Influence of Edible Starch and Sodium Bi-carbonate on Postharvest Quality of Minimally Processed Carrot and Potato


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Authors’ contributions

This work was carried out in collaboration among all authors. Author MNHM performed the statistical analysis and wrote the first draft of the manuscript. Author AH managed the analyses, lab activities of the study and literature searches. Author MFH designed the study, wrote the protocol and supervised the analyses. Author NIT performed the statistical analysis and literature searches. Authors MAR and JF managed the analyses of the study and literature searches. Author MAI managed the analyses of the study and finalizes the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The demand for healthy and ready-to-eat products has been growing steadily over the years. However, these products are very susceptible to spoilage and have a short shelf-life. In this research, edible coatings based on edible starch (aloe vera gel) and NaHCO₃ were applied on fresh-cut vegetable samples (carrot and potato), and the changes in their bio-chemical properties and microbial changes were monitored during 6 days of storage at 4°C. Two factor experiments, Factor A; postharvest treatments (different concentration of aloe gel and NaHCO₃) and Factor B; two vegetable species (Carrot and Potato) were laid out in a Completely Randomized Design (CRD) with three replications. Different concentration of aloe vera gel and NaHCO₃ solutions were prepared as per treatment. The prepared slices of vegetable species were treated with different

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Keywords: Fresh-cut vegetable; edible starch; sodium bi-carbonate; minimal processing; biochemical properties.

1. INTRODUCTION

Despite of the availability of agricultural products there are still significant losses of harvested fruits and vegetables due to inadequate use of technology during cultivation, postharvest handling, storage and conservation. An alternative technology to minimize postharvest losses is the minimal processing of fruits and vegetables. Minimally processed products are any fresh produce that have been physically altered from their native state but remain in a fresh form [1]. Due to the change in consumer tendencies for the demand of fresh, healthy and convenient foods, the consumption of minimally processed foods has increased steadily worldwide over the years. In today’s busy lifestyles, minimally processed fruits and vegetables constitute a suitable meal, as they do not require extra preparation and offer a range of minerals, vitamins, and phytochemicals essential for human health [2]. In fact, the minimally processed fruits and vegetables is one of the rapidly expanding sectors of the food industry and a multi-billion-dollar industry worldwide [3]. In vegetable processing fully processed vegetable loss its nutritional quality as fresh other hand the minimally processed vegetables maintain all nutritional quality and it save our time from the cutting, peeling of vegetables. The minimal processing operations (“mild technology”) necessary to produce fresh-cut foods, such as peeling, cutting, washing, treatments with sanitizing agents, drying, alter the physical integrity of these products, making them more perishable than the original raw materials. So, minimally processed of vegetables is important to keep the product fresh but convenient without losing its nutritional quality and the product should have a shelf life sufficient to distribution feasible within the region of consumption.

The application of edible coatings is a packaging strategy to extend the shelf-life of fresh cut fruits and vegetables. Edible coatings obtained from natural resources are environmentally friendly and can enhance the quality of processed products [4]. Utilizing edible coating with desirable physical, sensory and microbiological properties to minimally processed fruits and vegetables can reduce detrimental changes and consequently extend shelf-life [5]. Edible coating is a thin layer comprising edible material that acts as a primary food packaging and prevents food from physicochemical and microbiological spoilage [6,7]. Edible coating is usually applied to ready-to-eat fresh-cut fruits to slow their deterioration and extend their shelf lives [8]. It can be applied by various methods, including dipping, enrobing, and spraying. Among these, dipping is the most used method because of its ease of handling and efficient coverage of irregularly shaped surfaces [9].

Over the past years, the application of coatings has become more and more important in the food fields [10,11]. The application of coatings on food products allows an extension of shelf life of perishable and sensitive products, such as fruits and vegetables, since these materials act as an external protective layer. These coatings slow the respiration rate, reduce moisture and solute migration, gas exchange, oxidative reaction rates, and suppress physiological disorders of fresh-cut fruits [12,5]. To increase the shelf life of fruits and vegetables different types of synthetic chemicals are used commercially, which are harmful for human beings. Organic substances and safe salt can be the alternative of synthetic chemicals. Aloe gel [13], ClO₂ [14,15], different types of safe salt were used to increase the shelf life of minimally processed vegetables. Therefore, the objectives of this study were to find out the suitable concentration

