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Effect of various natural fruit juices on physico-chemical characteristics and browning inhibition of apple (Cv. White dotted red)

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Abstract
Fresh cut apple slices of 4mm thickness were dipped in various natural fruit juices viz., orange, kiwi, lime, pine apple, sour cherry, grape and distilled water (Control) in the sample to solution rati of 1:10 (250g apple slices: 2.5 litres of juice) and total of seven treatments were applied to ascertain their effect on physi-co-chemical characteristics and browning inhibition of apple (Cv. White dotted red).Treated apple slices were stored at low temperature (3 ºC) for seven days. Titrable acidity (1.16), Ascorbic acid (29.54 mg/100g), Total sugar (12.11%) and Anti-oxidant activity (86.84%) were recorded significantly higher (P≤0.05) in apple slices treated with lime juice while as pH and firmness was found to be lowest (3.09 and 31.08g) respectively. For control (T7) Titrable acidity (0.40%), Ascorbic acid (4.27 mg/100g) and total sugar (11.09 %) and anti-oxidant activity (49.76 %) were significantly lower than all other treatments while moisture content and Firmness were found to be highest (85.94% and 43.67 g). With respect to browning inhibition, Treatment of apple slices with lime juice (T3) was found to be most effective with lower polyphenol oxidase activity (7.66 U/mg fresh wt), browning index (4.47), and b* value (25.45) and significantly highest L* value (69.99) recorded in apple slices treated with lime juice, While as for control (T7) Polyphenol oxidase activity (42.00), browning index (47.87), L* value (38.25) were recorded lowest and a* value (4.16) and b * values (42.83) were recorded highest. All the other treatments exhibited their superiority over control. However for most of the physi-co-chemical characteristics and browning parameters under study, treatment of apple slices with lime juice (T3) was found to be the most effective for maintaining overall quality of apple slices.

Keywords: Apple, browning index, enzymatic browning, firmness, Fruit juices, Poly phenol oxidase activity, quality

1. Introduction
The growth market for minimally processed products is beyond the convenience of having them ready-to-eat. It is mostly related to the increasing awareness of the consumers about health benefits associated with the consumption of fresh fruits and vegetables. In the recent years, a rapid market growth for fresh cut fruits and vegetables as such has increased, because of demand for fresh like quality, and high nutritive value (Rico *et al*., 2007) [33] Fresh cut apple slices in particular are desired as convenience snacks for catering services to salad bars, school and company cafeterias (Saftner *et al*., 2005) [35]. Surface color is one of the most important quality attribute because consumers usually judge the quality of fresh cut fruits and vegetables on the basis of appearance. However, mechanical damage during processing results in cellular delocalization of enzymes and their substrates leading to biochemical degradation such as enzymatic browning, off flavor, and textures breakdown of fresh cut fruits and vegetables. Enzymatic browning in many fruits and vegetables is catalyzed by enzyme polyphenol oxidase (PPO) which is present in most plants. Browning reaction occurs in fruits and vegetables upon bruising and when such products are kept exposed to air (Labuza and Schmidt, 1985) [23]. The method used to prevent undesirable browning used in fruits and vegetables is based on inhibition of PPO, which can be easily attained by heat treatment. A common heat treatment employed for fresh cut fruits and vegetables is blanching consisting of dipping fresh cut fruits and vegetable slices in hot water or subjecting them to steam at a temperature of 96-99 ˚C for 1-2 minutes and then immediately cooling them to 7-10 ˚C. However, this treatment results in softening of product that is undesirable. Alternative to the heat treatment many compounds may be used to reduce polyphenol oxidase browning in foods (McGhie *et al*., 2005) [26].

