IMPACT OF ALOE VERA GEL, LEMON ESSENTIAL OIL AND ASCORBIC ACID ON THE SHELF LIFE OF FRESH CUT APPLE

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ABSTRACT

This study was conducted to evaluate impact of adding aloe vera gel (2%), lemon essential oil (1.5%), and ascorbic acid (2.5%) and their combination to freshly cut apple slices stored at 4±1°C temperature and 65±5% relative humidity for 16 days. The slices were analysed after every 4 days for different physicochemical quality factors including, electrolyte leakage, weight loss, total soluble solids, total sugar, titratable acidity, pH, ascorbic acid, color, firmness, and decay index and consumers' acceptability. Combined coating with aloe vera, ascorbic acid, and lemon essential oil showed statistically significant ($P \leq 0.05$) results in maintaining physicochemical quality and consumers' acceptability as compared to untreated apple slices. During the study combined coated apple showed minimum mean electrolyte leakage (13.53%), weight loss (5.47%), reduced rise in TSS (12.27°brix) and total sugar (9.09%), retained loss in TA (0.37%), reduced rise in pH (3.37), lowered down losses of ascorbic acid (19.27 mg/100ml), retained h° and L value (81.13 and 69.60, respectively), maintained firmness (19.33N), lowered decay index (5%), and improved consumers' acceptability score (7.73) as compared to control sample (31.80%), (17.73%), (13.49°brix), (10.3%), (0.29%), (4.44), (11.67 mg/100ml), (69.27 and 60.80), (13.41N), (44%) and (4.73), respectively. Keeping in view the above results it can beconcluded that combined application of aloe vera gel, ascorbic acid and lemon essential oil effectively maintained quality of fresh cut apple slices at refrigerated storage conditions with improved consumers' acceptability. This coating can be used as viable treatment for preservationof apple slices at industrial scale. However, this study was conducted on small scale as laboratory experiment; therefore, the findings of current research should be validated at larger scale before commercialization.

INTRODUCTION

Apple (*Malus domestica* Borkh.) belongs to the subfamily pomoideae of the rosacea family. It is one of the delicious and nutrient-rich fruits of temperate climate (Sun *et al*., 2020). Apple is an ancient fruit because Greek and Romans grew it 2,500 years ago (Janick *et al.*, 1996). The modern apple (*M. domestica* Borkh) is considered the hybridized descendent of its wild ancestor *Malus sieversii*, found in the range between the border of Western China and the former Soviet Union (Cornille *et al*., 2019). That is why Asia especially Kazakhstan is accepted as the origin place of apple fruit (Forsline *et al*., 2003). The wild fruit represent full ranges of colors, forms, tastes and other attributes found in domesticated apple around the world. There aremany varieties of apple but a few are there which dominates World fruit production. Different varieties with varying quality characteristics have been developed over the centuries. However, very few are actively cultivated among which Idared, Gala and Golden delicious are on the top (Jakobek *et al.*, 2020). Apart from these Nuggets, Starking, Double red, Red golden, Jona gold, Sky spur, Spartin, Red chief, Kandhari, Amri and Meshaddi are also grown in different temperate areas of Pakistan (Hussain *et al*.,

2020).

An apple fruit contains 86.15% water, 12.03% carbohydrate and 2.38% ash content alongwith minimum amount of protein and fat content. Among minerals, it contains Potassium,Phosphorus, Calcium, Magnesium, Iron and Zinc (Patocka *et al*., 2020). Moreover, it is also a rich source of certain vitamins including A, C, E, B1, B2, B3, B6, B9 and K. Like other fruits organic acids are also present in apple among which malic acid and citric acid are found in appreciable quantities (Gogia *et al*., 2015). Furthermore, apple fruit is also an excellent source of several bioactive compounds, few of them are: Cinnamic acid species, Caffeic acid, Chlorogenic acid, Caffeoylquinic acid, Ferulic acid, Catechin, Epicatechin, Proantho cyanidins, Quercetin andAnthocyanin (Patocka *et al*., 2020). Due to the presence of these compounds apple is associated with reduction of certain deadly diseases such as cancer, diabetes and cardiovascular diseases in human beings (Bemi *et al*., 2019).

MATERIALS AND METHODS

3.1 Sample and minimal processing

Fresh apple fruit were purchased from the local fruit market of Peshawar region. The apples were handled carefully, avoiding heat and physical injuries. Apples were then packed in corrugated boxes and transferred to the Post-harvest laboratory of the Dept. of Food Science and Technology, The University of Agriculture, Peshawar. The fruit of uniform size and with no physical damage were selected for the study. The fresh apples were stored at 4±1°C, until minimal processing. Apples were washed, rinsed and dried prior to the peeling process. After peeling and coring, apple slices were diced into10×10×10mm cubes. These fresh-cut slices were then dipped in selected edible coating formulations for 2min (Shyu *et al*., 2019).

3.2 Coating of apple slices

Aloe Vera gel, Lemon essential oil (LEO) and ascorbic acid (Laboratory grade) were procured from local chemical shop situated in Peshawar. Coating solutions were prepared using different percentages of the mentioned coating agents. After dipping in prescribed coating solution for two minutes as shown in (Table 3.1) the slices were placed on mesh trays to drip off excess coating. After dipping, excess coating was allowed to drip off until a nice layer of coating was formed. After 30 minutes of drying out, the coated samples were stored at 4.0°C andchecked through various parameters after 4, 8, 12 and 16 days of storage (Najafi *et al.,* 2021).

Table 3.1 Plan of study for application of coating formulation on fresh-cut apple slices

Treatments	Washing	Aloe Vera (%)	Lemon essential oil(%)	Ascorbic acid (%)
TCO	2mins	0	0	0
TALV	-do-	2	0	0
TLEL	-do-	0	1.5	0
TASA	-do-	0	0	2.5
TAE	-do-	2	1.5	0
TLA	-do-	0	1.5	2.5
TAA	-do-	2	0	2.5
TALA	-do-	2	1.5	2.5

3.3 Qualitative Study

3.3.1 Electrolyte leakage analysis (%)

The measurement of electrolyte leakage was carried out by using the method specified byNajafi *et al.* (2021). Initially, 6 discs of 0.7 mm diameter and 0.8 mm length were taken from all the samples. The discs were place into 50 ml glass bottle filled with 35 ml deionized water. The glass bottles were incubated at 23°C. All the samples were agitated through a shaker at 200 rpm. After 1 minute (E_{c1}) and 180 minute (E_{c180}) of incubation, electrical conductivity of the sample solutions was measured using conductivity meter. The glass bottles were then autoclaved for 15 minutes at 121°C. The samples were cooled and electrical conductivity was measured again to get final conductivity values (E_{ct}). The following equation was used to calculate electrolyte leakage (EL) and expressed in percentage (%).