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TSS (3.856), pH (3.827) NRS (0.133). Growth of bacterial colonies on NA media had statistically assessed. Higher rate of edible starch (30%) + NaHCO₃ (2%) treated potato (CT₁₂) showed the superior performance on TA (1.290), TSS (5.200% Brix), NRS content (0.340) and pH (4.773% Brix) compare to control and other interaction treatments of the study at 6 days after storage while untreated potato (T₀) showed statistically lower AA (6.575 mg/25 g) TA (0.464) TSS (3.856), pH (3.827) NRS (0.133). Growth of bacterial colonies on NA media had statistically highest (14.00) in untreated potato and lowest (5.00) in T₁₂ treated potato while fungal colonies on PDA media range of 4.00 to 11 at 6 DAS. The study may help small-scale establishments to increase the shelf-life of minimally processed vegetables.

Keywords: Fresh-cut vegetable; edible starch; sodium bi-carbonate; minimal processing; biochemical properties.

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of aloe gel and NaHCO₃ with determining the physic-chemical properties and microbial changes as well as shelf life of minimally processed carrot and potato.

2. MATERIALS AND METHODS

Two factor experiments viz. Factor A; postharvest treatments (T0: Control-unprocessed fresh vegetable), T1: 10% aloe gel (extracted from aloe vera plant and prepared different concentration), T2: 10% aloe gel + 1% NaHCO₃, T3: 10% aloe gel + 1.5% NaHCO₃, T4: 10% aloe gel + 2% NaHCO₃, T5: 20% aloe gel, T6: 20% aloe gel + 1% NaHCO₃, T7: 20% aloe gel + 1.5% NaHCO₃, T8: 20% aloe gel + 2% NaHCO₃, T9: 30% aloe gel, T10: 30% aloe gel + 1% NaHCO₃, T11: 30% aloe gel + 1.5% NaHCO₃, T12: 30% aloe gel + 2% NaHCO₃ and Factor B; two vegetable species (Carrot and Potato) were laid out in a Completely Randomized Design (CRD) with three replications. The postharvest treatments were assigned randomly in each replication. The minimally processed vegetables were carefully selected during the study where fifty grams of each sample was used for each replication of a treatment.

Fresh carrots and potatoes were obtained from a local market from the same batch. Visual inspection was conducted to ensure consistent shape, size, color, maturity and absence of any significant defects or physical damages that could interfere with the experiments. The potatoes and carrots were washed in running water, peeled with sharp stainless steel knives and immersed in cold water at 7ºC for 15 min. Potato and carrots were slice/cut in to 3 mm thick slices round shape using a knife. These were then immersed in cold water at 7ºC for 15 min. For sanitation, Different concentration of aloe vera gel and NaHCO₃ solutions were prepared as per treatment. Every sample of minimally processed vegetables (potato and carrot) was kept separately in a tray. Thereafter the individual sample of potato and carrots were treated by the postharvest treatments of aloe vera gel and NaHCO₃ for 5 min as per replication treatment by gloves wearing hand. After completing the dipping process of slice sample as ready to storage. Then the products were put into polyethylene bags. The bags of 200 g capacity were used for stored 50 g of both potato and carrot sliced (round shape) samples and sealed under air, vacuum or modified active atmosphere.

Vegetables of each treatment were selected at 2–6 days after storage (DAS), different bio-chemical parameters like Titratable acidity (TA), Total soluble solids (TSS), Ascorbic acid (AA), Reducing sugar, Non–Reducing sugar and pH were determined through the methods adopted by [16]. In case of microbial changes, minimally processed vegetables sample stored in normal freezing condition were collected and treated by PDA media for fungal count and NA media for bacterial count. The numbers of fungal and bacterial colonies in a solution were quantified by using the spread plate technique. After colonies are grown, they are counted and the number of colonies in the original sample is calculated. The collected data on various parameters were statistically analyzed using MSTAT–C statistical package. The means for all the treatments were calculated and analysis of variances (ANOVA) for all the parameters was performed by F–test. The significance of difference between the pair of means was compared by Duncan’s Multiple Range Test (DMRT) test at the 5% levels of probability [17].