Alternative browning inhibitors have been investigated by several researchers (Sapers and Ziolkowski, 1987) [37]. Potential alternative to sulfites include Ascorbic acid, ascorbic acid phosphate, sodium acsorbate, citric acid, benzoic acid, sodium benzoate etc. Ascorbic acid (AA) is one of the reducing agents currently used. It reduces the O-Benzoquinones to O-diphenols. Since during the reaction this compound is consumed by oxidation, protection conferred is only temporary. So, organic acid may also be incorporated to control enzymatic browning. Citric acid is widely used in combination with ascorbic acid, since it helps reduce the pH and thus ensure microbiological safety. In Brazilian fruit market, there are fruit salads which are immersed in fruit juices which are natural sources of ascorbic acid and citric acid. Pineapple, papaya and lemon juices have been reported to prevent discoloration of cut surfaces of fruits and vegetables (Benion, 1990) [8]. Citric acid present in the fruit juices can act as the chelator of copper. Maleic acid may help in inhibition by lowering the pH below the optimum pH of PPO. So, natural fruit juices can contribute as an alternative to anti-browning chemical agents, as it is natural, innocuous and a low cost alternative compared to chemical dips. Study of literature revealed very less work conducted on the efficacy of various natural fruit juices on browning inhibition in apple. No such work has been conducted so far on white dotted red cultivar of apple. Besides there is no such report on effect of natural fruit juices on physicochemical characteristics of fresh cut apple slices (cv.white dotted red) as physicochemical characteristics of the fruit are related to the quality of fresh cut fruits and vegetables. So a study was conducted to (1) evaluate the potential of various natural fruit juices or as inhibitors of enzymatic browning in fresh cut apple slices (cv.white dotted red) and (2) to study the effect of various natural fruit juices on physicochemical characteristics of fresh cut apple slices (cv.white dotted red).

2. Materials and methods

An experiment was conducted in the Division of Food Science and Technology, SKUAST-K, Shalimar to study the effect of various natural fruit juices on physicochemical characteristics of fresh cut apple slices (cv. white dotted red) and its impact on browning inhibition. Methodology employed and procedures laid for the said investigation are as follows:

2.1 Procurement of raw material

The apples (*Malus domestica* Borkh, cv. white dotted red) were procured from the local fruit market of district Srinagar. The apples procured were of uniform size, age and maturity as well as free from diseases and blemishes. The apples were then immediately shifted to cold store facility of the Division of Food Science and Technology, and were kept at a temperature of 4 °C until further use. For the purpose of obtaining natural fruit juices, fruits *viz.* orange, kiwi, lime, pineapple and grapes were also procured from the market except sour cherry in which case the stored pulp was used as the raw material. Natural fruit juices from the above mentioned fruits were extracted using a juice extractor in Food Processing and Training Facility of the Division of Food Science and Technology.

2.2 Sample preparation and pre-treatment

For sample preparation the stored apples (cv. white dotted red) were taken from the cold store to Food Processing and Training Centre (FPTC) where the apples were washed thoroughly with running cold water to remove any adhered dirt or pesticide residue. After washing, the apples were peeled, cored and cut into slices of 4 mm thickness with the help of a manual slicer. The apple slices were divided into seven equal lots of 250 g each. Each lot of apple slices was then subjected to following pre-treatments as mentioned in table 1. Each treatment comprised of apple slices (250 g each) dipped in natural fruit juices (250 g : 2.5 l) in the sample solution ratio of 1:10 which was kept constant, whereas for control treatment apple slices (250g) were dipped in distilled water (250g:2.5L) in the sample to solution ratio of 1:10. The treated apple slices (4mm thick) as per the treatments mentioned above were kept in the dip solution for 15 minutes. Treated slices were then drained thoroughly with excess moisture removed and were packed in Low density polyethylene pouches (LDPE pouches). After packing they were immediately transferred to cold store chamber and stored at a temperature of 3^0C for 7 days for further evaluation. Prior to the treatment of apple slices, untreated raw apples were evaluated for physicochemical parameters viz. moisture, content, pH, titrable acidity (%), total sugar (%), ascorbic acid (mg/100g), antioxidant activity (%), firmness (g), color values (L, a^*, b^*). Likewise various natural fruit juices were also analyzed for physicochemical characteristics viz. pH, titrable acidity (%), ascorbic acid (mg/100g), TSS (^{0}Brix), and antioxidant activity (%) before being used as dipping media. Pretreated apple slices after 7 days of storage in cold chamber at 3^0C were analyzed for various physical and chemical characteristics viz. moisture content (%), antioxidant activity (%), polyphenol oxidase activity (U/g fresh wt), Browning Index and color values (L, a*, b*).