$$Electrolyte\ Leakage\ (\%) = \frac{(Ec180) - (Ec1)}{(Ect)}\ X\ 100 \qquad Equation\ 3.1$$

3.3.2 Weight loss of apple slices (%)

Weight loss percentage was determined by using the method of Nicolau-Lapena *et al.* (2021). After cutting into slices, each slice weight was measured using weight balance to get initial weight (W_i) of the samples. After each storage interval the samples were reweighed again to get final values for weight (W_f). The final and initial values were used to calculate percent weight loss by following the given formula.

$$Weight\ Loss\ (\%) = \frac{(Wi - Wf)}{(Wf)}\ X\ 100 \qquad Equation\ 3.2$$

3.3.3 Total Soluble Solids (^{0}brix)

The method specified by Butkeviciute *et al.* (2021) was followed to measure TSS of the apple slices. Flesh of three slices of each box was mixed. The apple flesh homogenate (3 gm)was extracted through mortar and pestle along with 30 ml of distilled water. To homogenize the extract, it was placed in centrifuge machine at 6000 rpm. After 15 minutes, the supernatant was removed and used to measure TSS by using Abbe refractometer and the results were expressedin degree brix (^{o}brix).

3.3.4 Total sugars (%)

Total sugars in the apple slices was measured using the well followed method of (AOAC,2012) and the results were expressed in percentage.

Preparation of the reagents

To prepare Fehling's solution A, 34.64g of Copper sulfate was dissolved in 200mldistilled water. The solution was further diluted to 500ml and filtered using filter paper. To prepare Fehling's solution B, 173g of Potassium sodium tartrate was dissolved in 200ml distilledwater. The volume was raised to 500ml with further addition of water. The solutions were stored in dark and cool place.

Preparation of standard sugar solution

Firstly, sugar stock solution was prepared by dissolving 5g sucrose in 2.5ml concentrated Hydrochloric acid (HCL) and 100ml distilled water. The solution was kept in ambient temperature for 3 days. After three days, the solution was diluted to 500ml using distilled waterto prepare 10mg/ml stock solution. 62ml of the stock solution was transferred into 250mlvolumetric flask with few drops of Phenolphthalein indicator. The solution was neutralized using20% NaOH till faint pink color appeared. The solution was then diluted to 250ml with distilled water to prepare standard sugar solution of 2.5mg/ml.

Slice sample preparation

The pulp of the slices was homogenized and 5g sample was transferred to a conical flask followed by the addition of 150ml hot water (60^{o}C). The solution was stirred to dissolve the sample for 30 minutes in water bath. After shaking, the solution was cooled and diluted in 250mlconical flask using distilled water. The solution was filtered through a filter paper. After filtration50ml filtrate was taken in 100ml volumetric flask and 2.5ml concentrated HCL was added to it and stored for 24 hours. After the storage, 3 drops of Phenolphthalein indicator were added, and neutralized with 20% NaOH until faint pink color appeared. Then, few drops of 1 normal HCL were added till the solution become color less again. Finally, the solution volume was raised to 100ml using distilled water to get the sample solution.

Blank titration

For blank titration, 5ml of Fehling's solution A and 5ml of Fehling's solution B were taken in conical flask. About 17ml standard sugar solution was added to it and then diluted with 30ml distilled water. The solution was placed in preheated hot plate and titrated against sugar standard solution until the color of the solution changed to bright orange. The solution wasboiled for 2 minutes with the addition of four drops of 1% methylene blue. Titration was continued until color of the solution resumed back to bright orange. Final burette reading was noted.

Sample titration

For sample titration, 5ml of Fehling's solution A and 5ml of Fehling's solution B were taken in conical flask with 30ml of sample solution. The solution was then diluted with 50ml distilled water. The flask was placed on a preheated plate and boiled to bright orange color. Sugar standard solution was loaded in the burette and titration was started after adding four dropsof 1% methylene blue indicator to the solution in conical flask. After appearance of bright red color titration was stopped and burette reading was taken and percent total sugar was calculated using the following formula.

$$Total\ sugar\ (\%) = \frac{(Sb - Ss)\ X\ Cs\ X\ 250\ X\ 100\ X100}{Ws\ X\ Vf\ X\ 50} \qquad Equation\ 3.3$$

Where,

Sb = the volume of standard sugar solution used for blank titration Ss = the volume of standard sugar solution used for sample titrationCs = the concentration of standard sugar solution

Ws = weight of the sample

Vf = the volume of final sample solution used during titration

3.3.5 Titratable acidity of apple slices (%)

The well followed procedure of (AOAC, 2012) was used for the determination of percentTitratable acidity (TA) of the apple slices.

Standardization of Sodium Hydroxide (NaOH) solution

By the addition of 6.3g of Oxalic acid powder into distilled water (1L) a stock solution was prepared. Similarly, 4.5g of NaOH powder was added to distilled water to obtain 0.1N solution. A burette was filled with freshly prepared solution of NaOH. Oxalic acid was poured into conical a flask with the addition of 2-3 drops of Phenolphthalein as an indicator. Titration was carried out until pink color appeared and prevailed for ten seconds. The following formula was used to assess normality of NaOH.

$$(N1V1 - N2V2) \qquad Equation\ 3.4$$

Where,

N1 = the normality of Oxalic acid

N2 = the normality of Sodium HydroxideV1 = the volume of Oxalic acid

V2 = the volume of Sodium Hydroxide

Titration of the apple pulp samples

Flesh of three slices of each box was mixed. The apple flesh homogenate (3 gm) was extracted through mortar and pestle along with 30 ml of distilled water. To homogenize the extract, it was placed in centrifuge machine at 6000 rpm. After 15 minutes, 10ml of the supernatant was transferred to graduated cylinder and volume was raised to 100ml using distilledwater. Again, 10ml of diluted sample was taken and 2-3 drops of Phenolphthalein was added toit. The sample was titrated against 0.1N sodium hydroxide solution until pink color appeared.The following formula was used to calculate TA.

$$Titratable\ acidity\ (\%) = \frac{CF\ X\ ml\ of\ NaOH\ X\ 100\ X\ 100}{A\ X\ B} \qquad Equation\ 3.5$$

Where,

A = pulp sample used for dilution

B = pulp sample used for titration

CF = correction factor (Malic acid 0.067)

3.3.6 pH of apple slices

The pH of slices was determined using the standard method of (AOAC, 2012). Calibration of the pH meter was done before taking readings for the samples. Buffer solutions (4.0 and 7.0) were used for calibration. After calibration, the electrode was rinsed with distilled water and cleaned with tissue paper. The cleaned electrode was then placed in the beakercontaining well mixed pulp. After reading was taken, the meter was reset and next reading was taken. pH values were directly noted from the screen of the meter.

3.3.7 Ascorbic acid analysis (mg/100ml)

The ascorbic acid (AA) of apple slices was measured by the method of (AOAC, 2012).