3. RESULTS AND DISCUSSION

3.1 Bio-chemical Changes of Minimally Processed Vegetables

3.1.1 Titratable acidity (TA)

Titratable acidity at different days of the minimally processed vegetables varied significantly because of different concentration of treatment with carrot and potato as well as different combinations while it decreased significantly in increasing storage period. The observing data revealed that the carrot showed statistically higher TA (3.019%, 2.627% and 2.457%) compared to potato (1.171%, 1.059 and 0.983%) at 2, 4 and 6 DAS (Table 1). At 2 DAS, TA was the highest (2.437%) in 30% aloe gel along with 2% NaHCO₃ (T12) treated ready to cook vegetables where without treated recorded the lowest TA (1.390%). At 4 DAS, 30% aloe gel along with 2% NaHCO₃ (T12) recorded the statistically highest TA (2.202%) while without treated recorded the lowest TA (1.117%). At 6 DAS, treatment T12 recorded the statistically highest TA (2.140%) compared to processed and other treatments of the study while without treated vegetable recorded the lowest TA(1.101) at 6 days (Table 2). However, TA significantly decreased in increasing study period but the reduction of TA had higher in control while
treatment T12 hold up the best quality of the storage vegetable compare other treatments of the study which indicated that the high rates of edible coating had more effective for keeping the good quality of processed vegetables. In interaction effect, TA at 2 and 4 DAS (3.553 and 3.097%, respectively) at 30% aloe gel coating + 2% NaHCO₃ (CT₁₂) treated minimally processed carrot showed the statistically highest TA at 6 DAS (2.990%) compare to control and other treatments of the study. Similarly, without treated vegetable showed the statistically lowest (1.756, 1.809 & 1.733) at 2, 4, and 6 days respectively. These results revealed that the 30% aloe vera gel + 2% NaHCO₃ had highly effective to maintenance the fresh vegetable quality as well as the higher TA at 6 DAS while other rates of edible coating or treatments was less effective. The uncoated carrot was the most ripe, presented higher titratable acidity values than coated carrot at the initial stage of storage [18].

3.2 Ascorbic Acid (mg/25 g)

Ascorbic acid content of the minimally processed vegetables was statistically higher (9.441, 9.125 and 8.035 mg/25 g) in potato than carrot (5.528, 5.104 and 4.932 mg/25 g) at 2, 4 and 6 DAS, respectively. These results showed that the AA content significantly decreased with the advancement of the storage period. However, 30% aloe gel along with 2% NaHCO₃ (T₁₂) treated processed vegetables (at 2 DAS) showed statistically highest AA content (8.138 mg/25 g) but it decreased rapidly at 4 DAS (7.840 mg/25 g) and 6 DAS (7.142 mg/25 g). On the other hand, without treated vegetable showed statistically lowest AA (5.203, 5.638 & 5.109) at 2, 4 and 6 days respectively. These result indicated that the without treated vegetable rapidly decreased the freshness quality and lost early the consumption value while edible coating hold up the consumption quality. As a result, all the interaction treatment showed statistically highest AA content compared to control other treatment at 2 DAS while 30% Aloe gel coating + with 2% NaHCO₃ treated potato (PT₁₂) showed statistically highest AA content (9.927, 8.633 mg/25 g and) at 4 and 6 DAS, respectively. Similarly, edible coatings based on Chitosan (CH), Aloe gel (AL) and its combination with Aloe gel (CHAL) showed significant effect on ascorbic acid content, where coated sample showed higher ascorbic acid than uncoated sample under storage condition [19].

3.3 Total Soluble Solid (TSS) Content (% Brix)

From carrot, it was obtained the statistically highest TSS (8.581, 8.184 and 7.962% Brix) than potato (6.991, 5.792 and 4.762% Brix) at 2, 4 and 6 DAS, respectively. Above result indicated the TSS content decreased in increasing storage period concerning both species might be due to the genetic makeup of the species. It was found that the 30% Aloe gel along with 2% NaHCO₃ (T₁₂) treated MP vegetable showed the statistically highest TSS (8.393, 7.567 and 7.017% Brix) at 2, 4 and 6 DAS, respectively compare to control and other edible coating treatments. On the other hand, untreated vegetable treated vegetables showed the statistically lowest TSS (6.498, 5.791, 4.950% Brix) at those stages, respectively. In interaction effect, it was also found that the 30% Aloe gel coating + with 2% NaHCO₃ treated carrot (CT₁₂) showed the statistically highest TSS compare to control and other treatments of the study while without treated potato recorded the lowest TSS content at (6.1534, 5.762 & 3.856 % Brix) at 2, 4 and 6 DAS. This result revealed that the minimally processed vegetable can be consume for longer time while it would be treated by high edible coating due to the higher longevity of MP in freezing condition. The higher rate of edible coating (30% aloe vera gel) would be optimum level for getting the better quality MP vegetable for extended period. Similarly, the ability of Aloe gel based antimicrobial coatings to reduce/control the loss of postharvest fruit quality in carrot. Freshly harvested carrot fruits were coated with Aloe gel/AG (50%), carrot extract/PLE incorporated Aloe gel (1:1) and 2.5% chitosan where pH, titratable acidity and TSS had higher in coated fruits than control while coated fruits survived the storage period of 15 days and uncoated controls decayed within 10 days [20]. Significant variation was found on TSS due to treatments where chitosan (CH) mixed with Aloe gel (CHAL) had more significant in carrot [19].

