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Effect of Different Level of Chitosan and Beeswax Edible Coating on Storage Life and Physio-Chemical Properties of Strawberry (*Fragaria × ananassa*) cv Winter Dawn

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present investigation was done to understand the effect of different edible coating on increasing the shelf-life of strawberry at room temperature. Postharvest losses in fruits are a serious problem due to rapid deterioration during storage. Use of edible coatings over fruits is used to improve their quality and enhance the shelf life. The main purpose of this study was to assess

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the effect of Chitosan and beeswax coating in extending the shelf-life of strawberry including physio -chemical changes at room temperature. The experiment was laid out in completely randomized design (CRD) with 10 treatments and 3 replications. The treatment consisted of coating material with Chitosan (1.5g%), Chitosan +TPP (1.5g+0.5g%), Chitosan +TPP (1.5g+1%), beeswax (5g), beeswax + TPP (5G+1.5%), Chitosan+ beeswax (0.75g+ 2.5g), Chitosan+ beeswax +TPP(0.75g+2.5g+0.5%), Chitosan+ beeswax +TPP (0.75g+2.5g+1%). Statistical analysis revealed that the treatment chitosan 1.5g+ TPP 1% had the minimum Weight loss 0.08g, while having the maximum amount of Vitamin C 38.45mg/100g, Hardness 8.07 kg/inch2, Bulk Density 1.9g/cm3 and TSS 5.13°Bx. However, Chitosan 1.5g+TPP 0.5% showed maximum Reducing sugar 3.73% and non-reducing sugar 0.92%. While chitosan 0.75g+ beeswax 2.5g+TPP 0.5g have the maximum Total sugar 5.23%.

Keywords: Strawberry; chitosan; beeswax; physio-chemical characteristics; shelf-life.

1. INTRODUCTION

"Strawberry is one of the most economically important fruits consumed due to its well nutritional value, aroma, attractive and juicy fruits. They are rich in polyphenols and anthocyanins, vitamins and amino acids. The main characteristics related to the quality of the ripe strawberries are their texture, flavour (organic acids and soluble sugars content) and colour" [1]. "Due to their very active metabolism strawberries are highly perishable and have high physiological post-harvest activities which lead to short ripening and senescence periods that make their marketing a challenge" [2]. "Loss of quality in this fruit is connected with its sensitivity to fungal infection and susceptibility to water loss, bruising, mechanical injuries and texture softening due to the lack of protective rind" [3,4,5].

Edible films and coatings are promising systems for the improvement of food quality, shelf life, safety, and functionality. The efficiency and functional properties of edible film and coating materials are highly dependent on the inherent characteristics of film-forming materials, namely biopolymers (such as proteins, carbohydrates, and lipids), plasticizers, and other additives [6,7].

"Development of edible coatings has been based upon the use of polysaccharides, proteins, lipids or their combination in different ways. Polysaccharides and proteins are known to form films with good mechanical properties, but with poor permeability, while the lipids form brittle films but with improved permeability. Therefore, the newly developed coatings are focused on combining the polymer matrix with some hydrophobic component" [8,9].

Chitosan coatings are gaining significant attention in post-harvest preservation due to their antimicrobial, and antioxidant properties as well as other desirable characteristics including, moisture barrier, gas permeability, biodegradability, film-forming ability, enhanced nutritional value, compatibility with other treatments and compliance with food safety standards [10-13]. Overall, chitosan coatings have demonstrated promising results in extending the shelf-life of fruits and vegetables while maintaining their quality, making them a significant development in post-harvest preservation that can contribute to both economic and environmental sustainability in the agricultural industry [14,15].

Beeswax in biopolymer-based films enhances their barrier and tensile features. The coating is capable of tuning the release of bioactive from the polymer matrices. Beeswax coatings have great potential for reducing food waste, which is a major issue for food security and sustainability. Beeswax is natural glazing agent that can be used in food to prevent water loss and provide protection during storage. It is often used to prevent water loss and retard shrinkage and spoilage in fruit.

2. MATERIALS AND METHODS

2.1 Study Location and Treatment Combination

The experiment was conducted at Post Harvest Laboratory, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, and Prayagraj (UP). The experimental design was CRD (Completely Randomized Design) with 10 treatments and 3 replications. The strawberries were procured from Mundera market and then they were washed and kept it on the same day at room temperature. Uniform and good quality strawberry were picked. The coated fruits were kept at room temperature for 9 days and observation on Physiological loss in weight, total soluble solid, vitamin C/ascorbic acid, Total sugar, reducing sugar, non-reducing sugar, bulk density and hardness of the fruit was taken at 3 days interval. The fruits were divided into equal lots. The fruits were washed with water and allowed to dry under fan and then treated with Chitosan (1.5g%), Chitosan +TPP (1.5g+0.5g%), Chitosan +TPP (1.5g+1%), beeswax (5g), beeswax + TPP (5G+1.5%), Chitosan+ beeswax (0.75g+ 2.5g), Chitosan+ beeswax +TPP(0.75g+2.5g+0.5%), Chitosan+ beeswax +TPP (0.75g+2.5g+1%).

