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Aloe vera gel and Starch Coatings on Organoleptic and Shelf Life of Strawberry Fruits (*Fragaria x ananassa* Duch.)

Basir Ahmad Rahimi

Herat University

Email: brahimi031987@gmail.com (corresponding author)

ABSTRACT

Strawberry fruit is highly perishable and spoils rapidly due to contamination by pathogenic and nonpathogenic microorganisms, causing serious reduction in quality. We studied two treatments on shelf-life: 1) Aloe vera gel (AV)-based edible coatings in combination with ascorbic acid (AA) and 2) cassava starch (CS) with potassium sorbate (PS). Strawberries were coated with AV (15 and 25% v/v) + AA (3% w/v) and CS (2 and 3% w/v) + PS (0.1%), while uncoated fruit served as a control. After treatment, fruit weight loss, firmness loss, TSS, titratable acidity (TA), ascorbic acid content, total anthocyanin, and total microbial count were evaluated at 0, 1, and 3 days of storage (under room temperature) and 0, 3, 6, 9, and 12 days of storage (9 ± 1°C, 70 to 80% RH). Compared to uncoated strawberries, all coating treatments significantly ($P < 0.01$) reduced weight loss, firmness loss, and total bacteria, yeast, and mold. Coated strawberries also had significantly ($P < 0.01$) higher TSS and ascorbic acid. The treatment with 25% Aloe vera gel was most effective ($P < 0.01$), resulting in better retention of ascorbic acid and TSS, besides reduced microbial load. The edible coatings were found to reduce postharvest spoilage in strawberry fruits.

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Introduction

The global demand for fresh fruits and vegetables is increasing daily, as they are important food components and key ingredients in many processed foods (Jongen, 2002). The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) recommend consuming a minimum of 400g of fruits and vegetables per person per day for the prevention of micronutrient deficiencies and chronic diseases (WHO, 2003). The strawberry (Fragaria × ananassa Duch.) is an important fruit crop cultivated worldwide. It is one of the most attractive, delicious, and nutritious fruit crops, consumed in large quantities either fresh or processed, as it is rich in polyphenols (anthocyanin, flavonols, ellagic acid, hydroxycinnamic acid) and many essential nutrients beneficial for human health (Giampieri et al., 2012). This valuable fruit has a very short shelf life and senescent period due to its perishability, susceptibility to mechanical injury, texture softening, physiological disorders, and infections caused by several microorganisms that can rapidly reduce fruit quality and make its marketing challenging. Various preservation methods are available to improve strawberry quality and extend its shelf life, such as freezing, heat treatment, controlled atmospheres, gamma irradiation, and chemical treatments (Marina et al., 2015; Vu et al., 2011). However, consumers prefer near-natural fruits without harmful chemical preservatives.

Hence, edible coatings appear to be an effective treatment to enhance shelf life by controlling microbial spoilage of fruits (Rahimi et al., 2019). Edible coatings are films of edible materials that extend the shelf life of fruits and vegetables by reducing their metabolism and physiological disorders. These coatings also control maturation, development, and respiratory rate, prevent oxidative browning, and decrease microorganism growth (Kumar and Bhatnagar, 2014; Raghav et al., 2016). Edible coatings such as Aloe vera (AV) gel, ascorbic acid, and starch can be safely eaten as part of the product and do not add unfavorable properties to the food. Aloe vera gel, obtained from the inner leaf pulp of the Aloe vera plant, has antifungal activity against several spoilage fungi, including Botrytis cinerea. It modifies the internal gas atmosphere, reduces moisture loss, respiration rate, and microbial proliferation, and delays oxidative browning in fruits such as sweet cherries and table grapes. Ascorbic acid has antimicrobial effects on fresh-cut fruits such as jackfruit, apple, and papaya and also reduces vitamin C losses by adding antioxidant properties (Tapia et al., 2008). Starch, a polysaccharide, can be used as an edible coating (Chauhan et al., 2011). Cassava starch is particularly suitable as an edible coating material since it is inexpensive, tasteless, odorless, colorless, nontoxic, biodegradable, and a safe polysaccharide with low oxygen permeability (Fontes et al., 2008). Similarly, sorbic acid and its potassium salt (sorbates) are considered GRAS additives. Using sorbate in edible films and coatings can minimize microbial contamination (Vasconez et al., 2009).