3.4 Reducing Sugar (RS) Content (%)

Reducing sugar content of MP vegetables were significantly the highest (1.682, 1.415 and 1.262%) in carrot than that of potato (1.271, 1.101 and 0.982%) at 2, 4 and 6 DAS, respectively. Aloe Gel along with 2% NaHCO₃ showed the highest reducing sugar content (1.950, 1.662 & 1.443) at 2, 4 & 6 DAS while untreated vegetable showed the statistically lowest sugar content (1.067, 0.891 & 0.810) at 2,
4 and 6 DAS respectively. Aloe gel along with 2% NaHCO₃ showed the statistically highest RS content (1.950, 1.662 & 1.443) at 2, 4 & 6 DAS while untreated vegetable showed the statistically lowest results (1.129, 0.733 & 0.817) at 2, 4 & 6 DAS respectively. However, significant decrease in sugar content affected the storage quality and decreased the longevity but the quality changes had lowest in treated vegetable than untreated vegetable. From the obtained result it was found that the minimally processed vegetable showed longevity for keeping the freshness quality under the high (30%) edible coating compare to lower rates. Similarly, Aloe vera coating showed significant variation for sugars content while Aloe gel showed more sugar than control [21].

### 3.5 Non-reducing Sugar (NRS) Content (%)

It was found that the carrot showed better NRS content (1.250, 1.049 and 0.914) than potato (0.301, 0.307 and 0.233) at 2, 4 and 6 DAS, respectively. At 2 DAS, the highest reducing sugar content (1.033) was found in treatment T₁₂ (30% Aloe vera gel along with 2% NaHCO₃) showed statistically highest NRS content. Similarly, treatment T₁₂ and T₁ further showed the statistically identical NRS (0.952 and 0.873, respectively) at 4 DAS while treatment T₁₂ showed statistically identical NRS (0.887%) at 6 DAS where NRS rapidly decreased due to control vegetable at 6 DAS. On the other hand, untreated vegetable showed the lowest NRS content (0.350, 0.333, & 0.233) at 2, 4 and 6 DAS, respectively. At 2 DAS, the highest reducing sugar content (1.033) was found in treatment T₁₂ (30% Aloe vera gel along with 2% NaHCO₃) showed statistically highest NRS content. On the other hand, untreated vegetable (T₀) showed the lowest NRS content (0.700, 0.333, & 0.233% Brix) at 2, 4 and 6 DAS, respectively. Again in potato 30% Aloe vera gel along with 2% NaHCO₃ showed statistically highest NRS (0.390, 0.467 & 0.413% ) content while untreated vegetable showed the statistically lowest NRS (0.200, 0.190 & 0.133% ) 2, 4 and 6 DAS, respectively. This result revealed that the treatment CT₁₂ had highly significant for hold up the good qualities of minimally processed vegetables compare to other treatments of the study [22].

### 3.6 pH

Aloe gel along with 2% NaHCO₃ showed the statistically highest carrot showed the more pH (5.190, 4.755 and 4.612) than potato (4.866, 4.572 and 4.302) at 2, 4 and 6 DAS, respectively. The treatment T₁₂ showed the statistically higher pH (5.660, 5.443 & 5.337) at 2, 4 & 6 DAS respectively. Again, untreated vegetable showed the statistically lowest pH (3.599, 3.801 & 3.725) at 2, 4 & 6 DAS respectively. Similarly, edible coatings based on chitosan (CH), Aloe gel (AL) and its combination with Aloe gel showed significant effect on pH where CHAL was the best for reduced pH. From the above result it was found that the reduction of pH content had much higher in control while it was much lower in T₁₂ (30% Aloe gel + 2% NaHCO₃) compared other treatments of the study [19]. This finding suggested that the treatment T₁₂ would be the optimum rate of edible starch for longevity the storage period and maintenance the freshness quality of minimally processed vegetables for longer period.