Standardization of 2,6-dichlorophenol indophenol dye

Firstly, 50g of 2,6-dichlorophenol indophenol dye along 42mg of sodium bicarbonate was taken in a graduated cylinder. Distilled water was added till the volume reached to 250ml. Inthe meantime, standard ascorbic acid solution was diluted with 0.4% Oxalic acid. At last, 2ml of the prepared solution of ascorbic acid was loaded into the burette. Titration was carried out until pink color appeared.

$$Indophenol\ dye\ factor\ (Fd) = \frac{ml\ of\ ascorbic\ acid}{ml\ of\ dye} \qquad Equation\ 3.6$$

Slice sample titration

Flesh of three slices of each box was mixed. The apple flesh homogenate 3g wasextracted through mortar and pestle along with 30ml of distilled water. To homogenize the extract, it was placed in centrifuge machine at 6000 rpm. After 15 minutes, 10ml of the supernatant was transferred to graduated cylinder and volume was raised to 100ml using distilledwater. From the diluted solution, 10ml sample was taken and titrated against Indophenol dye until pink color appeared. The following formula was used to calculated ascorbic acid of the apple slices.

$$Ascorbic\ acid\ (mg/100ml) = \frac{Ld\ X\ Fd}{Sd\ X\ Pt}\ X\ 100 \qquad Equation\ 3.7$$

Where,

Fd = dye factor

Ld = dye used (ml)

Sd = diluted solution used in titration (ml) Pt = sample volume used in titration (ml)

3.3.8 Slice color (Hue angle and L* value)

Using Colorimeter (PCE-CSM 2) Hue angle (h^o) and L* value were measured by making use of the method specified (Chiabrando and Giacalone, 2015). The colorimeter was calibrated for black and white conditions. The aperture of the colorimeter was placed on the surface of apple slice and reading was recorded form both sides and average was taken as final values.

3.3.9 Firmness of apple slices (N)

To determine firmness of the apple slices, Lutron penetrometer with 3mm probe was used(Osuga *et al.*, 2021). The penetrometer switched on, and from the unit options Newton was selected. The probe was fixed tightly and the penetrometer was set to zero. The apple slices were placed at the base, gently the probe was inserted and reading was recorded in newton (N). The same procedure was followed on other side of the slices. Then average of the two reading was calculated to get firmness of the samples.

3.3.10 Decay index (%)

Decay index of apple slices was determined by following the method of (El-Gioushy *et al.*, 2022). The decayed area was measured using digital caliper. The total area and decayed area were then used to measure decay index using the below given formula.

$$Decay\ index\ (\%) = \frac{Decay\ area\ in\ mm}{Total\ area\ in\ mm}\ X\ 100\ E \qquad Equation\ 3.8$$

3.3.11 Consumers' acceptability of apple slices

During the storage of apple slices at 4±1ºC and 70±5% relative humidity, consumers' acceptability of apple slices was determined by using 9 point Hedonic scale (Larmond, 1977). Tocarry out sensory analysis, twenty (20) semi-trained judges were employed from the students of department of Food Science and Technology, The University of Agriculture, Peshawar. Before the study, the judges were trained by providing them freshly cut apple slices in three consecutive sessions. For sensory analysis the judges were moved to the sensory analysis laboratory of the food science and technology department. The judges were placed in individual sensory analysis booth in proper lighting. The judges were provided with potable water to rinse their mouth after every analysis. The slices were placed in disposable plates and brought to the judges. Thejudges then rated the slices for acceptability in terms of color, taste, flavor, and aroma. Rating of apple slices was done using 9-point hedonic scale, where, 1-4 (extreme dislike to dislike), 5 (neither like nor dislike), and 6-9 (like to extremely like).

3.4 Statistical analysis

The study results were statistically analyzed using 2-factorial completely randomized design (CRD) through Statistix 8.1 sofware. The results' means were separated through least significant difference (LSD) at 95% confidence interval (P≤0.05) following the method of (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

4.1 Electrolyte leakage Analysis (%)

Impact of aloe vera, lemon essential oil, and ascorbic acid coating on the electrolyte leakage of fresh-cut apple slices is presented in the Table 4.1. Coating of apple slices with aloe vera, lemon essential oil, ascorbic acid and combination of these treatments significantly (P≤0.05) reduced electrolyte leakage during the storage period of 16 days. A gradual rise was observed in electrolyte leakage during the study intervals. The interaction between treatment and storage time also came out to be significant. During the study period TALA effectively controlled electrolyte leakage followed by TAA and TLA as compared to control where 57% electrolyte leakage was observed after 16 days refrigerated storage. The results of individual application of aloe vera gel, lemon essential oil and ascorbic acid showed statistically similar results, however, combining these coating treatments augmented their efficiency to control electrolyte leakage.

According to Mao *et al.* (2007) electrolyte leakage in apple slices was in the range of 20-40% that increased up to 60% or more depending on storage conditions, while storing apple slices under controlled atmosphere led to 20-25% reduction in electrolyte leakage. Similarly, Najafi *et al.* (2021) found combination of alginate and ascorbic acid edible coating effective against electrolyte leakage leading to 20% less electrolyte leakage compared to uncoated apple slices. Guo *et al.* (2011) reported that electrolyte leakage in fresh cut Hami melon increased with increasing storage life. In the same way electrolyte leakage in minimally processed mango can rise up to 60-65% during storage period of 14 days (de Sousa *et al.*, 2017). All of the above mentioned studies strengthen the findings of current study. Electrolyte leakage is an indirect measurement of bio membrane damage caused by adverse conditions and senescence

of tissues and it is directly dependent on temperature of the surrounding atmosphere (Iakimova and Woltering, 2018). Moreover, browning of apple slices also accelerates leakage of electrolytes (Najafi *et al.*, 2021). All coating treatments either individually or in combination effectively controlled electrolyte leakage from the apple slices which might be due to the fact that coating formed a protective layer on the surface resulting in reduction of oxidative changes occurring in the cells (Jiang, 2013). The antioxidant properties of ascorbic acid and lemon essential oil have the ability to lower processing stress consequently reducing loss of electrolytes (Najafi *et al.*,2021). Thus combination of aloe vera gel, lemon essential oil, and ascorbic acid might reduce processing stress due to their antioxidant potential and oxidative reactions through the formation of protective layer on the surface of apple slices ultimately leading to lowered electrolyteleakage.