2.2.1. Moisture Content: Moisture content was determined by the standard oven drying method as described by Ranganna (2000) as:

M.C (%wb) = $W_w/W_i * 100$

Where W_i = initial wt of product (g)

W_w = wt of water removed (g)

2.2.2. pH: pH was determined by using digital pH meter (Inolab WTW Series 720). The pH meter was first calibrated using buffer of pH 4.0 and 7.0 at room temperature. The sample was then taken in 100ml beaker and electrode of pH meter dipped in it to get the direct readings.

2.2.3. Titrable Acidity: Titrable acidity was determined using the method of (AOAC, 2000) [1].

2.2.4. Total Soluble Solids: TSS was determined by the method of Ahmed *et al*., (2000) [3]. A hand held refractometer (^{0}Brix 0-32% ATAGO Japan) was used to determine the TSS by calibrating with distilled water followed by dropping 1-2 drops of sample solution on to clean surface of refractometer.

2.2.5. Total Sugar: Total sugar content (%) was determined by using the method of Lane and Eyon as described by Ranganna (2000) [32].

2.2.6. Ascorbic Acid

Ascorbic acid (mg/100g) was determined by 2,6 dichlorophenolindophenol dye method as described by Ranganna (2000) [32].

2.2.7. Antioxidant Activity

Antioxidant activity in terms of radical scavenging activity of DPPH (2, 2 diphenyl 1 picryl hydrazyl) was determined by methodology as modified by Chun *et al.*, (2005) [11]. 3ml of DPPH 60µM in ethanol was added to 1ml of alcoholic extract of the sample and incubated at room temperature for 15 minutes. The absorbance of the mixture was measured at 517nm and the antioxidant activity was calculated and inhibition % age of DPPH as per formula:

% Inhibition = $\{A_{517}^{control} - A_{517}^{extract} / A_{517}^{control}\} * 100$

For control, 1ml of 95% ethanol was used to replace the extracts.

2.2.8. Polyphenol oxidase activity

A sample of 1g was homogenized in 2ml of 0.1M sodium phosphate buffer (pH 6.5) at 4^0C. The homogenate was centrifuged to 15000rpm for 15 minutes. The supernatant served as enzyme source. The reaction mixture consisted of 1.5ml of 0.1 M sodium phosphate buffer (pH 6.5) and 200µl of enzyme extract. To this mixture 200 µl catechol(0.1M) was added and change in absorbance at 495nm at 30 seconds interval for 5 minutes was noted. A change in the absorbance of 0.01/minute was expressed as one unit of enzymatic activity (Haplin and Lee, 1987) [17].

2.2.9. Firmness

For measuring the firmness of apple slices, a texture profile analyzer (Stable microsystem-TAXT Plus (United Kingdom) was used. Apple slices were subjected to compression test. The probe used during the test (P/2 N) travelled to a distance of 6mm with a trigger force of 1g. Texture analyzer was attached to a load cell of 5kgd and Test force was expressed in grams.

2.2.10. Browning Index

Browning Index was measured by the method as described by Labuza *et al*., (1990) [22]. Browning Index was calculated as per the formula:

$B.I = \Delta L^*/L_0 * 100$ where $\Delta L = L_0^* - L^*$

Where L_0^* is the color value of fresh untreated apple slices and L* is the value of treated apple slices after 7 days of storage.

2.2.11. Color Values

The color was measured using Hunter Lab Colorimeter (Color Tec_USA). The equipment was calibrated using white and black standard ceramic tiles. The color of the sample was denoted by three dimensions L*, a* and b*. L* refers to the lightness of the color and ranges from black (0) to white (100). A negative value of a* indicates a green color whereas positive value indicates red-purple color. A positive value of b* indicates a yellow color and negative value a blue color.

2.2.12. Statistical Analysis

All the treatments under study in the present investigation were replicated thrice and the results were expressed as mean of triplicate analysis. One way analysis of variance was used to establish the significance of difference among the mean values at 0.05significance level. The statistical analysis was performed using OPSTAT Software (version 0.1).