### 3.7 Microbial Changes of Minimally Processed Vegetables

#### 3.7.1 Number of fungal colonies on PDA media

Number of fungal colony growth was counted maximum in potato (7.333, 8.256 and 9.256) than carrot (6.692, 8.462 and 9.462) at 2, 4 and 6 DAS, respectively. Growth of fungal colonies on PDA media had the maximum in control or without treated vegetable (9.00) and there after fungal colonies significantly decreased in increasing edible starch (Aloe gel) along with increasing sodium bicarbonate as well as the higher rate of edible starch (30% Aloe Gel) along with higher rate of sodium bicarbonate (2% NaHCO₃) recorded the minimum colony (1.667) at 2 DAS. However, fungal colonies also significantly increased with the advancement of the storage period due to significant reduction of freshness quality of minimally processed vegetables as well as the changes in physical and chemical characters.

#### 3.7.2 Number of bacterial colony on NA media

Potato showed the highest number of bacterial colonies (9.33, 5.974 and 6.974) than carrot (8.69, 5.154 and 6.154) at 2, 4 and 6 DAS, respectively. Without minimally processed (control) vegetables showed the maximum bacterial colonies (7.00, 8.67 and 9.67) at 2, 4 and 6 DAS, respectively while higher rates of both edible starch and sodium bicarbonate (30% Aloe gel + 2% NaHCO₃) recorded the minimum
Table 1. Changes in titratable acidity, ascorbic acid content and total soluble solid (% Brix) of MP vegetables

<table>
<thead>
<tr>
<th>Variety</th>
<th>Titratable acidity (%)</th>
<th>Ascorbic acid (mg/25 g)</th>
<th>Total Soluble Sugar (% Brix)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Carrot</td>
<td>3.019 a</td>
<td>2.627 a</td>
<td>2.457 a</td>
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<tr>
<td>Potato</td>
<td>1.171 b</td>
<td>1.059 b</td>
<td>0.983 b</td>
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<tr>
<td>CV (%)</td>
<td>12.5</td>
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<td>5.43</td>
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<tr>
<td>LSD (0.05)</td>
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<td>0.0448</td>
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<tr>
<td>Level of Sig.</td>
<td>**</td>
<td>**</td>
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</tr>
</tbody>
</table>

Table 2. Effect of edible starch along with NaHCO₃ on changes in titratable acidity, ascorbic acid content and total soluble solids (TSS) of MP vegetables

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Titratable acidity (%)</th>
<th>Ascorbic acid (mg/25 g)</th>
<th>Total soluble sugar (% Brix)</th>
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<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
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<tr>
<td>T₀</td>
<td>1.320 fg</td>
<td>1.171 f</td>
<td>1.101 f</td>
</tr>
<tr>
<td>T₁</td>
<td>1.415 fg</td>
<td>1.390 e</td>
<td>1.215 h</td>
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<td>1.593 fg</td>
<td>1.425 de</td>
<td>1.260 h</td>
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<td>T₃</td>
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<td>1.403 e</td>
<td>1.313 h</td>
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<td>1.630 c–e</td>
<td>1.537 g</td>
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<td>T₅</td>
<td>1.922 d–g</td>
<td>1.708 b–e</td>
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<td>T₆</td>
<td>1.983 c–f</td>
<td>1.817 a–d</td>
<td>1.720 f</td>
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<tr>
<td>T₈</td>
<td>2.482 ab</td>
<td>1.993 a–c</td>
<td>1.923 cd</td>
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<td>T₉</td>
<td>2.203 b–d</td>
<td>2.033 a–c</td>
<td>1.978 bc</td>
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<td>T₁₀</td>
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<td>T₁₁</td>
<td>2.318 bc</td>
<td>2.137 a</td>
<td>2.065 ab</td>
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<td>T₁₂</td>
<td>2.437 a</td>
<td>2.202 a</td>
<td>2.140 a</td>
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<td>CV (%)</td>
<td>12.5</td>
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<td>LSD (0.05)</td>
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Table 3. Interaction effect of vegetable species and edible starch along with NaHCO₃ on changes in titratable acidity, ascorbic acid content and total soluble solid of MP vegetables

<table>
<thead>
<tr>
<th>Interaction treatment</th>
<th>Titratable acidity (%)</th>
<th>Ascorbic acid (mg/25 g)</th>
<th>Total soluble sugar (% Brix)</th>
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<tr>
<td>T₀</td>
<td>1.566ij</td>
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<td>1.247 jk</td>
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<tr>
<td><strong>CV (%)</strong></td>
<td>12.5</td>
<td>5.43</td>
<td>5.43</td>
</tr>
<tr>
<td><strong>LSD (0.05)</strong></td>
<td>0.430</td>
<td>0.163</td>
<td>0.155</td>
</tr>
<tr>
<td><strong>Level of Sig.</strong></td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