Table 4.1 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the electrolyte leakage (%) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

Days after coating						
Treatments	**Initial**	**4**	**8**	**12**	**16**	**Mean**
TCO	0.00	20.00	32.00	50.00	57.00	***31.80 a***
TALV	0.00	14.00	26.00	35.33	44.00	**23.87 b**
TLEL	0.00	15.67	28.33	37.33	47.00	**25.67 b**
TASA	0.00	15.00	27.33	36.33	45.33	**24.80 b**
TAE	0.00	11.33	19.67	27.67	36.67	**19.07 d**
TLA	0.00	13.00	23.00	30.33	39.67	**21.20 c**
TAA	0.00	9.67	17.00	24.67	33.00	**16.87 e**
TALA	0.00	6.33	13.33	21.00	27.00	**13.53 f**
Mean	**0.00 e**	**13.13 d**	**23.33 c**	**32.83 b**	**41.21 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon esential oil and 2.5% ascorbic acid

4.2 Weight loss of apple slices (%)

Weight loss is one of the important factors that affect the storage quality of apple slices. Excess loss of water cause wilting, adversely affect visual appearance and firmness of fruits that resulting in reduction in market price of the commodities (Xanthopoulos *et al.*, 2017). Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on the percent weight loss of fresh-cut apple slices is presented in the Table 4.2. Coating of apple slices with aloe vera gel, lemon essential oil, and ascorbic acid or combination of these treatments significantly (P≤0.05)

reduced weight loss during the storage period of 16 days. A gradual rise was observed in weight loss during the study intervals. The interaction between treatment and storage time also came out to be significant. During the study period TALA effectively controlled weight loss followed by TAA and TLA as compared to control where 26% weight loss was observed after 16 days refrigerated storage. The results of individual application of aloe vera, lemon essential oil, or ascorbic acid showed statistically similar results. However, combining these coating treatments augmented their efficiency to control weight loss significantly.

Table 4.2 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the weight loss (%) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	0.00	16.67	21.67	24.00	26.33	**17.73 a**
TALV	0.00	9.67	16.33	19.67	22.67	**13.67 b**
TLEL	0.00	10.67	17.00	20.67	23.67	**14.40 b**
TASA	0.00	9.67	16.33	20.33	23.00	**13.87 b**
TAE	0.00	6.67	12.33	17.33	21.00	**11.47 c**
TLA	0.00	5.00	9.67	14.33	19.00	**9.60 d**
TAA	0.00	3.67	7.00	11.67	15.67	**7.60 e**
TALA	0.00	2.00	4.00	8.67	12.67	**5.47 f**
Mean	**0.00 e**	**8.00 d**	**13.04 c**	**17.08 b**	**20.50 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

According to Sumonsiri (2017) weight loss in ascorbic acid coated fresh cut apples stored for 12 days was in the range of 25-30%. Najafi *et al.* (2021) also reported that coating of freshly cut apples prevent weight loss during storage. Similarly, Nicolau-Lapena *et al.* (2021) also found aloe vera gel effective in maintaining weight loss in cut apple slices. Moreover, Shirzadeh and Kazemi, (2012) recommended lemon essential oil as efficient coating treatment against weight loss in apple. On the other hand, Butkeviciute *et al.* (2021) reported loss of weight differ with

varieties and storage conditions. The findings of current study are in line with the above mentioned literature. Weight loss is one of the important factors that affect the storage quality of apple slices. Excess water loss cause wilting, adversely affect visual appearance and firmness of fruits, especially fresh fruits and subsequently resulting in reduction in market price of the products (Xanthopoulos *et al*., 2017). Different metabolic reactions occur in fruit during storage as a result water is produced (Huan *et al.,* 2021). This water transpired from the fruit surface through different pores into the surrounding atmosphere due to lower relative humidity of the storage atmosphere (Kabir *et al.,* 2020). Weight loss in cut slices also occur due to removal of fruit skin exposing the tissues to the environment with lower humidity. Weight loss is variety specific phenomenon, which also depend on number of cuticles present on surface of the slice (Mahato *et al.,* 2019). Lower weight loss in coated samples might be due to hygroscopic characteristics of the coating agents that form water barrier between the apple slices and the surrounding as a result moisture is prevented from being released into surrounding environment (Misir *et al.*, 2014). Moreover, water content is conserved by the coating materials leading to reduced weight loss along with prevention of wilting and shriveling (Xanthopoulos *et al*., 2017). Similarly, edible coating act as a barrier against Oxygen (O_2), Carbon dioxide (CO_2), and water vapor transmission that help reduce weight loss of the apple slices (Aidilla and Thevinta, 2017). Previously, aloe vera gel, lemon essential oil, and ascorbic acid alone and in combination with other coating agents have been proved fruitful against weight loss through the formation of layer on the surface, inhibition of metabolic processed like respiration, and prevention of gaseous exchange (Shirzadeh and Kazemi, 2012; Sumonsiri, 2017; Najafi *et al.,* 2021; Nicolau-Lapena *et al.,* 2021). The combination of all these three coating agents proved very effective in current study due to the above reported functions.

4.3 Total Soluble Solids (^{o}Brix)

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on total soluble solids (TSS) of fresh-cut apple slices presented in the Table 4.3. Coating of apple slices with aloevera gel, lemon essential oil, ascorbic acid and combination of these treatments significantly ($P \leq 0.05$) maintained TSS during the storage period of 16 days. However, a gradual rise was observed in TSS of fresh cut apple slices was observed during the study intervals. The interaction between treatment and storage time also came out to be significant. During the study period T_{ALA} effectively prevented rise in TSS of apple slices followed by T_{AA} and T_{LA} as compared to control where TSS reached to 14.70^{o}Brix after 16 days refrigerated storage. The results of individual application of aloe vera gel, lemon essential oil and ascorbic acid showed statistically similar results. However, combining these coating treatments had positively reduced rise in TSS of freshcut apple slices.

According to Shirzadeh and Kazemi, (2012); Roble *et al*. (2010) and Ergun and Satici, (2012) reported total soluble solids of apple fruit ranged between 12-14.5^{o}brix. Previously, Ale over gel coating effectively maintained TSS of fresh cut apple slices (Nicolau-Lapena *et* al., 2021). Ascorbic acid in combination with alginate significantly control increase in TSS of apple slices (Najafi *et al.,* 2021). Furthermore, findings of Chiabrando and Giacalone, (2019) strengthened outcomes of this study, who observed that application of essential oil and alginate retained changes in TSS of apple slices during storage.

Table 4.3 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the TSS (^{0}brix) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

Days after coating						
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	12.00	12.55	13.70	14.50	14.70	**13.49 a**
TALV	12.00	12.48	13.10	14.00	14.50	**13.22 b**
TLEL	12.00	12.48	13.10	13.83	14.43	**13.17 b**
TASA	12.00	12.47	13.07	13.87	14.37	**13.15 b**
TAE	12.00	12.27	12.57	13.10	13.70	**12.73 c**
TLA	12.00	12.30	12.60	13.17	13.83	**12.78 c**
TAA	12.00	12.20	12.37	12.73	13.33	**12.53 d**
TALA	12.00	12.10	12.20	12.40	12.67	**12.27 e**
Mean	**12.00 e**	**12.36 d**	**12.84 c**	**13.45 b**	**13.94 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

TSS is used to represents number of dissolved solids in a given solution. Sugars are the major constituents besides other minor compounds such as minerals, pectin, and amino acids thatcontribute to TSS and determine commercial quality as an important parameter (Kurubas and Erkan, 2018). With increasing storage life, large and complex carbohydrates are broken down into mono and disaccharides as a result rise in TSS occur (Ergun and Satici, 2012). The major sugars in apple are fructose, glucose, sucrose, and sorbitol, which are responsible for the sweetness (Butkeviciute *et al.*, 2021). All of the coating treatments form layer on the surface of apple slices of proper air permeability and thickness, as a result certain catabolic reactions like respiration, nutrients degradation and water desorption is decreased and TSS is maintainedduring storage (Zhang *et al.*, 2022). Combination of aloe vera gel, ascorbic acid, and lemon essential oil are far more effective against rise of the TSS in apple slices during the storage period of 16 days in refrigerated conditions (4^{o}C).