Materials and Methods

Strawberry (Fragaria × ananassa Duch.), cv. 'Camarosa,' supplied from Mahabaleshwar, Maharashtra, having uniform size, shape, color, and maturity, was selected for the treatments free from mechanical damage, blemishes, and disease. Fresh Aloe vera gel extracted from leaves and pasteurized at 70°C for 45 min was used for coating strawberry fruits. Aloe vera gel of two different concentrations (15 and 25% v/v) was mixed with ascorbic acid (3%) separately, and fruits were coated by dipping for 10 minutes (Rahimi et al., 2019). Similarly, 30 and 20 grams of cassava starch were dissolved in 1000 ml of distilled water separately and added with 1 g each of potassium sorbate. The solutions were heated to 70°C, agitated to achieve starch gelatinization, and then cooled to room temperature. The fruits were treated by dipping in respective solutions for 3 minutes. A control without any treatment was maintained for comparison.

The shelf life study of strawberry fruits was evaluated under room temperature and cold storage (9±1°C) using a completely randomized design (CRD) with five treatments and four replications, using 500g of fruits in punnet boxes. Physical (weight loss), chemical (total soluble solids), and biological parameters (titratable acidity, ascorbic acid content, and total anthocyanin), along with sensory evaluations, were analyzed at 0, 2, and 3 days for ambient storage and 0, 3, 6, 9, and 12 days for cold storage studies.

The physiological loss of weight was determined using an electronic weighing balance. Total soluble solids (TSS) were determined using a digital hand refractometer and expressed as degrees Brix (°B) (Rahimi et al., 2018). The refractometer prism was washed with distilled water and wiped dry before each reading (AOAC, 2006). Total titratable acidity (percentage) was measured by titration (Cohen, 1971). Ascorbic acid content (mg $100g^{-1}$) was determined using 2,6-dichlorophenol indophenol sodium salt (AOAC, 2006). The pH differential method measured the total anthocyanin content (mg $100g^{-1}$) (Giusti and Wrolstad, 2001). A panel of ten judges using a nine-point Hedonic scale conducted The organoleptic examination based on color, aroma, taste, texture, and overall acceptability (Amerine et al., 1965). Microbial load was assessed using the FDA method (Peter et al., 2017).

Results and Discussion

The results of this research indicated that physiological loss of weight, total soluble solids (TSS), titratable acidity, ascorbic acid content, total anthocyanin content, sensory acceptance, and microbial load varied among treatments with Aloe vera gel and cassava starch during cold storage (3, 6, 9, and 12 days) and ambient temperature storage (1 and 3 days).

The physiological weight loss increased with prolonged storage across all treatments (Table 1).

Table 1: *Effect of edible coatings on physiological loss in weight (PLW) of strawberry fruits stored under cold and ambient condition*

Treatments	Physiological loss in weight (PLW) %					
	Cold Storage				Ambient Storage	
	3 DAS	6 DAS	9 DAS	12 DAS	1 DAS	3 DAS
T1 - *Aloe vera* @ 15% + 3% ascorbic acid for 10 minutes	1.37^{b}	2.97^{c}	4.31^{bc}	5.46^{b}	2.29^{cd}	6.44^{c}
T2 - *Aloe vera* @ 25% + 3% ascorbic acid for 10 minutes	0.93^{b}	2.33^{c}	3.14^{d}	4.41^{c}	2.13^{d}	6.07^{d}
T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes	1.35^{b}	3.93^{b}	4.41^{b}	6.53^{a}	2.81^{b}	6.32^{cd}
T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes	1.20^{b}	2.82^{c}	3.81^{c}	6.94^{a}	2.64^{bc}	6.80^{b}
T5 - Control (no pretreatment)	3.12^{a}	7.30^{a}	10.98^{a}	x	8.46^{a}	13.27^{a}
S. Em ±	0.25	0.24	0.19	0.28	0.12	0.11
CD @ 1%	1.04	1.01	0.78	1.21	0.50	0.46
F- test	**	**	**	**	**	**