2.2 Preparation and Application of Edible Coating

Chitosan solution was prepared by dissolving 1.5g, 0.75g chitosan in 100ml of acetic acid with continuous stirring at room temperature. After the complete dissolution of the chitosan, 2g of glycerol and 2g of tween 80 was added and stirred the solution for 30min. The result solution was used for coating. For preparing beeswax 5g of beeswax in 50ml of ethanol heated to 70°C was melted and mixed with 50ml distilled water and the wax solution was emulsified with 25% of tween 80 with respect to the wax content.

The cross -linking of the chitosan coating was carried out with 0.5g, 1g/100g sodium tripolyphosphate, TPP, prepared as aqueous solutions by dissolving the salt in distilled water under vigorous stirring. The cross-linking lasted few minutes and then the excess of the cross-linking solution was bottled with adsorbent paper. Preparation of chitosan and beeswax was done by using 100ml of 0.75g/100g chitosan solution mixed with 5g of wax. The chitosan coating solution was prepared, as described previously then heated to 70℃. The wax was melted in the heated solutions and the whole mixture was homogenized.

The treated strawberry was tested for their physical and quality parameter such as, physiological weight loss, bulk density, hardness, TSS, vitamin C, total sugar, reducing sugar and nonreducing sugar.

3. RESULTS AND DISUSSION

The weight of the fruit was measure at 3 days interval during the conduction of the experiment. This help in the determination of weight loss during the experiment.

3.1 Weight Loss (g) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

Strawberry fruits are highly susceptible to rapid loss of water which results in fruit shrinkage and weakening of the tissue due to their very thin skin. Therefore, the weight loss was followed over the storage period of 9 days to evaluate the effects of the coatings. T_3 chitosan 1.5g +STPP 1% show the lowest amount of weight loss (1.07, 1.20, 0.80). The chitosan + STPP emulsion served as a physical barrier around the fruit which partially closed the stomatal openings and lenticels thereby reducing the rates of transpiration and respiration [16].

3.2 Hardness (kg/nch^2) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

"Strawberries soften considerably during ripening due to degradation of the middle lamella of he cell wall of cortical parenchyma cells" [17]. The coating helps in slowing down the softness and prolong the shelf life. Among the different treatments, T3 (9.73,8.80,8.63,8.07) retain the maximum hardness after storage closely flowed by T2 (9.1, 8.30,7.34,6.78). "The controlled fruits registered the lowest texture (5.13, 3.88, 3.23 and 2.58) at all the days. The decrease in fruit texture with the storage period might be due to breakdown of insoluble pectin to soluble form and also due to cellular disintegration leading to permeability of the cell membrane which ultimately helps in gaseous exchange" [18]. "The higher texture in coconut oil and paraffin wax coated fruits might be due to reduced transpiration and respiration along with delay ethylene production and thus retained more turgidity of the cells of the fruits" [19].

3.3 Density (g/cm$^{3)}$ of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

Bulk density is a very complex product property and is a great importance for economical and functional reasons. High bulk density is desirable as it would indicate ample abundance of the edible fruit content. By checking the various bulk density data, we were able to identify that the bulk density of the coated strawberry shows significant on 3th day, 6th day ,9th days. The maximum bulk density was found in T3 chitosan 1.5g +STPP 0.5g (3.30, 2.95, 2.63, 1.9).

Table 1. Physiological weight loss and hardness (kg/inch²) of the strawberry as affected by the different levels of Chitosan and Beeswax solution

Sl. No.	Treatment combination	No. of days at room temperature						
		PLW (g)			Hardness (kg/inch²)			
		3day	6day	9day	Initial day	3day	6day	9day
1	T_0(control)	1.10	1.37	1.97	5.13	3.88	3.27	2.8
2	T_1(chitosan)	1.07	1.40	1.97	9.33	8.27	7.73	7.03
3	T_2(chitosan + STPP)	1.33	1.40	1.13	9.10	8.30	7.70	7.13
4	T_3(chitosan+ STPP)	1.07	1.20	0.80	9.73	8.80	8.63	8.07
5	T_4(Beeswax)	1.33	1.60	1.60	9.10	9.3	8.10	6.87
6	T_5(beeswax+ SSTPP)	0.93	2.30	1.67	9.53	9	8.40	6.77
7	T_6(beeswax+ STPP)	1.27	1.13	1.07	8.43	7.67	7.43	6.33
8	T_7(Chitosan+ beeswax)	1.17	1.33	1.40	9.23	7.9	7.67	6.63
9	T_8(chitosan+ beeswax+ STPP)	1.13	1.20	1.50	8.2	7.57	7.00	6.20
10	T_9(chitosan+ beeswax+ STPP)	1.07	1.27	1.47	9.27	7.67	7.04	6.13
F test		NS	NS	NS	S	S	S	S
S.E (d) (±)		0.39	0.40	0.45	0.20	0.20	0.29	0.23
C.V		41.35	34.42	38.04	2.69	4.29	4.66	4.22

