 and C_2P_6 was at par with each other than the rest of the treatments. The minimum TSS of 23.63, 24.03, 25.43 and 26.07 ^{0}Brixwas recorded in C_1P_4 *i.e.* without wax coating and packed in 50 µ LDPE bags with 2% perforation on the 2nd, 4th, 6th and 8th day, respectively. Results are in agreement with Ingawale and Jadhav (2005) [9], Kad (2014) [13], Venkatesha and Reddy (1994) [24] and Jholgiker and Reddy (2007) [12] in custard apple.

The increase in TSS could be attributed to the breakdown of starch (Beaudry *et al.*, 1989) [1] into sugars (Crouch, 2003) [5] or the hydrolysis of cell wall polysaccharides (Ben and Gaweda, 1985) [2].

Total sugars (%)

Significantly, the maximum total sugars (Table 2) of 24.97, 26.87, 28.25 and 24.01% was observed in the treatment combination C_2P_5 *i.e.* fruit treated with wax coating and packed in 50 µ LDPE bags without perforation on 2nd, 4th, 6th and 8th day of storage, followed by fruits with wax coating and packed in Punnet box *i.e.* C_2P_6 and it was 24.55, 26.42, 27.26 and 23.65% on the, respectively. On 2ndand 4thday C_2P_5 and C_2P_6 were at par with each other than rest of the treatments. On 6thday C_2P_5 was superior to rest of the treatments and on 8th day C_2P_5 and C_2P_6 were at par with each other than rest of the treatments. The minimum total sugar was recorded in C_1P_4 *i.e.* without wax coating and packed in 50 µ LDPE bags with 2% perforation which was 19.47, 20.49, 21.79 and 18.30%, on the 2nd, 4th, 6th and 8th day, respectively. Jan and Rab (2012) [10] also recorded significant increase in total sugars with increase in storage duration in apples and Singh *et al.* (2011) [23] in mango.

The starch to sugar conversion continue during storage (Beaudry, *et al.*, 1989) [1] resulting in increased total sugars with storage duration (Crouch, 2003) [5]. Later on i.e. on 8th day od storage, there was decline in total sugars on during storage and this might be due to their rate of consumption of sugars in respiration and other energy sources reported by Gohlini and Bisen (2012) [7], Patel *et al*. (2011) [17], Chouksey *et al.* (2013) [4] in custard apple

Moisture (%)

As The minimum reduction in moisture content (Table 4) was observed in C_2P_5 *i.e.* fruit treated with wax coating and packed in 50 µ LDPE bags without perforation as 79.90, 78.22, 77.71 and 75.76% on the 2nd, 4th, 6th and 8th day of storage, respectively followed by the fruit treated with wax coating and packed in punnet box *i.e.* (C_2P_6) as 79.51, 78.14, 77.19 and 75.42 on the 2nd, 4th, 6th and 8th day of storage, respectively. On 2nd day C_2P_5 was superior than rest of the treatments. On 4nd day C_2P_5 and C_2P_6 was at par with each other than rest of the treatments. On 6th day C_2P_5 was superior to rest of the treatments. On 8nd day C_2P_5 and C_2P_6 was at par with each other than all the treatments. The maximum reduction moisture was recorded in C_1P_4 *i.e.* without wax coating and packed in 50 µ LDPE bags with 2% perforation as 78.19, 76.26, 74.29 and 71.39% on the 2nd, 4th, 6th and 8th day, respectively. The results are in accordance withKad (2014) [13] in custard apple. Similar results were also reported by Farooqi *et al.* (1988) [8] in kinnow mandarin and Salvador (2003) [22] in apples.

Reduction in moisture content might be due to loss of moisture through transpirationand respiration during storage. However, comparatively less loss in the treatment C_2P_5 might be due to wax coating coupled with packaging in non-perforated polyethylene bag.