3. Result and Discussion

3.1 Physicochemical Characteristics of apple slices (Cv. White dotted red)

Physicochemical characteristics of fresh apple slices have been presented in Table 2. Apple slices (cv.white dotted red) possessed moisture content (84.43%), pH (3.80), Titrable acidity (0.56%), Total sugar (11.59%), Ascorbic acid (7.20 mg/100g), Anti-oxidant activity (69.94%), Firmness (55g), L*, a* and b* value of 73.27, -1.96, 21.89 respectively The results are in agreement with earlier work conducted by various researchers on organoleptic and physi-co-chemical characteristics of various apple cultivars (Hussain *et al.*, 2014; Campeanu *et al*., 2009 ; Kheiralipar *et al.*, 2008; Pirlak *et al*., 2003 ; Viera *et al*., 2011; Bahukhandi *et al*., 2017) [19, 9, 21, 30, 39, 7].

3.2 Physicochemical characteristics of Natural fruit juices

Physicochemical characteristics of various natural fruit juices have been presented in Table 3. Wide variation was exhibited among the various natural fruit juices for physicochemical characteristics under study. pH, acidity (%), Ascorbic acid (mg/100g), TSS (^{o}Brix) and antioxidant activity (%) of various natural fruit juices was recorded at 3.56, 0.97%, 37.92 mg/100g, 12.23, and 62.83 % for orange juice, 3.43, 3.86 %, 79.38 mg/100g, 11.81^{o}Brix and 60.97 % for kiwi juice, 2.43, 6.34 %, 65.25 mg/100g, 7.60^{o}Brix and 52.86 % for lime juice,3.48, 0.69 %, 23.41mg/100g, 13.0^{0}Brix and 20.83 % for pine apple juice, 3.21, 1.32 %, 12.80 mg/100g, 13.50^0 Brix and 22.16 % for sour cherry juice and 3.53, 0.78 %, 4.60 mg/100g, 14.26^0 Brix and 39.26 % for grape juce respectively. Several workers while investigating the physi-co- chemical characteristics of various natural fruit juice have reported pH, Titrable acidity (%), Ascorbic acid (mg/100g), TSS^0 (Brix) and anti oxidant activity (%) in the range similar to our findings (Frazier and Westhoff, 1986; Ndife *et al.*, 2013;. Lawlor *et al.*, 2009; Abel and Aidoo,2016; Shrestha *et al*., 2012; Ali *et al.*, 2015; Fatahi *et al.* 2010) [15, 28, 25, 2, 38, 5, 14].

3.3. Effect of various natural fruit juices as pretreatments on physi-co-chemical characteristics of apple slices (Cv. white dotted red)

Physicochemical characteristics of apple slices treated with natural fruit juices as dip treatments has been presented in Table 4. It was evident from the Table that treatments exhibited significant differences ($P \leq 0.05$) with respect to all physical and chemical parameters under study.

3.3.1. Moisture Content

With respect to moisture content, significant differences were observed among the treatments. Moisture Content was found to decrease slightly in case of apple slices treated with different natural fruit juice when compared to fresh untreated apple slice (84.43%) as presented in Table 2, while as control treatment (T_7) exhibited a slight increase in the moisture content (85.94%). Among the treated samples moisture content was recorded lowest in T_6 (81.81%) and significantly highest moisture content was recorded in apple slices treated with control (T_7) where it was reported to be 85.94 %. Decrease in the moisture content of apple slice treated with different natural fruit juices with respect to fresh untreated apple slice can be attributed to movement of the water molecules from the fruit tissue into the more concentrated solution of fruit juices as a function of water potential difference (Meloe *et al.*, 2014) [27]. Natural fruit juices contain varying amounts dissolved sugars, salts and other chemical compounds making the medium more concentrated for osmosis to take its course. Conversely, control treatment(T_7) wherein apple slices were dipped in distilled water (de-

ionized water) will exhibit the infusion of water into fruit slices raising its moisture content slightly because of vapor pressure difference between the pure water and water present in the fruit tissues. Since treated sample were sealed in polyethylene pouches and stored in a cold chamber at 3^0C for 7 days with relative humidity inside the chamber in excess of 90%, moisture content of treated apple slice was more or less maintained with no appreciable losses.