4.4 Total sugars (%)

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on the total sugar percentage of fresh-cut apple slices is presented in Table 4.4. Applied edible coating had significantly (P≤0.05) retained increase in total sugars of fresh cut apple slices. However, a gradual rise was observed in total sugars during 16 days of storage.

Furthermore, interaction between treatment and storage time also significantly influenced total sugar content of the slices. During the study period T_{ALA} effectively prevented increase in total sugars followed by T_{AA} and T_{LA} as compared to control where total sugar increased to 11.49% after the storage period in refrigerated conditions. This is also reveal from data of individual application of aloe vera gel, lemon essential oil, and ascorbic acid showed statistically similar results, however, combining these coating treatments augmented their effectiveness to control increase in total sugars.

Butkeviciute *et al.* (2021) observed an increase in total sugar content in apple samples during storage from 9.67-12.47%. Similar, results were obtained from the study conducted by Núñez-Gastélum *et al.* (2015). Previously, Nicolau-Lapena *et al.* (2021) found that aloe vera gel coating maintained total sugar of fresh cut apple slices. Likewise, ascorbic acid in combination with alginate significantly control increase in total sugar of apple slices (Najafi *et al.*, 2021). Risein total sugar of apple slices is also retained by combined application of essential oil and alginate (Chiabrando and Giacalone, 2019). The major sugars in apple are fructose, glucose, sucrose, and sorbitol, which are responsible for the sweetness of the fruit (Butkeviciute *et* al., 2021). With increase storage life, higher and complex carbohydrates are broken down into mono and disaccharides as a result rise in total sugars occur (Ergun and Satici, 2012). All of the coating treatments form layer on the surface of apple slices of proper air permeability and thickness, as a result certain catabolic reactions like respiration, nutrients degradation and water desorption is decreased and prevented rise in total sugars during storage (Zhang *et al.*, 2022).

Table 4.4 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the total sugars (%) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	8.90	9.34	10.49	11.29	11.49	**10.30 a**
TALV	8.90	9.27	9.89	10.79	11.29	**10.03 b**
TLEL	8.90	9.27	9.89	10.62	11.22	**9.98 b**
TASA	8.90	9.26	9.86	10.66	11.16	**9.97 b**
TAE	8.90	9.06	9.36	9.89	10.49	**9.54 c**
TLA	8.90	9.09	9.39	9.96	10.62	**9.59 c**
TAA	8.90	8.99	9.16	9.52	10.12	**9.34 d**
TALA	8.90	8.89	8.99	9.19	9.46	**9.09 e**
Mean	**8.90 e**	**9.15 d**	**9.63 c**	**10.24 b**	**10.73 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and

1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid.

4.5 Titratable acidity of apple slices (%)

Impact of aloe vera, lemon essential oil, and ascorbic acid coating on the titratableacidity (TA) of fresh-cut apple slices is presented in the Table 4.5. Treatment of apple slices withthese edible coatings and their combination significantly ($P \leq 0.05$) maintained TA content during storage period of 16 days, however, a gradual decrease was observed in TA of fresh cut apple slices. Additionally, it was found that treatment and storage interaction had significant influence on TA of the fresh cut apple slices. During the study period T_{ALA} effectively controlled decrease in TA followed by T_{AA} and T_{LA} as compared to control where TA content reduced to 0.17%. The results of individual application of aloe vera gel, lemon essential oil, and ascorbic acid showed statistically similar results, however, combining these coating treatments augmented their efficiency to maintain TA of the apple slices.

Table 4.5 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the titratable acidity (%) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
TCO	**1**	**4**	**8**	**12**	**16**	**Mean**
TALV	0.40	0.35	0.28	0.23	0.17	**0.29 e**
TLEL	0.40	0.36	0.31	0.27	0.22	**0.31 d**
TASA	0.40	0.36	0.30	0.26	0.21	**0.31 d**
TAE	0.40	0.36	0.31	0.26	0.22	**0.31 d**
TLA	0.40	0.37	0.34	0.32	0.29	**0.34 bc**
TAA	0.40	0.37	0.33	0.30	0.27	**0.33 c**
TALA	0.40	0.38	0.35	0.33	0.30	**0.35 b**
TCO	0.40	0.39	0.37	0.35	0.32	**0.37 a**
Mean	**0.40 a**	**0.37 b**	**0.33 c**	**0.29 d**	**0.25 e**	

Different letters accompanying mean values show significant difference among them at $P \leq 0.05$. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

Cofelice *at al.* (2019) study showed that titratable acidity of fresh cut apple decreased during storage and were in the range of (0.35-0.15%). Likewise, Mbili *et al.* (2018) and Najafi*et* al., 2021) both reported similar decreasing trend in titratable acidity of apple slices in storage. Coating of apple slices with ascorbic acid in combination with alginate had significantly influence titratable acidity (Najafi *et al.*, 2021). Ergun and Staici (2012)

also observed that aloe vera gel coating of apple slices positively prevent decrease in TA during storage. Additionally, lemon essential oil has also been reported to prevent decrease in titratable acidity (Zhang *et al.,* 2022). Titratable acidity is commonly used to represent amount of different organic acids presentin the food system that affect the taste of that particular food. Malic acid is the predominant acid in apple, not only affect flavor but also had important impact on quality of the fruit (Guan *et al.,* 2015; Najafi *et al.,* 2021). During ripening and fruit senescence decrease in titratable acidity might be due to oxidation of the acids to fulfill energy requirements (Butkeviciute *et al.,* 2021). After carbohydrates, organic acids serve as major respiratory substrate in food system (Huan *et al*., 2021). Ascorbic acid, aloe vera gel, and lemon essential coating of apple slices form appropriate layer on the surface of apple slice leading to reduced gaseous exchange and lowered respiration thereby prevent reduction of titratable acidity during storage (Ergun and Satici, 2012; Najafi *et al.,* 2021; Zhang *et al*., 2022).