Note: ** significant at p < 0.01

V₁: Carrot, V₂: Potato, T₀: Control, T₁: 10% Aloe Gel, T₂: 10% Aloe Gel + 1% NaHCO₃, T₃: 10% Aloe Gel + 1.5% NaHCO₃, T₄: 10% Aloe Gel + 2% NaHCO₃, T₅: 20% Aloe Gel + 1% NaHCO₃, T₆: 20% Aloe Gel + 1.5% NaHCO₃, T₇: 20% Aloe Gel + 2% NaHCO₃, T₈: 30% Aloe Gel + 1% NaHCO₃, T₉: 30% Aloe Gel + 1.5% NaHCO₃, T₁₀: 30% Aloe Gel + 2% NaHCO₃.
Table 4. Effect of vegetable species on changes in reducing sugar, non-reducing sugar content and pH of MP vegetables

<table>
<thead>
<tr>
<th>Variety</th>
<th>Reducing sugar</th>
<th>Non-reducing sugar</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Carrot</td>
<td>1.682 a</td>
<td>1.415 a</td>
<td>1.262 a</td>
</tr>
<tr>
<td>Potato</td>
<td>1.271 b</td>
<td>1.101 b</td>
<td>0.982 b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.47</td>
<td>10.2</td>
<td>9.9</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.028</td>
<td>0.059</td>
<td>0.051</td>
</tr>
<tr>
<td>Level of Sig.</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

Table 5. Effect of different concentration of edible starch and NaHO₃ on changes in reducing sugar, non–reducing sugar and pH of MP vegetables

<table>
<thead>
<tr>
<th>Variety</th>
<th>Reducing sugar</th>
<th>Non-reducing sugar</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>T₀</td>
<td>1.001 l</td>
<td>0.763 i</td>
<td>0.689 g</td>
</tr>
<tr>
<td>T₁</td>
<td>1.075 jk</td>
<td>0.910g</td>
<td>0.815fg</td>
</tr>
<tr>
<td>T₂</td>
<td>1.043 k</td>
<td>0.977fg</td>
<td>0.887 fg</td>
</tr>
<tr>
<td>T₃</td>
<td>1.128 j</td>
<td>1.018 fg</td>
<td>0.883 fg</td>
</tr>
<tr>
<td>T₄</td>
<td>1.253 i</td>
<td>1.048 fg</td>
<td>1.008 ef</td>
</tr>
<tr>
<td>T₅</td>
<td>1.338 h</td>
<td>1.133 ef</td>
<td>0.828 g</td>
</tr>
<tr>
<td>T₆</td>
<td>1.398 gh</td>
<td>1.205 de</td>
<td>1.058 de</td>
</tr>
<tr>
<td>T₇</td>
<td>1.447 fg</td>
<td>1.272 cde</td>
<td>1.172 cd</td>
</tr>
<tr>
<td>T₈</td>
<td>1.510 ef</td>
<td>1.347 bcd</td>
<td>1.220 bc</td>
</tr>
<tr>
<td>T₉</td>
<td>1.562 ded</td>
<td>1.360 bcd</td>
<td>1.257 bc</td>
</tr>
<tr>
<td>T₁₀</td>
<td>1.632 c</td>
<td>1.437 b</td>
<td>1.343 ab</td>
</tr>
<tr>
<td>T₁₁</td>
<td>1.790 b</td>
<td>1.588 a</td>
<td>1.463 a</td>
</tr>
<tr>
<td>T₁₂</td>
<td>1.950 a</td>
<td>1.662 a</td>
<td>1.443 a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.47</td>
<td>10.2</td>
<td>9.9</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.073</td>
<td>0.146</td>
<td>0.126</td>
</tr>
<tr>
<td>Level of Sig.</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>
Table 6. Interaction effect of species and edible starch along with NaHCO₃ on changes in total soluble sugar and reducing sugar of MP vegetables