3.3.2 pH

With respect to the pH significant difference were observed among the treatments ($P \leq 0.05$). Significantly lowest pH (3.09) was recorded in apple slices treated with lime juice (T_3) while as the pH of control treated apple slices(T_7) was recorded to be the highest (3.80) after 7 days of storage. This can be attributed to increase in the acidity of treated apple slices due to the action of acidulants present in the natural fruit juices i.e. citric acid and ascorbic acid and their infusion into fruit tissue. Akyildiz and Fenercioglu (2016) [4] also reported decrease in the pH due to presence of citric acid in the solution. Possible explanation of the low pH recorded in apple slices treated with lime juice (T_3) after storage can be attributed to high concentration of citric acid in lime juice (6.34%). Conversely, control treatment (T_7) recorded higher pH value (3.96) which can be attributed to leaching of the organic acid in pure de-ionized water.

3.3.3. Titrable acidity

Titrable acidity was recorded highest in apple slices dipped in lime juice (1.16) after 7 days of storage while as lowest titrable acidity was recorded in the control, T_7 (0.40). Since acidity and pH are interdependent lower the pH, higher is the acidity during storage. Since pH was lowered in the treated samples except control, former showed higher acidity than latter. Appreciable increase in the acidity as observed in T_3 (apple slices dipped in lime juice) can be attributed to strength of acidulants (citric acid). As reported by Nisar *et al.,* (2015) [29], higher acidity was observed in apple pulp after storage due to addition of citric acid. Another possible explanation of increase acidity can be attributed to production of more acids due to degradation of pectic substance and polysaccharides during storage (Durani *et al.,* 2010) [13]. In case of treatments where dipping medium contained lesser concentration of citric acid (T_1, T_2, T_4, T_5 and T_6), less increase in acidity was observed (Table 3). However, lower acidity of apple slices (0.40) in control treatment (T_7) can be attributed to utilization of organic acids as substrates in respiration during storage.

3.3.4 Ascorbic Acid

Significant differences were observed among the treatments ($P \leq 0.05$**)** with respect to Ascorbic Acid (mg/100g) after storage period of 7 days, with highest ascorbic acid content (29.54 mg/100g) reported in apple slices treated with lime juice (T_3) followed by T_2 (24.78mg/100g), wherein apple slices were dipped in kiwi juice. Lowest ascorbic acid (4.27mg/100g) was recorded in control (T_7). This can be attributed to the impact of acidulants (citric acid) in maintaining high levels of ascorbic acid. Citric acid is a strong reducing agent and as such prevents the conversion of ascorbic acid to dehydroascorbic acid during storage. Moreover, higher concentration of ascorbic acid in natural fruit juices might also have increased the ascorbic acid content of treated apple slices. It was apparent from Table 3 that ascorbic acid content of treated apple slices was higher than control (T_7) and even higher than the untreated fresh apple slices (7.2mg/100g). Our results are in agreement with previous findings of Javadani *et al.,* (2013) [20], who reported decrease in the vitamin C content of control, whereas pretreatment with ascorbic acid maintained higher Vitamin C content at the end of storage.

3.3.5. Total sugar

Significant difference was also observed in Total Sugar content after 7 days of storage wherein higher sugar content (12.11%) was recorded in apple slices treated with lime juice (T3) as observed in Table 3. Total sugar content was higher in all treated apple slices than untreated fresh apples. The lowest sugar content was recorded in control (T7) 11.09 %) after 7 days of storage which was slightly lower than the fresh cut apple slices (11.59 %). This can be attributed to gradual increase in reducing sugar content during storage as reported by Nisar *et al.,* (2015) [29] in apple pulp. The results are also in agreement with earlier findings of Ali *et al.,* (2004) [6]. According to Hakim *et al.,* (2013) [16], increase in reducing sugar content with storage could be due to degradation of starch, glucose and fructose by the activity of amylase and maltase.