Note: ** Significant at 1 per cent level   Initial TSS: 5.5 (°Brix)   DAS: Days after storage

* Significant at 5 per cent level   Nsig: non-significant

Note: ** Significant at 1 per cent level   DAS: Days after storage

Notable variations were observed between treated and untreated fruits. Strawberry fruits coated with 25% Aloe vera gel + 3% ascorbic acid for 10 minutes (T2) showed significantly minimum physiological weight loss (0.93, 2.33, 3.14, and 4.41) as recorded after 3rd, 6th, 9th, and 12th days of cold storage, respectively. Similarly, ambient-stored strawberries treated with 25% Aloe vera gel and 3% ascorbic acid showed less physiological weight loss than other treatments (2.13 and 6.07) after 1st and 3rd days of storage, respectively. The Aloe vera gel is a physical barrier to control moisture loss, thereby preventing dehydration and fruit shriveling (Hernandez et al., 2006). Untreated fruit samples in the control treatment showed maximum weight loss under both storage conditions throughout the storage period.

An increasing trend was recorded for the total soluble solids (TSS) content of the fruits with prolonged storage (Table 2).

***Table 2**: Effect of edible coatings on total soluble solids (TSS) of strawberry fruits under cold* storage and ambient condition

Treatments	TSS (°Brix)					
	Cold Storage				Ambient Storage	
	3 DAS	6 DAS	9 DAS	12 DAS	1 DAS	3 DAS
T1 - *Aloe vera* @ 15% + 3% ascorbic acid for 10 minutes	5.70	5.60[ab]	5.58[a]	5.50[a]	5.88	6.01[bc]
T2 - *Aloe vera* @ 25% + 3% ascorbic acid for 10 minutes	5.73	5.65[a]	5.63[a]	5.53[a]	5.88	5.93[c]
T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes	5.50	5.43[cd]	5.35[bc]	5.33[ab]	5.70	6.20[ab]
T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes	5.55	5.50[bc]	5.45[ab]	5.20[b]	5.73	6.21[ab]
T5 - Control (no pretreatment)	5.45	5.35[d]	5.15[c]	x	5.95	6.43[a]
S. Em ±	0.07	0.05	0.07	0.07	0.10	0.08
CD @ 1%	0.30	0.21	0.29	0.31	0.41	0.35
F- test	Nsig	**	**	*	Nsig	**

Strawberry fruits treated with 3% starch added with 0.1% potassium sorbate (T3) exhibited minimal variation (5.50, 5.43, 5.35, and 5.33 °B) in TSS content during cold storage. At the same time, uncoated samples showed higher variation at different storage times under both cold and room temperature conditions. Conversely, ambient-stored strawberry fruits showed higher variation in TSS content (6.20 °B) during storage. The higher TSS content observed in the control treatment is attributed to moisture loss in strawberries during storage. Similar observations were reported by Emamifar and Bavaisi (2017) and Nasrin et al. (2017) in strawberries. Significant variation in titratable acidity of strawberry fruits was observed due to treatments (Table 3).

***Table 3**: Effect of edible coatings on titratable acidity (TA) of strawberry fruits under cold storage and ambient condition*