<table>
<thead>
<tr>
<th>Variety</th>
<th>Reducing sugar</th>
<th>Non-reducing sugar</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>V₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T₀</td>
<td>1.291 i</td>
<td>0.733 jk</td>
<td>0.817 o</td>
</tr>
<tr>
<td>T₁</td>
<td>1.233 k</td>
<td>1.100 f-j</td>
<td>1.027 g-l</td>
</tr>
<tr>
<td>T₂</td>
<td>1.733 mn</td>
<td>0.900 jk</td>
<td>0.793 m-o</td>
</tr>
<tr>
<td>T₃</td>
<td>1.217 kl</td>
<td>1.067 g–k</td>
<td>0.893 j–o</td>
</tr>
<tr>
<td>T₄</td>
<td>1.387 j</td>
<td>1.100 f–j</td>
<td>1.100 f–j</td>
</tr>
<tr>
<td>T₅</td>
<td>1.490 ij</td>
<td>1.233 d–g</td>
<td>0.723 o</td>
</tr>
<tr>
<td>T₆</td>
<td>1.580 hi</td>
<td>1.333 c–f</td>
<td>1.137 f–h</td>
</tr>
<tr>
<td>T₇</td>
<td>1.653 gh</td>
<td>1.433 cd</td>
<td>1.333 de</td>
</tr>
<tr>
<td>T₈</td>
<td>1.763 ef</td>
<td>1.533 bc</td>
<td>1.400 cd</td>
</tr>
<tr>
<td>T₉</td>
<td>1.877 d</td>
<td>1.533 bc</td>
<td>1.433 b–d</td>
</tr>
<tr>
<td>T₁₀</td>
<td>2.000b c</td>
<td>1.667 ab</td>
<td>1.567 a–c</td>
</tr>
<tr>
<td>T₁₁</td>
<td>2.097 ab</td>
<td>1.833 a</td>
<td>1.573 a</td>
</tr>
<tr>
<td>T₁₂</td>
<td>2.187 a</td>
<td>1.833 a</td>
<td>1.600 a</td>
</tr>
<tr>
<td>V₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T₀</td>
<td>0.867q</td>
<td>0.636 l</td>
<td>0.553 o</td>
</tr>
<tr>
<td>T₁</td>
<td>0.917 p</td>
<td>0.853 k</td>
<td>0.747 no</td>
</tr>
<tr>
<td>T₂</td>
<td>0.987 op</td>
<td>0.920 l–k</td>
<td>0.837 l–o</td>
</tr>
<tr>
<td>T₃</td>
<td>1.040 no</td>
<td>0.970 h–k</td>
<td>0.873 k–o</td>
</tr>
<tr>
<td>T₄</td>
<td>1.110 l–n</td>
<td>0.997 g–k</td>
<td>0.917 i–o</td>
</tr>
<tr>
<td>T₅</td>
<td>1.187 k–m</td>
<td>1.033 g–k</td>
<td>0.933 h–n</td>
</tr>
<tr>
<td>T₆</td>
<td>1.217 kl</td>
<td>1.077 g–k</td>
<td>0.980 h–m</td>
</tr>
<tr>
<td>T₇</td>
<td>1.240 k</td>
<td>1.110 e–l</td>
<td>1.010 g–l</td>
</tr>
<tr>
<td>T₈</td>
<td>1.257 k</td>
<td>1.160 e–i</td>
<td>1.040 g–l</td>
</tr>
<tr>
<td>T₉</td>
<td>1.247 k</td>
<td>1.187 e–h</td>
<td>1.080 g–k</td>
</tr>
<tr>
<td>T₁₀</td>
<td>1.263 k</td>
<td>1.207 d–h</td>
<td>1.120 f–l</td>
</tr>
<tr>
<td>T₁₁</td>
<td>1.483 ij</td>
<td>1.343 c–e</td>
<td>1.193 e–g</td>
</tr>
<tr>
<td>T₁₂</td>
<td>1.713 f</td>
<td>1.490 bc</td>
<td>1.287 d–f</td>
</tr>
</tbody>
</table>

CV (%) 4.47 10.2 9.9 102.37 14.11 37.57 9.4 2.41 2.89
LSD (0.05) 0.103 0.207 0.179 1.725 0.155 0.373 0.773 0.186 0.151
Level of Sig. ** ** ** ** ** ** Ns ** **

Note: ** significant at p < 0.01

V₁: Carrot, V₂: Potato, T₁: Control, T₂: 10% Aloe Gel, T₃: 10% Aloe Gel + 1% NaHCO₃, T₄: 10% Aloe Gel + 1.5% NaHCO₃, T₅: 10% Aloe Gel + 2% NaHCO₃, T₆: 20% Aloe Gel, T₇: 20% Aloe Gel + 1% NaHCO₃, T₈: 20% Aloe Gel + 1.5% NaHCO₃, T₉: 20% Aloe Gel + 2% NaHCO₃, T₁₀: 30% Aloe Gel, T₁₁: 30% Aloe Gel + 1% NaHCO₃, T₁₂: 30% Aloe Gel + 1.5% NaHCO₃, T₁₃: 30% Aloe Gel + 2% NaHCO₃