4.6 pH of apple slices

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating had significantly($P \leq 0.05$) control changes in pH of fresh-cut apple slices during the storage period of 16 days (Table 4.6). It was also observed from the analysis that treatment and storage interaction had significant impact on controlling the pH of the fresh cut apple slices. During the study period T_{ALA} effectively controlled increase in pH followed by T_{AA} and T_{LA} as compared to control where pH increased to 5.4 after the storage period. Individual application of aloe vera gel, lemon essential oil, and ascorbic acid showed statistically significant results in maintaining quality of fruits. However, combining these coating treatments augmented their effectiveness to prevent increase in pH of the apple slices.

According to Cofelice and Cuomo (2019) pH of fresh cut apple was in the rangeof (3.5-4.0) that increased during the storage period of 15 days in controlled samples. Nicolau-Lapena *et al.* (2021) also reported that pH of apple slices was (3.5-3.9). Chiabrando and Giacalone (2015) found that pH of fresh cut apple was in the range of (4-4.5) which increased during storage up to 5.2 during storage period of 10 days. Previously, aloe vera gel in combination with ferulic acid has been found effective in lowering down increase in pH of fresh cut apples (Nicolau-Lapena *et al.,* 2021). Ascorbic acid combined with alginate also lowered down increased in pH of apple during storage (Najafi *et al.,* 2021). No literature is available regarding effect of lemon essential oil on the pH of apple fruit; however, it has been found to prevent rise in TA of different fruits, thus, it can be said that lemon essential oil affect pH of apple slices because there is an indirect relation between pH and TA of the fruits (Zhang *et al.,* 2022). During respiration organic acids are utilized resulting in increase in the pH of apple slices (Butkeviciute *et al.,* 2021). All the coating treatment prevented gaseous exchange, slowed down further ripening, inhibit respiration leading to maintenance of pH of the samples (Ergun and Satici, 2012; Najafi *et al.,* 2021; Zhang *et al.,* 2022).

Table 4.6 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the pH of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	3.50	3.90	4.40	5.00	5.40	**4.44 a**
TALV	3.50	3.80	4.20	4.60	4.93	**4.21 b**
TLEL	3.50	3.87	4.27	4.70	5.03	**4.27 b**
TASA	3.50	3.83	4.23	4.67	5.00	**4.25 b**
TAE	3.50	3.70	3.93	4.17	4.37	**3.93 cd**
TLA	3.50	3.77	4.03	4.27	4.47	**4.01 c**
TAA	3.50	3.63	3.83	4.07	4.27	**3.86 d**
TALA	3.50	3.53	3.67	3.87	4.07	**3.73 e**
Mean	**3.50 e**	**3.75 d**	**4.07 c**	**4.42 b**	**4.69 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

4.7 Ascorbic acid analysis (mg/100ml)

Impact of aloe vera, lemon essential oil, and ascorbic acid coating on the ascorbic acid content of fresh-cut apple slices is presented in the Table 4.7. Coating of apple slices with aloe vera gel, lemon essential oil, ascorbic acid and combination of these treatments significantly (P≤0.05) retained ascorbic acid content during the storage period of 16 days. However, a gradualdecrease was observed in ascorbic acid of apple slices during the storage intervals. The interaction between treatment and storage time also came out to be significant. During the study period TALA (19.27 mg/100ml) effectively control decrease in ascorbic acid followed by TLA and TAA as compared to control samples (3.67 mg/100ml) after the storage period. The results of individual application of aloe vera gel, lemon essential oil, and ascorbic acid showed statistically similar result; however, combining these coating treatments augmented their efficiency to retain ascorbic acid content of the apple slices more effectively.

Table 4.7 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the ascorbic acid (mg/100ml) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	22.00	14.67	10.67	7.33	3.67	**11.67 f**
TALV	22.00	16.33	12.33	9.67	6.00	**13.27 e**
TLEL	22.00	17.67	13.67	11.00	8.00	**14.47 d**
TASA	22.00	18.33	14.67	12.33	9.33	**15.33 cd**
TAE	22.00	18.33	15.33	13.67	11.00	**16.07 c**
TLA	22.00	20.00	17.67	16.00	13.67	**17.87 b**
TAA	22.00	19.00	16.67	15.00	12.67	**17.07 b**
TALA	22.00	21.33	19.33	18.00	15.67	**19.27 a**
Mean	**22.00 e**	**18.21 d**	**15.04 c**	**12.88 b**	**10.00 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid.

Varming *et al.* (2013) has studied ascorbic acid content in different apple cultivars which was in the range of 1-27 mg/100ml. The ascorbic acid content of apple tends to decrease with increasing storage duration at 4°C (Farina *et al.*, 2020). Similar decreasing trend in ascorbic acid content of apple was also reported in another study (Lemmens *et al.*, 2020). Previously, ascorbic acid and aloe vera gel coating has been proved effective in retaining ascorbic acid content of different fruit slice (Sogvar *et al.*, 2016; Ali *et al.*, 2020). Similarly, lemon essential oil coating also proved effective in retaining ascorbic acid content during storage (Niolau-Lapena *et al.*, 2021). Ascorbic acid found in different fruits has excellent antioxidant capacity and have positive impact on the health of consumers (Sogvar *et al*., 2016). During storage different factorscause degradation of ascorbic acid, including, increase in storage time and temperature, water loss, mechanical injuries, presence of oxygen (Mbili *et al*., 2018; Tapia *et al*., 2008). As application of ascorbic acid, lemon essential oil, and aloe vera gel coating form proper layer on the surface of fresh cut apples, thereby prevent gaseous exchange and water loss leading to reduction in ascorbic acid losses (Shirzadeh and Kazemi, 2012; Sogvar *et al*., 2016; Sumonsiri, 2017; Najafi *et al.*, 2021).

4.8 Color of slices (h^o and L value)

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on the color in terms of hue (h^o) and lightness (L*) of fresh-cut apple slices is presented in the Table 4.8 and 4.9,respectively. Coating of apple slices with

aloe vera gel, lemon essential oil, and ascorbic acid andtheir combination has significantly (P≤0.05) reduced the degradation in h° and L* value, however, a gradual decrease was observed in h° and L value of apple slices during the 16 days ofstorage. This was also observed that treatment and storage interaction was more effective against the losses in hue and L* of the fresh cut apple slices during storage. Additionally, the study revealed that TALA effectively controlled decrease in h° and L value followed by TAA and TLA as in comparison to compared samples (52° and 46, respectively) after the storage period. Furthermore, it was also observed that individual application of aloe vera gel, lemon essentialoil, and ascorbic acid showed statistically similar but significant results. However, combining these coating treatments augmented their efficiency to maintain decrease in h° and L* value of the apple slices.