Treatments	Titratable acidity (%)					
	Cold Storage				Ambient Storage	
	3 DAS	6 DAS	9 DAS	12 DAS	1 DAS	3 DAS
T1 - *Aloe vera* @ 15% + 3% ascorbic acid for 10 minutes	1.06	1.02[ab]	1.00[ab]	0.92[ab]	1.16	1.04[a]
T2 - *Aloe vera* @ 25% + 3% ascorbic acid for 10 minutes	1.20	1.12[a]	1.10[a]	1.04[a]	1.12	1.08[a]
T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes	1.00	0.88[cd]	0.84[bc]	0.70[c]	1.08	0.96[ab]
T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes	1.04	0.94[bc]	0.86[bc]	0.72[bc]	1.04	1.00[a]
T5 - Control (no pretreatment)	0.92	0.78[d]	0.72[c]	x	1.00	0.84[b]
S. Em ±	0.06	0.04	0.07	0.07	0.05	0.05
CD @ 1%	0.26	0.16	0.32	0.29	0.20	0.19
F- test	Nsig	**	*	*	Nsig	*

Note: ** Significant at 1 per cent level Initial titratable acidity: 1.28% DAS: Days after storage
* Significant at 5 per cent level Nsig: non-significant

Fruits treated with different coating materials (T1 to T4) showed a slight decrease in titratable acidity (1.00, 1.10, 0.84, and 0.86%) from the initial 1.28%, in contrast to untreated fruits (T5- 0.72%) after the ninth day of storage. Fruits treated with 25% Aloe vera integrated with 3% ascorbic acid (T2) showed minimum reduction in titratable acidity (1.20, 1.12, 1.10, and 1.04) after 3rd, 6th, 9th, and 12th days of storage, respectively, under cold conditions. Conversely, titratable acidity decreased drastically in strawberry fruits stored at room temperature (0.96%) after the storage period. While titratable acidity decreased in untreated and treated fruits, it was relatively higher in untreated fruits than coated treatments (Gol et al., 2013; Sogvar et al., 2016).

The ascorbic acid content of strawberry fruits varied under the influence of different edible coatings. It decreased with the storage period across all treatments (Table 4).

Ambient-stored fruits treated with 15% Aloe vera + 3% ascorbic acid (T1) retained maximum ascorbic acid content of 39.18 and 36.32 mg $100g^{-1}$ on 1st and 3rd days of storage, respectively, compared to untreated fruits (34.98 and 29.16 mg $100g^{-1}$). Cold-stored strawberry fruits maintained ascorbic acid content with slight reduction up to the twelfth day of storage, while ambient-stored fruits had to be terminated after three days. The decrease in ascorbic acid content during storage is likely due to oxidation by oxidizing enzymes (ascorbic acid oxidase, peroxidase, catalase, and polyphenol oxidase) as previously reported by Singh et al. (2005) and Rahimi et al. (2018) in strawberry.

***Table 4**: Effect of edible coatings on ascorbic acid content of strawberry fruits under cold and ambient condition*

Treatments	Ascorbic acid (mg 100g^{-1})					
	Cold Storage				Ambient Storage	
	3 DAS	6 DAS	9 DAS	12 DAS	1 DAS	3 DAS
T1 - *Aloe vera* @ 15% + 3% ascorbic acid for 10 minutes	41.41^{a}	38.48^{b}	35.63^{b}	33.84^{b}	39.18^{a}	36.32^{a}
T2 - *Aloe vera* @ 25% + 3% ascorbic acid for 10 minutes	41.32^{a}	39.07^{a}	36.59^{a}	34.89^{a}	38.96^{a}	36.31^{a}
T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes	36.75^{b}	34.30^{c}	30.20^{c}	28.52^{c}	37.39^{b}	34.56^{b}
T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes	37.04^{b}	34.00^{c}	29.93^{c}	27.29^{d}	37.30^{b}	34.30^{b}
T5 - Control (no pretreatment)	35.07^{c}	29.39^{d}	25.52^{d}	x	34.98^{c}	29.16^{c}
S. Em ±	0.17	0.17	0.11	0.08	0.30	0.17
CD @ 1%	0.71	0.70	0.46	0.33	1.24	0.72
F- test	**	**	**	**	**	**

Note: ** Significant at 1 per cent level Initial ascorbic acid content: 40.11 (mg 100g^{-1}) DAS: Days after storage

Despite storage conditions and edible coatings, increased anthocyanin was observed due to coatings during the ninth and third days of storage for cold and ambient-stored fruits, respectively (Table 5).