Physiological loss in fruit weight (%)

As revealed from the Table 5, wax coating and packaging material has profound effect on physiological loss in weight of custard apple. Further, it was also observed the loss in weight was constantly high in untreated fruits than the treated fruits. The minimum physiological loss in weight was observed in the treatment C_2P_5 *i.e.* fruit treated with wax coating and packed in 50 µ LDPE bags without perforation and was 0.70, 0.94, 2.11 and 3.70% during storage on the 2nd, 4th, 6th and 8th day of storage. This was followed by the treatment C_2P_6 means fruit treated with wax coating and packed in punnet box and it was 0.91, 0.99, 2.22 and 4.26%, respectively. On 2nd day C_2P_5 was superior to rest of the treatment and C_2P_6 and C_2P_1 was at par with each other. On 4thand 6thday C_2P_5 and C_2P_6 was at par with each other than rest of the treatments. On 8th day C_2P_5 was superior to rest of treatments. The maximum physiological loss in weight was recorded in C_1P_4 *i.e.* without wax coating and packed in 50 µ LDPE bags with 2% perforation and was 3.86, 6.33, 7.68 and 9.30% on the 2nd, 4th, 6th and 8th day, respectively during storage. Similar results were found by Jawadagi *et al.* (2013) [11] and Sahu (2016) [21] in custard apple.

There is linear increase in moisture and weight loss in fruits with the increase in storage duration due to water loss and respiration (Ghafir *et al*., 2009) [6]. Reduction in weight loss in treated fruits might be due to the retardation of transpiration and respiration. This might be due to formation of a fine coating which would be retarded the loss of moisture and thus physiological loss in weight. Retardation in transpiration losses on treatment of permeable edible coating has been reported in custard apple (Patel *et al.*, 2011). [17] Nath *et al.* (2012) [15] observed that minimum weight loss in non-perforated polythene packed fruits could be due to lesser availability of oxygen for respiration, which retarded the rate of respiration and thereby lowering the moisture loss due to transpiration.

Table 1: Effect of wax coating and packaging materials on fruit weight (g) of custard apple along with their interactions during storage

Treatment combinations	Days				
	0	2	4	6	8
C_1	166.02	163.32	159.23	156.56	148.64
C_2	166.81	164.96	161.29	157.84	151.35
SE (±)	0.42	0.24	0.16	0.22	
CD@5%	NS	0.68	0.44	0.63	0.84
P_1	167.81	164.62	160.80	158.35	151.30
P_2	164.97	163.67	159.96	156.11	149.28
P_3	163.82	162.93	158.60	155.73	147.08
P_4	163.12	161.27	157.95	154.73	145.03
P_5	169.74	166.21	162.40	159.58	154.26
P_6	169.05	166.15	161.86	158.69	152.99
SE (±)	0.73	0.42	0.27	0.39	0.52
CD@5%	2.05	1.18	0.77	1.09	1.45
C_1P_1	167.91	163.64	160.38	157.97	151.09
C_1P_2	163.81	162.47	159.50	156.55	147.51
C_1P_3	162.06	160.95	157.89	154.43	145.28
C_1P_4	161.85	160.81	156.25	153.94	142.55
C_1P_5	170.37	165.81	161.12	158.97	152.95
C_1P_6	170.15	166.25	160.24	157.50	152.44
C_2P_1	167.70	165.59	161.21	158.74	151.52
C_2P_2	166.13	164.88	160.42	155.67	151.05
C_2P_3	165.58	164.91	159.31	157.04	148.88
C_2P_4	164.38	161.74	159.64	155.51	147.51
C_2P_5	169.10	166.61	163.67	160.19	155.58
C_2P_6	167.96	166.05	163.48	159.87	153.54
SE (±)	1.03	0.59	0.39	0.55	0.73
CD@5%	NS	1.66	1.09	1.55	2.06

Table 2: Effect of wax coating and packaging materials on total soluble solids (^{0}B) of custard applealong with their interactions during storage