According to studies conducted, h° and L* value for fresh cut apple was in the range of 81-96 and 64-77, respectively (Chiabrando and Giacalone, 2015; Rux *et al.*, 2019). Likewise, Farina *et al.* (2020) also observed h° and L* value within the given range in the study on freshcut apple slices. A decrease was observed in h° and L* value of fresh cut apples with increase in storage duration (Plesoianu *et al.*, 2021). Previously, aloe vera gel coating has been found effective in retaining color of fresh cut apple slices (Supapvanich *et al.*, 2016; Song *et al.*, 2013). Similarly, lemon essential oil and ascorbic acid coating also proved effective in retaining color ofdifferent fruits (Chiabrando and Giacalone, 2015; Plesoianu *et al.*, 2021; Zhang *et al.*, 2021). All of the mentioned literature supports the results of current research findings.The L value is used torepresent lightness and h° shows information about color of the sample (Chiabrando and Giacalone, 2015). Decrease occurred during storage in L value and h° indicating occurrence of browning during storage of the apple slices (Supapvanich *et al.*, 2016). Ascorbic acid, lemon essential oil, and aloe vera gel coating formed desired layer on the surface of apple slices (Shirzadeh and Kazemi, 2012; Sogvar *et al.*, 2016; Sumonsiri, 2017; Najafi *et al.*, 2021), prevent gaseous exchange (Zhang *et al.*, 2021) leading to prevention of browning Chauhan *et al.*, 2011; Song *et al.*, 2013, Chauhan *et al.*, 2015) as a result h° and L value are maintained.

Table 4.8 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the slice hue (h^0) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	87.00	77.33	69.00	61.00	52.00	**69.27 e**
TALV	87.00	80.67	73.33	66.67	60.33	**73.60 d**
TLEL	87.00	79.33	72.00	65.33	59.00	**72.53 d**
TASA	87.00	80.00	72.67	66.00	59.67	**73.07 d**
TAE	87.00	83.33	78.00	73.33	69.00	**78.13 bc**
TLA	87.00	82.00	76.67	71.67	67.33	**76.93 c**
TAA	87.00	84.00	79.33	75.00	71.33	**79.33 b**
TALA	87.00	85.00	82.00	77.67	74.00	**81.13 a**

Mean	**87.00 a**	**81.46 b**	**75.38 c**	**69.58 d**	**64.08 e**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

Table 4.9 Effect of aloe vera gel, lemon essential oil, and ascorbic acid coating and their combination on the slice color (L* value) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

Days after coating						
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	74.00	68.33	61.33	54.33	46.00	***60.80 f***
TALV	74.00	69.33	62.67	57.67	51.00	***62.93 e***
TLEL	74.00	69.67	64.00	59.00	52.33	***63.80 e***
TASA	74.00	69.33	63.33	58.33	52.00	***63.40 e***
TAE	74.00	70.67	66.67	63.00	59.33	***66.73 c***
TLA	74.00	69.33	65.33	61.33	56.33	***65.27 d***
TAA	74.00	71.33	68.33	64.67	62.33	***68.13 b***
TALA	74.00	72.00	69.67	67.33	65.00	***69.60 a***
Mean	***74.00 a***	***70.00 b***	***65.17 c***	***60.71 d***	***55.54 e***	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

4.9 Firmness of apple slices (N)

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on the firmness of fresh-cut apple slices is presented in the Table 4.10. Statistical analysis indicated that coating of apple slices with aloe vera gel, lemon essential oil, and ascorbic acid and combination of these treatments significantly (P≤0.05) maintained firmness during the storage period of 16 days. Buta gradual decrease was observed in firmness of apple slices during the study intervals. The interaction between treatment and storage time also came out to be significant. During the study period TALA effectively maintained firmness followed by TAA and TLA as compared to control sample that reduced to (11.3N) after the storage period. The results of individual application of either aloe vera gel, lemon essential oil, or ascorbic acid showed statistically similar but significant results, however, combining these coating treatments augmented their efficiency to maintain firmness of the apple slices.

Table 4.10 Effect of aloe vera, lemon essential oil, and ascorbic acid coating and their combination on firmness (N) of apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	22.00	12.13	10.20	11.37	11.33	**13.41 e**
TALV	22.00	13.93	11.00	11.67	12.33	**14.19 e**
TLEL	22.00	13.33	10.67	11.33	12.00	**13.87 e**
TASA	22.00	13.00	10.33	11.67	11.33	**13.67 e**
TAE	22.00	17.67	16.33	14.67	13.00	**16.73 c**
TLA	22.00	16.33	14.67	13.00	12.33	**15.67 d**
TAA	22.00	19.00	17.67	16.00	14.00	**17.73 b**
TALA	22.00	21.33	19.67	18.00	15.67	**19.33 a**
Mean	**22.00 a**	**15.84 b**	**13.82 c**	**13.46 cd**	**12.75 d**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

Özdemir and Gökmen (2019) found out that firmness of fresh cut apple slices was in the range of 17-21N during their study on the stability of fresh cut apples during refrigerated storage.Giacalone and Chiabrando (2012) reported firmness of fresh cut apple in the range of 17-24N which decrease with increasing storage duration. Similarly, Osuga *et al.* (2021) also reported similar trend in firmness of fresh cut apples. Previously, Ergun and Satici (2012) found aloe vera gel coating effective in maintaining firmness of flesh of apple fruit. Ascorbic acid and ethanol have been found to efficiently retained firmness of fresh cut apples during storage (Yan *et al.*, 2017). During storage of cut apples polygalacturonase enzyme cause break down of pectin changing texture and subsequently cause firmness loss (Özdemir and Gökmen, 2019). Firmnessis considered as the most important quality parameter of the fruits by resisting changes in the shape (Xu *et al.*, 2018). Coating of apple slices with ascorbic acid, aloe vera gel, and lemon essential oil prevent oxygen into the food system (Aidilla and Thevinta, 2017) thereby inhibiting respiration rate as a result hydrolysis of starch is delayed (Mahajan *et al.*, 2010; Jiang, 2013) and firmness is retained.

4.10 Decay index (%)

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on thedecay index of fresh-cut apple slices is presented in the Table 4.10. Application of edible coatingof apple slices with aloe vera, lemon essential oil, and ascorbic acid and their combination had significantly (P≤0.05) reduced decay incidence during the storage period of 16 days. This was also noted that treatment and storage interaction had significantly influence the

decay incidence. During the study period TALA effectively reduced decay index and till day 16 only 25% decay incidence was observed followed by TAA (3.0% on day 8) and TLA (8.0% on day 8) was observed which intensified with further increase in storage duration as compared to control sample thathad 50% decay incidence was observed on day 8 of storage, which further increased 100% onday 16 of the storage period.