***Table 5:** Effect of edible coatings on anthocyanin content of strawberry fruits under cold storage and ambient condition*

Treatments	Anthocyanin (mg 100g-1)					
	Cold Storage				Ambient Storage	
	3 DAS	6 DAS	9 DAS	12 DAS	1 DAS	3 DAS
T1 - Aloe vera @ 15% + 3% ascorbic acid for 10 minutes	7.48	7.62	7.64b	7.95	8.86	9.10b
T2 - Aloe vera @ 25% + 3% ascorbic acid for 10 minutes	7.40	7.48	7.58b	7.96	8.24	9.86b
T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes	7.43	7.66	7.70b	8.01	8.96	9.30b
T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes	7.45	7.56	7.84b	8.62	8.95	9.44b
T5 - Control (no pretreatment)	8.18	8.40	8.89a	x	9.41	10.86a
S. Em ±	0.25	025	0.23	0.24	0.30	0.28
CD @ 1%	1.05	1.06	0.97	1.02	1.24	1.16
F- test	Nsig	Nsig	**	Nsig	Nsig	**

Note: ** Significant at 1 per cent level Initial anthocyanin content: 7.09 (mg 100g^{-1}) DAS: Days after storage
Nsig: non-significant

Strawberry fruits treated with 25% Aloe vera plus 3% ascorbic acid (T2) showed minimum anthocyanin content (7.40, 7.48, 7.58, and 7.96 mg 100g^{-1} after the third, sixth, ninth, and twelfth days of storage, respectively). In contrast, untreated fruits (T5) contained the highest anthocyanin content (8.18, 8.40, and 8.89 mg 100g^{-1} after the 3rd, 6th, and 9th days of storage, respectively) under cold conditions. Conversely, fruits stored at room temperature exhibited higher anthocyanin content across all treatments during the storage period. The higher anthocyanin content in untreated samples was possibly due to increased respiration rate and metabolic activity, resulting in greater pigment production, as reported by Garcia et al. (2011).

Significant variation was recorded in total bacteria, fungi, and yeasts due to different treatments throughout the storage period under cold and ambient conditions. The initial microbial populations (total bacteria, fungi, and yeasts) observed in strawberry fruits were 6.79, 11.5, and 8.13×10^3 CFU g^{-1}, respectively (Table 6).

Table 6: *Effect of edible coatings on microbial population (CFU g^{-1}) of strawberry fruits stored under cold storage and ambient condition*

Treatments	Cold Storage						Ambient Storage					
	Bacteria 10^3		Fungi 10^3		Yeast 10^3		Bacteria 10^3		Fungi 10^3		Yeast 10^3	
	3 DAS	12 DAS	3 DAS	12 DAS	3 DAS	12 DAS	2 DAS	4 DAS	2 DAS	4 DAS	2 DAS	4 DAS
T_1	8.00^{c}	13.75^{c}	8.50^{c}	15.75^{c}	10.25^{c}	18.50^{c}	12.00^{c}	19.50^{c}	10.50^{c}	21.50^{c}	15.00^{b}	50.50^{d}
T_2	7.00^{c}	9.00^{d}	7.00^{c}	12.25^{d}	8.00^{d}	15.75^{d}	9.00^{d}	17.50^{c}	9.00^{c}	17.50^{d}	12.00^{c}	36.50^{e}
T_3	14.25^{b}	22.75^{b}	12.50^{b}	26.50^{b}	12.50^{b}	28.25^{b}	16.50^{b}	31.00^{b}	15.50^{b}	57.50^{b}	14.00^{b}	86.50^{c}
T_4	14.50^{b}	21.00^{b}	12.50^{b}	28.50^{b}	10.50^{c}	27.00^{b}	16.50^{b}	31.00^{b}	16.00^{b}	57.50^{b}	15.50^{b}	89.50^{b}
T_5	22.75^{a}	46.50^{a}	23.75^{a}	70.00^{a}	25.50^{a}	109.50^{a}	24.50^{a}	59.50^{a}	25.50^{a}	110.50^{a}	29.50^{a}	124.50^{a}
S. Em	0.58	0.69	0.81	0.75	0.57	0.87	0.56	0.67	0.56	0.65	0.52	0.65
CD @	2.44	2.87	3.39	3.11	2.39	3.63	2.35	2.80	2.35	2.69	2.15	2.69
F-test	**	**	**	**	**	**	**	**	**	**	**	**