Treatment combinations	Days				
	0	2	4	6	8
C_1	22.54	23.88	24.44	25.86	26.83
C_2	22.54	24.58	25.38	26.77	27.66
SE (±)	0.00	0.04	0.03	0.04	0.02
CD@5%	0.00	0.10	0.09	0.12	0.05
P_1	22.54	24.18	25.07	26.13	27.37
P_2	22.54	24.23	24.57	26.27	27.13
P_3	22.54	24.07	24.68	26.22	26.92
P_4	22.54	23.82	24.52	25.88	26.57
P_5	22.54	24.62	25.57	26.75	27.87
P_6	22.54	24.48	25.08	26.65	27.63
SE (±)	0.00	0.07	0.06	0.07	0.04
CD@5%	0.00	0.18	0.16	0.20	0.11
C_1P_1	22.54	23.90	24.70	25.83	26.87
C_1P_2	22.54	23.80	24.27	25.73	26.73
C_1P_3	22.54	23.73	24.17	25.97	26.63
C_1P_4	22.54	23.63	24.03	25.43	26.07
C_1P_5	22.54	24.17	25.10	26.03	27.50
C_1P_6	22.54	24.07	24.40	26.17	27.20

C_2P_1	22.54	24.47	25.43	26.43	27.87
C_2P_2	22.54	24.67	24.73	26.80	27.53
C_2P_3	22.54	24.40	25.00	26.47	27.20
C_2P_4	22.54	24.00	25.20	26.33	27.07
C_2P_5	22.54	25.07	26.03	27.47	28.23
C_2P_6	22.54	24.90	25.77	27.13	28.07
SE (±)	0.00	0.09	0.08	0.10	0.06
CD@5%	0.00	0.25	0.23	0.28	0.16

Table 3: Effect of wax coating and packaging materials on total sugar (%) of custard applealong with their interactions during storage

Treatment combinations	Days				
	0	2	4	6	8
C_1	19.35	20.47	22.51	23.62	20.55
C_2	19.35	22.95	24.94	26.00	22.76
SE (±)	0.00	0.07	0.08	0.07	0.06
CD@5%	0.00	0.20	0.23	0.21	0.16
P_1	19.35	22.02	23.46	24.80	21.87
P_2	19.35	21.44	23.20	24.06	21.27
P_3	19.35	20.96	22.95	23.74	21.03
P_4	19.35	20.59	22.55	23.68	20.40
P_5	19.35	22.90	25.16	26.53	22.87
P_6	19.35	22.37	25.03	26.05	22.57
SE (±)	0.00	0.12	0.14	0.13	0.10
CD@5%	0.00	0.34	0.39	0.36	0.28
C_1P_1	19.35	21.56	22.55	24.33	21.09
C_1P_2	19.35	20.72	23.07	23.50	20.50
C_1P_3	19.35	20.06	21.86	22.46	20.16
C_1P_4	19.35	19.47	20.49	21.79	18.30
C_1P_5	19.35	20.83	23.45	24.80	21.73
C_1P_6	19.35	20.19	23.63	24.84	21.49
C_2P_1	19.35	22.48	24.36	25.27	22.46
C_2P_2	19.35	22.16	23.33	24.62	22.04
C_2P_3	19.35	21.85	24.04	25.03	21.90
C_2P_4	19.35	21.70	24.61	25.57	22.50
C_2P_5	19.35	24.97	26.87	28.25	24.01
C_2P_6	19.35	24.55	26.42	27.26	23.65
SE (±)	0.00	0.17	0.20	0.18	0.14
CD@5%	0.00	0.49	0.56	0.52	0.39

Table 4: Effect of wax coating and packaging materials on moisture % of custard apple along with their interactions during storage