3.3.6. Anti-oxidant activity

Antioxidant activity as presented in Table 4 revealed significant difference among the treatments ($P \leq 0.05$) for this parameter. Antioxidant activity was higher in apple slices treated with kiwi juice (T_2) which was recorded at 80.13%, followed by T_3 wherein apple slices were dipped in lime juice. Control treatment (T_7) reported lowest antioxidant activity (49.76%). It was also observed that antioxidant activity of apple slices treated with natural fruit juices (T_1, T_2, T_3, T_4, T_5, and T_6) was higher than untreated fresh apple slices as can be seen from Table 3. This can be attributed to pH lowering ability of fruit juices thus preventing the oxidation of phenolic compounds. Moreover, in case of apple slices treated with kiwi juice (T_2) higher concentration of ascorbic acid (79.38mg/100g) and higher antioxidant activity (62.83%) might have led to subsequent increase in antioxidant activity of apple slices. Further, role of citric acid in increasing the antioxidant activity is well documented. Seangil *et al.,* (2006) [16] reported increase in total phenol content of treated samples than untreated samples with 0.1% KMS and 0.1% citric acid. Besides citric acid acts as the chelating agent and binds to copper preventing degradation of phenolic compounds. Another possible explanation of increase in antioxidant activity after storage can be attributed to release of phenolic compounds in cell matrix secondary to disruption of vacuole membrane due to action of citric acid at higher concentration.

3.3.7. Firmness

Significant difference was also observed among all the parameters with respect to the firmness values as indicated in Table 4. All the treatment showed lower firmness values when compared to untreated fresh cut apple slices. Highest firmness expressed in terms of test force in grams was observed in control (T_7=43.67g) as shown in Table 3, while lowest firmness value (31.08) was found in apple slices treated with lime juice (T7). Moreover, as shown in the table, the higher the concentration of citric acid in the lime juice, more softening of the fruit tissue in apple slices dipped in lime juice was observed. Thus, it can be inferred that fruit tissue softening was probably related to concentration of acidulants in natural fruit juices than distilled water. Decrease in slice firmness can be attributed to acid hydrolysis of pectin

in the presence of acidulants causing flesh softening during storage. Flesh softening can also be attributed to dissolution of middle lamella and subsequent cell separation and is the consequence of activity of pectin methyl esterase, an enzyme that remains active even at low temperature (Cocci *et al.*, 2006) [12].

3.4. Polyphenol oxidase activity and browning inhibition

Effect of various natural fruit juices as pretreatments on polyphenol oxidase activity and browning inhibition has been presented in Table 5.

3.4.1 Polyphenol oxidase activity

All the treatments were effective in lowering the polyphenol oxidase activity in treated apple slices after 7 days of storage with significantly lower Polyphenol oxidase activity recorded in T_3 (7.66 U/g fresh wt) while control recorded highest PPO activity (42.0 U/g fresh wt). This can be attributed to pH lowering activity of lime juice in treated apple slices. It can be seen that apple slices treated with lime juice had lowest pH recorded after 7 days of storage due to its higher acidity (Table 3) having pH of 3.09. Moreover, lime juice also contains higher ascorbic acid content (65.25mg/100g) and the highest concentration of citric acid (6.34%). Both ascorbic acid and citric acid in combination have been found to be effective in controlling the enzymatic activity. Pizzacaro *et al.,* (1993) [31] reported that 5 minute dip in a solution containing mixture of 1% ascorbic acid and 0.2% citric acid resulted in 90-100% inhibition of PPO, which is in agreement with our findings. Moreover citric acid is highly effective acidulant causing decrease of pH and thus inhibiting the enzyme activity (Melo *et al.*, 2014) [27].

3.4.2 Browning index

Significant difference was observed in Browning Index values among treatments with lowest Browning Index score of 4.47 recorded in treatment (T_3) after 7 days of storage while as browning of apple slices was higher in control samples (47.87), wherein apple slices were dipped in distilled water (T_7). It was also observed that in all the treatments other than control browning was reduced considerably indicating all the fruit juices lowered the pH of apple slices and the presence of citric acid, ascorbic acid, and maleic acid had a reducing effect on the fruit tissue. Both ascorbic acid and citric acid are strong reducing agents which prevent the oxidation of phenolic compounds present in fruit tissue and considerably lower browning. Besides, ascorbic acid also acts as an antioxidant agent while citric acid is an effective chelator which inhibits the enzymatic browning by reducing the availability of copper ions (Cu^{2+}) at the site of PPO (Sapers, 1990) [36].