Table 2. Bulk density and TSS of the strawberry as affected by the different levels of Chitosan and beeswax solution

Sl. No.	Treatment combination	No. of days at room temperature							
		Bulk Density (g/cm³)				TSS (°Brix)			
		Initial day	3day	6day	9day	Initial day	3day	6day	9day
1	T_0(control)	1.97	1.7	1.17	0.77	3.70	4.13	4.2	4.3
2	T_1(chitosan)	2.13	1.72	1.20	0.91	3.40	3.93	4.5	5.23
3	T_2(chitosan + STPP)	2.43	2.02	1.7	0.97	5	5.4	5.97	6.37
4	T_3(chitosan+ STPP)	3.30	2.93	2.63	1.9	3.27	3.83	4.59	5.13
5	T_4(Beeswax)	2.03	1.78	1.3	0.92	3.47	4	4.67	5.37
6	T_5(beeswax+ SSTPP)	2.77	2.83	2.38	1.67	3.20	3.77	4.83	5.33
7	T_6(beeswax+ STPP)	1.95	1.46	1.2	0.95	3.47	4	4.87	4.7
8	T_7(Chitosan+ beeswax)	2.1	1.79	1.41	1.17	2.97	3.43	4.13	4.7
9	T_8(chitosan+ beeswax+ STPP)	2.20	1.83	1.34	0.95	4.40	4.7	5.17	5.63
10	T_9(chitosan+ beeswax+ STPP)	2.01	1.6	1.37	0.96	3.37	3.8	4.47	5.07
F test		S	S	S	S	S	S	S	S
S.E (d) (±)		0.26	0.18	0.19	0.13	0.27	0.28	0.30	0.28
C.V		13.89	11.70	15.18	13.96	9.29	8.31	7.83	6.46

Table 3. Total Sugar and reducing sugar of the strawberry as affected by the different levels of chitosan and beeswax solution

Sl. No.	Treatment combination	No. of days at room temperature							
		Total Sugar%				Reducing Sugar%			
		Initial day	3day	6day	9day	Initial day	3day	6day	9day
1	T_0(control)	4	4.43	4.8	5	2.57	3.00	3.20	3.2
2	T_1(chitosan)	4.17	4.8	5	5.2	2.67	2.86	3.20	3.533
3	T_2(chitosan + STPP)	3.78	4.76	4.77	5.1	2.57	2.99	3.33	3.73
4	T_3(chitosan+ STPP)	4.02	4.82	4.99	5.2	2.63	2.72	3.27	3.6
5	T_4(Beeswax)	3.66	4.57	5.01	5.17	2.27	2.72	3.14	3.7
6	T_5(beeswax+ SSTPP)	3.75	4.53	5.1	5.37	2.34	2.78	3.03	3.63
7	T_6(beeswax+ STPP)	3.75	4.82	5	5.33	2.30	2.88	3.20	3.63
8	T_7(Chitosan+ beeswax)	3.96	4.95	5.23	5.7	2.44	2.71	3.06	3.6
9	T_8(chitosan+ beeswax+ STPP)	3.84	4.39	4.96	5.23	2.27	2.76	3.20	3.67
10	T_9(chitosan+ beeswax+ STPP)	3.58	4.62	4.93	5.05	2.27	3.23	3.47	3.6
F test		NS	S	S	NS	S	S	NS	NS
S.E (d) (±)		0.22	0.15	0.12	0.13	0.13	0.12	0.17	0.15
C.V		7.10	4.05	3.01	3.09	6.27	5.21	6.30	5

Table 4. Non reducing sugar and vitamin C of the strawberry as affected by the different levels of chitosan and beeswax solution