Previously, Supapvanich *et al.* (2016) found aloe vera gel coating delayed decay incidence of fresh cut apples for 6 days. Similarly, Sogvar *et al.* (2016) reported that aloe vera gel and ascorbic acid coating proved effective in reducing disease incidence in strawberry fruit. Lemon essential oil coating successfully lowered decay incidence in fresh cut apples (Cofelice *etal.,* 2019). Ascorbic acid combined with electrolyzed water inhibited growth of different microorganisms and delayed decay incidence in fresh cut apples (Plesoianu *et al.,* 2021). Lemon essential oil has also reduced disease incidence in citrus fruits during storage (Zhang *et al.,* 2021). Fresh cut apples contain sufficient amount of nutrients and water content which make them susceptible to microbial invasions (Najafi *et al.,* 2021). On the other hand, removal of peel from the slices makes them prone to browning making them less desirable to the consumers (Cofelice *at al.,* 2019). Both lemon essential oil and ascorbic acid directly prevented proliferationof microbes due to their antimicrobial properties, hence, prevented decay of the samples (Plesoianu *et al.,* 2021). Similarly, aloe vera gel prevents the growth of microorganism especiallyepiphytic microbiota (Zapata *et al.,* 2013). Furthermore, entering of oxygen is blocked and free radicals are removed by antioxidant capacities (Zhang *et al.,* 2021) and layer formation on the surface of apple slices reduced browning of the slices consequently reducing decay incidence (Sogyar *et al.,* 2016).

Table 4.11 Effect of aloe vera, lemon essential oil, and ascorbic acid coating and their combination on the decay index (%) of fresh cut apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	0.00	0.00	50.00	70.00	100.00	**44.00 a**
TALV	0.00	0.00	33.33	55.00	75.00	**32.67 b**
TLEL	0.00	0.00	20.00	37.67	60.00	**23.53 c**
TASA	0.00	0.00	20.00	34.67	55.00	**21.93 c**
TAE	0.00	0.00	11.33	24.33	45.67	**16.27 d**
TLA	0.00	0.00	8.00	18.67	38.33	**13.00 e**
TAA	0.00	0.00	3.33	13.33	33.33	**10.00 f**
TALA	0.00	0.00	0.00	0.00	25.00	**5.00 g**
Mean	**0.00 d**	**0.00 d**	**18.25 c**	**31.71 b**	**54.04 a**	

Different letters accompanying mean values show significant difference among them at P≤0.05. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and

1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

4.11 Consumers' acceptability of apple slices

Impact of aloe vera gel, lemon essential oil, and ascorbic acid coating on consumers' acceptability of fresh-cut apple slices is presented in the Table 4.11. Statistically edible coatingof fresh cut apple slices with aloe vera, lemon essential oil, ascorbic acid and their combination had significantly ($P \leq 0.05$) affected consumers' acceptability during the storage period of 16 days. Furthermore, the interaction between treatment and storage time had also significantinfluence the consumers' acceptability. During the study period TALA remained highly acceptableto the consumers and till day 16 it was acceptable to the consumers with acceptability score 6.0 followed by TAA and TLA as compared to control which was acceptable to the consumers only till day 4. The control became slightly unacceptable on day 8 and strongly unacceptable on day 12. The data of individual application of aloe vera, lemon essential oil, or ascorbic acid showed statistically similar result. However, combining these coating treatments augmented their efficiency to improve consumers' acceptability of fresh cut apple slices.

Table 4.11 Effect of aloe vera, lemon essential oil, and ascorbic acid coating and their combination on the decay index (%) of fresh cut apple slices during refrigerated storage at 4±1°C and 65±5% relative humidity

	Days after coating					
Treatments	**1**	**4**	**8**	**12**	**16**	**Mean**
TCO	9.00	6.33	4.67	2.67	1.00	**4.73 f**
TALV	9.00	7.67	6.00	3.67	1.67	**5.60 de**
TLEL	9.00	7.00	5.33	3.67	1.67	**5.33 e**
TASA	9.00	7.33	5.67	3.67	1.67	**5.47 e**
TAE	9.00	8.00	6.67	5.33	3.67	**6.53 c**
TLA	9.00	7.67	6.33	4.33	2.67	**6.00 d**
TAA	9.00	8.33	7.33	6.00	4.67	**7.07 b**
TALA	9.00	8.67	8.00	7.00	6.00	**7.73 a**
Mean	**9.00 a**	**7.63 b**	**6.25 c**	**4.54 d**	**2.88 e**	

Different letters accompanying mean values show significant difference among them at $P \leq 0.05$. **TCO**= uncoated slices, **TALV**= 2% aloe vera, **TLEL**= 1.5% lemon essential oil, **TASA**= 2.5% ascorbic acid, **TAE**= 2% aloe vera and 1.5% lemon essential oil, **TLA**= 1.5% lemon essential oil and 2.5% ascorbic acid, **TAA**= 2% aloe vera and 2.5% ascorbic acid, **TALA**= 2% aloe vera, 1.5% lemon essential oil and 2.5% ascorbic acid

It is profoundly understood in the literature that ascorbic acid combined with alginate coating had significantly maintained sensory qualities of fresh cut apples which lead the product to higher consumers' acceptance (Najafi *et al.*, 2021). In another study essential oil in combination with alginate has also been reported to maintain organoleptic characteristics during storage (Chiabrando and Giacalone, 2015). Farina *et al.* (2015) found aloe vera gel coating effective in maintaining sensory properties of fresh cut apples which strengthens our findings of current study. Furthermore, changes in titratable acidity and TSS affected the taste of apple slices(Guan *et al.*, 2015; Najafi *et al.*, 2021). Enzymatic browning not only cause loss of nutrients but also adversely affect flavor (Chiabrando and Giacalone, 2015). As coating of apple slices with ascorbic acid, lemon essential oil, and aloe vera maintain physicochemical parameters such as weight loss (Guo *et al.*, 2011), Electrolyte leakage (Nicolau-lapena *et al.*, 2021), TSS, TA, and pH (Mbili *et al.*, 2018), ascorbic acid content (Lemmens *et al.*, 2020), color (Supapvanich *et al.*, 2016), firmness (Ergun and Satici, 2013) which directly affect organoleptic characteristics thereby directly influence consumers' acceptability. Furthermore, browning is inhibited by ediblecoating along with inhibition of microbial degradation of the food (Plesoianu *et al.*, 2021) which largely impact consumers' rejection and acceptance (Zhang *et al.*, 2021).

Conclusion

After fully analysing the results so obtained from the research conducted on fresh cut apple slices, it was concluded that;

1. Combined application of 2% aloe vera, 1.5% lemon essential oil, and 2.5% ascorbic acid significantly maintained physicochemical quality parameters and consumers' acceptability of fresh cut apples.
2. Formation of layer on the surface, antioxidant activity, and anti-microbial activities make the combined application more effective for preservation of fresh cut apple slices.
3. No undesirable flavor development and browning was observed after coating fresh cut apple slices with combine application of aloe vera gel, lemon essential oil, and ascorbic acid. Thus, can be used as viable commercial coating treatment after validation of these results.

Recommendations

Following recommendations are made based on the results of current study

4. Combined effect of aloe vera, lemon essential oil and ascorbic acid should be studied onother fresh cut fruits.
5. Combination of the given treatments should also be applied on whole fruits to check theireffectiveness

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