3.4.3 Instrumental colour (L*a*b*)

Treatments exhibited significant differences with respect to color coordinates (L* a* and b*) as shown in Table 5. Slight decrease in L* values were recorded after 7 days of storage in all the treatments in comparison to the fresh untreated apple slices. As can be seen from Table 1, L* value of fresh untreated apple slices was 73.27 indicating a slight increase in the color value. However, significantly higher L* value was reported in apple slices treated with lime juice (69.93) while as lightness in terms of L* value was recorded lowest in control (T_7) with the color magnitude of 38.25. It was apparent that color of control samples (T_7) deteriorated considerably during storage while rest of the treatments recorded superior L* value (Table 4). Higher L* values recorded in apple slices treated with natural fruit juices can be attributed to lowering of pH of apple slices, significant decrease in the polyphenol oxidase activity, and action of acidulants (citric acid and ascorbic acid) acting as reducing agents, thus preventing browning by controlling the oxidation of phenolic compounds as discussed earlier. However a slight decrease in the L* value in comparison to the fresh cut apple slices can be attributed to maillard condensation and destruction of pigments. The results are in agreement with Hassanane and Sharaf (2014) [18] who reported a similar trend in commercial drinks during storage under refrigerated conditions. Similar results were reported by Landl *et al.*, (2010) [24] in the apple product. It was also evident from the table that a* values increase slightly in comparison to fresh cut apple slice (-1.96) and effect was slightly more pronounced in T_3 (lime juice treated apple slices) and T_2 (kiwi juice treated apple slices) being more towards the positive side (0.99 and 0.80 respectively). It can be attributed to ascorbic acid present in these juices in higher amounts and consequently entering the maillard browning reaction. Similarly,b* values also showed a slight increase in treated apple slices with highest b* value reported in kiwi juice treated apple slices after 7 days of storage (T_2=25.94) followed by T_3 (25.45). However, color values in terms of b* values were recorded highest in T_7 (control) indicating more yellowness after 7 days of storage. So both a* and b* values were recorded highest in control i.e. 4.16 and 42.83 respectively. This indicates severe deterioration in color in case of apple slices treated with distilled water (T_7) in comparison to apple slices treated with natural fruit juices, due to both higher enzymatic browning and higher non enzymatic browning at the end of 7 days of storage period.

Table 1: Details of the treatments employed for pretreatment of Apple slices

Treatments	Dipping Medium	Sample:Solution
T_1	Orange Juice	1 : 10
T_2	Kiwi Juice	1 : 10
T_3	Lime Juice	1 : 10
T_4	Pineapple Juice	1 : 10
T_5	Sour-cherry Juice	1 : 10
T_6	Grape Juice	1 : 10
T_7 (Control)	Distilled Water	1 : 10

Table 2: Physi-co-Chemical Characteristics of fresh apple slices

Parameter	Value
Moisture content (%)	84.43
pH	3.80
Titrable Acidity (%)	0.56
Total Sugar (%)	11.59
Ascorbic Acid (mg/100gm)	7.2
Antioxidant Activity	69.94
Firmness (Test force in grams)	55.0
L* value	73.27
a * Value	-1.96
b *value	21.89

Table 3: Physi-co-Chemical Characteristics of various natural fruit juices

Fruit juice	pH	Titrable Acidity (%)	Ascorbic Acid (mg/100gm)	T.S.S (brix^0)	Antioxidant Activity (%)
Orange	3.56	0.97	37.92	12.23	62.83
Kiwi	3.43	3.86	79.38	11.81	60.97
Lime	2.43	6.34	65.25	7.60	52.68
Pine apple	3.48	0.69	23.41	13.0	20.83
Sour cherry	3.21	1.32	12.80	13.50	22.16
Grape	3.53	0.78	4.60	14.26	39.26

Table 4: Effect of various natural fruit juices as pretreatments on Physi-co-chemical characteristics of apple slices