Sl. No.	Treatment combination	No. of days at room temperature							
		Non Reducing Sugar%				Vitamin C (mg/ 100g fruit)			
		Initial day	3day	6day	9day	Initial day	3day	6day	9day
1	T_0(control)	1.17	1	0.8	0.81	41.00	40	39.67	38.07
2	T_1(chitosan)	1.5	1.17	1	0.85	42.02	44.67	45.63	39.43
3	T_2(chitosan + STPP)	1.4	1.24	1.1	0.92	41.90	44.67	45.13	39.20
4	T_3(chitosan+ STPP)	1.53	1.27	1.07	0.83	42.14	43.53	44.96	40
5	T_4(Beeswax)	1.6	1.4	1.17	0.85	41.00	40.67	45.47	38.43
6	T_5(beeswax+ SSTPP)	1.5	1.23	1.06	0.73	41.73	43.87	45.17	39.13
7	T_6(beeswax+ STPP)	1.57	1.267	1.03	0.89	41.57	42.77	43.43	38.93
8	T_7(Chitosan+ beeswax)	1.57	1.3	1.11	0.89	41.67	41.10	43.56	39
9	T_8(chitosan+ beeswax+ STPP)	1.37	1.1	0.9	0.63	41.70	42.87	45.73	38.63
10	T_9(chitosan+ beeswax+ STPP)	1.53	1.4	1.13	0.85	41.07	41.60	43.00	38.97
F test		S	NS	NS	NS	NS	S	S	NS
S.E (d) (±)		0.12	0.12	0.13	0.11	0.77	0.88	1.39	0.69
C.V		9.62	12.26	14.87	16.72	2.27	3.57	3.78	2.17

3.4 TSS (°Brix) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

It was observed that TSS of the fruits increased from 3th day to 9th day of the treatment. The maximum TSS (6.37) at 9 days of storage was recorded in chitosan 1.5g +STPP 1% coating followed by beeswax 5g (5.37) while, the least TSS was recorded in control (4.3). The gradual increase in TSS up to 9th day might be due to complete hydrolysis into sugars and the gradual decline after this period is due to no further increase in sugar since it is the primary substitute for respiration [20]. The increase in TSS in wax coated fruits was till the 9th day. The decrease of TSS might be due to the fact that wax has the capacity to delay the metabolic activities during ripening and storage of fruits [21].

3.5 Total Sugar (%) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

There was significant on the 3day -6days on the different coatings with respect to the total sugar content of the strawberry fruits. The total sugars of the fruits increased up to 9th day of treatment. Among all the treatments, T7 chitosan0,.75g+ beeswax 2.5g coating scored the maximum value with respect to total sugars (5.7%), followed by T5 chitosan+ STPP (5.37%). The increase in sugars might be due to the rapid conservation of polysaccharides into sugars. The decrease in sugars might be due to metabolic breakdown and senescence of fruits during storage [22].

3.6 Reducing Sugar (%) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

The reducing sugars of the fruits increased with the increase in storage period of 9 days (Table 4.8). Among all the edible coatings, fruits treated with T2 chitosan 1.5g+ STPP 0.5g have the maximum reducing sugars (3.73%), while the control had the lowest reducing sugars (3.2%) at 9 days There was an increase in sugars during storage period up to 9days and thereafter a gradual decline might happen due to conversion of organic acid into sugars (Baviskar *et al.* 1995). The reducing sugar in the treatment shows a significant in the 3 days.

3.7 Non-Reducing Sugar (%) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

The highest non-reducing sugar was found in T2 (chitosan 1.5g+ STPP 1%) at 0.97%, while T5 (chitosan +beeswax+ STPP) shows the lowest at 0.63%. The non-reducing sugar (sucrose) in strawberry is found to be less in compression to reducing sugar (fructose, glucose, etc) in strawberry.

3.8 Vitamin C (mg/ 100g fruit) of the Strawberry as Affected by the Different Levels of Chitosan and Beeswax Solution

It was observed that the vitamin C had increased till the 6th day of storage and thereafter decreased on the 9th day of storage. The fruits coated with T3 chitosan 1.5g+ STPP 1 % maintained higher levels of vitamin C compared to other tested coatings. It might be due to the retardation of the oxidation process and consequently slow rate of conversion of L-ascorbic acid into dehydroascorbic acid by ascorbic acid oxidase. The retention of higher ascorbic acid in wax coated fruits might be due to the ripening retarding effect and slow rate of biological activities during storage.

4. CONCLUSION

The shelf life of the strawberry which was coated with chitosan-based coatings, beeswax, chitosan and beeswax prolonged the storage period of strawberries for nine days at room temperature and slowed down their senescence process compared to uncoated strawberries.

From the present investigation, it was observed that Treatment ($T_{3,}$ chitosan 1.5g+ TPP 1%) had the minimum Weight loss of 0.08g, while having the maximum amount of Vitamin C 38.45mg/100g, Hardness 8.07 kg/inch^2, Bulk Density 1.9g/cm^3 and TSS 5.13°Bx. However, T_2(Chitosan 1.5g+TPP 0.5%) showed maximum Reducing sugar at 3.73% and non-reducing sugar at 0.92%. While T7 chitosan (0.75g+ beeswax 2.5g+TPP 0.5g) has the maximum Total sugar of 5.23%. The highest benefit-cost ratio was found in T_2(Chitosan 1.5g+TPP 0.5%) at 3.80.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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