Note: ** Significant at 1 per cent level Initial population; bacteria: 6.79x10^3 fungi: 11.5x10^3 yeast: 8.13x10^3 (CFU g^{-1}) DAS: Days after storage

T1 - *Aloe vera* @ 15% + 3% ascorbic acid for 10 minutes T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes

T2 - *Aloe vera* @ 25% + 3% ascorbic acid for 10 minutes T5 - Control (no pretreatment)

T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes

The population increased in strawberry fruits during storage, particularly in the control; however, fruits treated with 25% Aloe vera gel in combination with 3% ascorbic acid (T2) had minimum populations of bacteria, fungi, and yeast (9.00, 12.25, and 15.75×10^3 CFU per gram, respectively) on the last day of cold storage. Similarly, strawberry fruits treated with 25%

Aloe vera gel combined with ascorbic acid and stored at room temperature showed significantly lower bacteria, fungi, and yeast populations than other treatments. The lower microbial population in Aloe vera and ascorbic acid-coated fruits was due to microbial inhibition by the coating material (Habeeb et al., 2007; Tajkarimi and Ibrahim, 2011; Rahimi et al., 2018).

The overall acceptability of treated and untreated strawberry fruits showed a decreasing trend in sensory scores with prolonged storage under cold and room temperature conditions (Table 7).

***Table 7**: Effects of edible coatings on sensory evaluation (overall acceptability) of strawberry fruits stored under cold and ambient condition*

Treatments	Overall acceptability					
	Cold Storage			Ambient Storage		
	0 DAS	3 DAS	12 DAS	0 DAS	1 DAS	3 DAS
T1 - *Aloe vera* @ 15% + 3% ascorbic acid for 10 minutes	8.96	8.20	7.20	8.96	6.90	5.75
T2 - *Aloe vera* @ 25% + 3% ascorbic acid for 10 minutes	8.88	8.45	7.35	8.88	7.25	6.00
T3 - Starch 3% + 0.1% potassium sorbate for 3 minutes	8.83	7.95	7.10	8.83	6.65	5.20
T4 - Starch 2% + 0.1% potassium sorbate for 3 minutes	8.75	8.15	7.25	8.75	6.70	5.10
T5 - Control (no pretreatment)	8.88	7.60	x	8.88	6.43	5.60
Mean	8.86	8.07	7.23	8.86	6.79	5.53

DAS: Days after storage

The initial mean score of 8.86 decreased to 5.53 after three days of storage at ambient temperature, while cold-stored fruits maintained higher mean sensory scores of 7.23 up to twelve days of storage. The highest sensory scores (7.35 and 6.00) were recorded for 25% Aloe vera gel + 3% ascorbic acid (T2) under cold and ambient conditions, respectively. The treatment's lowest sensory score was recorded with 2% starch + 0.1% potassium sorbate (T4) after three days of storage under ambient conditions (5.10). The Aloe vera coating improved sensory quality while inhibiting spoilage (Rahimi et al., 2018).

Conclusion

The treatment coated with *Aloe vera* gel (25%) recorded as the most effective ($P < 0.01$) in retention of maximum TSS, titratable acidity, ascorbic acid, and reducing microbial load compared to other treatments at the end of 12 days of storage under cold condition whereas, uncoated fruits (control) showed the lowest ascorbic acid, TSS, titratable acidity and maximum microbial load and terminated by the day nine of storage. On the other hand, ambient stored strawberry fruits got spoiled after 3 days.

Conflict of Interest: The author(s) declared no conflict of interest.

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