Treatment combinations	Days				
	0	2	4	6	8
C_1	80.25	78.93	77.05	75.07	72.79
C_2	80.25	79.19	77.44	76.62	75.06
SE (±)	0.00	0.02	0.03	0.05	0.05
CD@5%	0.00	0.06	0.09	0.15	0.14
P_1	80.25	79.29	77.45	76.12	74.16
P_2	80.25	78.86	77.16	75.79	73.87
P_3	80.25	78.62	76.58	75.28	73.47
P_4	80.25	78.33	76.29	74.84	72.85
P_5	80.25	79.81	78.10	76.71	74.76
P_6	80.25	79.45	77.90	76.33	74.43
SE (±)	0.00	0.03	0.05	0.09	0.09
CD@5%	0.00	0.10	0.15	0.26	0.24
C_1P_1	80.25	79.19	77.07	75.39	73.10
C_1P_2	80.25	78.62	76.73	75.00	72.62
C_1P_3	80.25	78.47	76.59	74.59	72.40
C_1P_4	80.25	78.19	76.26	74.29	71.39
C_1P_5	80.25	79.72	77.98	75.71	73.76
C_1P_6	80.25	79.38	77.67	75.47	73.44
C_2P_1	80.25	79.38	77.83	76.86	75.22
C_2P_2	80.25	79.09	77.59	76.57	75.12
C_2P_3	80.25	78.76	76.57	75.97	74.54
C_2P_4	80.25	78.47	76.32	75.40	74.30
C_2P_5	80.25	79.90	78.22	77.71	75.76
C_2P_6	80.25	79.51	78.14	77.19	75.42
SE (±)	0.00	0.05	0.08	0.13	0.12
CD@5%	0.00	0.14	0.22	0.37	0.34

Table 5: Effect of wax coating and packaging materials on physiological loss in weight (%) of custard apple along with their interactions during storage

Treatment combinations	Days				
	0	2	4	6	8
C_1	0.00	3.10	5.31	6.42	8.27
C_2	0.00	1.09	1.92	3.52	5.26
SE (±)	0.00	0.06	0.04	0.04	0.05
CD@5%	0.00	0.16	0.11	0.13	0.14
P_1	0.00	2.03	3.44	4.70	6.71
P_2	0.00	2.33	3.80	5.24	7.08
P_3	0.00	2.46	4.18	5.88	7.60
P_4	0.00	2.68	4.73	6.46	7.87
P_5	0.00	1.45	2.69	3.71	5.39
P_6	0.00	1.62	2.89	3.84	5.95
SE (±)	0.00	0.10	0.07	0.08	0.09
CD@5%	0.00	0.27	0.20	0.22	0.24
C_1P_1	0.00	3.03	5.08	6.10	8.05
C_1P_2	0.00	3.48	5.39	6.67	8.49
C_1P_3	0.00	3.68	5.88	7.30	9.05
C_1P_4	0.00	3.86	6.33	7.68	9.30
C_1P_5	0.00	2.34	4.78	5.46	7.64
C_1P_6	0.00	2.21	4.43	5.31	7.08
C_2P_1	0.00	1.03	1.80	3.31	5.37
C_2P_2	0.00	1.17	2.21	3.81	5.67
C_2P_3	0.00	1.23	2.47	4.46	6.14
C_2P_4	0.00	1.51	3.13	5.24	6.43
C_2P_5	0.00	0.70	0.94	2.11	3.70
C_2P_6	0.00	0.91	0.99	2.22	4.26
SE (±)	0.00	0.14	0.10	0.11	0.12
CD@5%	0.00	0.39	0.28	0.31	0.34

Conclusion
The treatment C_2P_5 exhibited maximum TSS, maximum total sugars, less fruits reduction in moisture content and Physiological los in weight and fruits could be stored upto 8 days without adversely affecting their physicochemical and sensory parameters. Thus the fruits of custard apple fruits cv. Balanagarcoated with bee wax and packed in 50 µ LDPE bags without perforation was found most effective to retaining quality and prolonging shelf life which would help in stabilizing the prices and fulfill the market demand.

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