Treatment	Moisture content (%)	pH	Titrable Acidity (%)	Ascorbic Acid (mg/100g)	Total Sugar (%)	Antioxidant Activity (%)	Firmness (Test force in grams)
T1	83.19 ±0.049	3.53 ± 0.010	0.70 ± 0.006	19.10 ± 0.086	11.68 ± 0.009	76.57 ± 0.170	39.36 ± 0.053
T2	83.08 ±0.046	3.38 ± 0.012	0.90 ± 0.009	24.78 ± 0.034	11.86 ± 0.012	80.13 ± 0.082	36.17 ± 0.177
T3	84.14 ± 0.029	3.09 ± 0.009	1.16 ± 0.012	29.54 ± 0.192	12.11 ± 0.018	86.84 ± 0.017	31.08 ± 0.110
T4	82.99 ± 0.054	3.69 ± 0.009	0.68 ± 0.010	9.29 ± 0.029	11.61 ± 0.009	72.85 ± 0.040	40.21 ± 0.144
T5	82.85 ±0.012	3.47 ± 0.009	0.85 ± 0.006	9.29 ± 0.029	11.76 ± 0.009	70.74 ± 0.274	40.83 ± 0.121
T6	81.81 ± 0.024	3.81 ± 0.015	0.63 ± 0.012	7.360 ± 0.025	11.72 ± 0.009	69.27 ± 0.115	41.03 ± 0.078
T7 (Control)	85.94 ± 0.044	3.96 ± 0.009	0.40 ± 0.009	4.270 ± 0.015	11.09 ± 0.006	49.76 ± 0.040	43.67 ± 0.191
CD(P≤0.05)	0.124	0.032	0.028	0.257	0.033	0.413	0.408

T1= Apple slices dipped in orange juice, T2= Apple slices dipped in kiwi juice, T3= Apple slices dipped in lime juice, T4= Apple slices dipped in pine apple juice, T5=Apple slices dipped in sour cherry juice, T6= Apple slices dipped in grape juice, T7= Apple slices dipped in distilled water (Control).

Table 5: Effect of various natural fruit juices as pretreatments on polyphenol oxidase activity, browning index and colour of apple slices

Treatment	Polyphenol oxidase activity (U/gm fresh weight)	Browning index	Colour		
			L* value	a* value	b * value
T1	16.33 ± 0.333	11.86 ± 0.214	64.55 ± 0.147	0.54 ± 0.023	27.16 ± 0.027
T2	11.00 ± 0.577	8.89 ±0.035	66.75 ± 0.029	0.80 ± 0.009	25.94 ± 0.029
T3	7.66 ± 0.333	4.47 ± 0.047	69.99 ± 0.034	0.99 ± 0.006	25.45 ± 0.217
T4	20.00 ± 0.577	13.14 ± 0.189	63.63 ± 0.139	0.38 ± 0.012	28.81 ± 0.069
T5	17.33 ± 0.333	14.87 ± 0.040	62.37 ± 0.031	0.28 ± 0.006	29.28 ± 0.066
T6	18.33 ± 0.333	17.22 ± 0.270	60.64 ± 0.198	0.19 ± 0.009	29.66 ± 0.292
T7 (Control)	42.00 ± 0.577	47.78 ± 0.532	38.25 ± 0.390	4.16 ± 0.042	42.83 ± 0.078
CD (P≤0.05)	1.391	0.770	0.561	0.060	0.447

T1= Apple slices dipped in orange juice, T2= Apple slices dipped in kiwi juice, T3= Apple slices dipped in lime juice, T4= Apple slices dipped in pine apple juice, T5=Apple slices dipped in sour cherry juice, T6= Apple slices dipped in grape juice, T7= Apple slices dipped in distilled water (Control).

3.5 Conclusion

Effect of various natural fruit juices as pretreatments on physicochemical quality and browning inhibition in apple slices has been studied. It can be concluded from study that all the physicochemical characteristics of treated apple slices were improved while polyphenol oxidase activity and browning inhibition were considerably reduced in all treatments except control (T_7). However, among different treatments apple slices treated with lime juice (T_3) proved to be significantly superior to all other treatments with respect to physicochemical characteristics studied except firmness and was considerably much effective in reducing polyphenol oxidase activity and enzymatic browning in apple slices after 7 days of storage at 3^0C in cold chamber. So, apple slice dipped in natural lime juice can prove to be a reliable and cheaper alternative to chemical treatments for effectively controlling the browning of fresh cut apples.

4. References

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