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fungal colony (0.667, 3.00 and 4.00, respectively). However, treatment T_{11} (30% Aloe gel + 1.5% NaHCO\textsubscript{3}) also showed the same activity at 4 and 6 DAS. In the present study for reducing the microbial activity, Aloe vera gel mixed with sodium bicarbonate were used while 30% AVG and 2% NaHCO\textsubscript{3} had more effective to reduced microbial growth while aloe gel has inhibited the growth of both gram positive and gram negative bacteria.

![Fig. 1. Effect of vegetable species on growth of fungal colony on PDA media at different DAS of MP vegetables](image1)

![Fig. 2. Effect of edible starch along with NaHCO\textsubscript{3} on growth of fungal colony on PDA media at different DAS of MP vegetables](image2)

![Fig. 3. Effect of vegetable species on growth of bacterial colony on NA media at different DAS of MP vegetables](image3)
bicarbonate on the management of storage edible quality. Further studies are suggested to be the optimum rates for longer storage with quality for longer period, higher rates of edible MP or without MP potato for getting the good above observations it may be concluded that, performance compare to control. Considering the rate of edible starch (30%) + sodium bicarbonate the higher rate of edible starch (30%) + sodium without treated vegetable which indicated that edible starch + sodium bicarbonate compare to significantly reduced by the increasing rate of changes in quality characters during period than potato. Among the treatments, storage minimally processed vegetable for longer higher capability to hold up the better quality of to both varieties while carrot had statistically reduced with the minimally processed vegetables significantly concerning bio-chemical and microbial during storage at 2, 4 and 6 DAS were statistically significant while carrot had statistically higher effect than potato for maintaining the better quality during storage. Besides, storage quality of the minimally processed vegetables significantly reduced with the advancement of the study due to both varieties while carrot had statistically higher capability to hold up the better quality of storage minimally processed vegetable for longer period than potato. Among the treatments, changes in quality characters during storage significantly reduced by the increasing rate of edible starch + sodium bicarbonate compare to without treated vegetable which indicated that the higher rate of edible starch (30%) + sodium bicarbonate (2%) could be hold up the keeping quality for longer period during storage. Higher rate of edible starch (30%) + sodium bicarbonate (2%) treated potato (CT12) showed the superior performance compare to control. Considering the above observations it may be concluded that, minimally processed (MP) carrot is better than MP or without MP potato for getting the good quality for longer period, higher rates of edible starch (30% Aloe gel) and NaHCO$_3$ (2%) would be the optimum rates for longer storage with edible quality. Further studies are suggested to carry out to examine the effects of other or increasing rates of edible starch/sodium bicarbonate on the management of storage quality of fresh–cut or minimally processed vegetables.

Fig. 4. Effect of edible starch along with NaHCO$_3$ on growth of bacterial colony on NA media at different DAS of MP vegetables

4. CONCLUSION

In case of vegetable species, all the characters concerning bio-chemical and microbial during storage at 2, 4 and 6 DAS of MP vegetables were statistically significant while carrot had statistically higher effect than potato for maintaining the better quality during storage. Besides, storage quality of the minimally processed vegetables significantly reduced with the advancement of the study due to both varieties while carrot had statistically higher capability to hold up the better quality of storage minimally processed vegetable for longer period than potato. Among the treatments, changes in quality characters during storage significantly reduced by the increasing rate of edible starch + sodium bicarbonate compare to without treated vegetable which indicated that the higher rate of edible starch (30%) + sodium bicarbonate (2%) could be hold up the keeping quality for longer period during storage. Higher rate of edible starch (30%) + sodium bicarbonate (2%) treated potato (CT$_{12}$) showed the superior performance compare to control. Considering the above observations it may be concluded that, minimally processed (MP) carrot is better than MP or without MP potato for getting the good quality for longer period, higher rates of edible starch (30% Aloe gel) and NaHCO$_3$ (2%) would be the optimum rates for longer storage with edible quality. Further studies are suggested to carry out to examine the effects of other or increasing rates of edible starch/sodium bicarbonate on the management of storage quality of fresh–cut or minimally processed vegetables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


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