

Influence of edible starch and sodium bi-carbonate on postharvest quality of minimally processed Carrot and Potato

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 NaHCO_3 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 NaHCO_3) 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 NaHCO_3 solutions were prepared as per treatment. The prepared slices of vegetable species were treated with different treatment combinations and stored in 200 g capacity polyethylene bags sealed under air, vacuum or modified active atmosphere and then bio-chemically (Titratable Acidity (TA), Ascorbic Acid (AA) content, Total Soluble Solids (TSS), Reducing Sugar (RS), Non-reducing Sugar (NRS), pH) and microbiologically assessed. Higher rate of edible starch (30%) + NaHCO_3 (2%) treated potato (CT_{12}) 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 (T_0) 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 T_{12} 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, bio-chemical properties*

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 produces 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]. Employing 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], ClO_2 [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 of aloe gel and **NaHCO_3** with determining the physic-chemical properties and microbial changes as well as shelf life of minimally processed carrot and potato.

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% NaHCO_3 , T3: 10% aloe gel + 1.5% NaHCO_3 , T4: 10% aloe gel + 2% NaHCO_3 , T5: 20% aloe gel, T6: 20% aloe gel + 1% NaHCO_3 , T7: 20% aloe gel + 1.5% NaHCO_3 , T8: 20% aloe gel + 2% NaHCO_3 , T9: 30% aloe gel, T10: 30% aloe gel + 1% NaHCO_3 , T11: 30% aloe gel + 1.5% NaHCO_3 , T12: 30% aloe gel + 2% NaHCO_3 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 7°C 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 (7°C) with 100 mg of free chlorine L⁻¹ at pH 7.0 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 biochemical 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].

RESULTS AND DISCUSSION

Bio-chemical changes of minimally processed vegetables

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].

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 compare 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].

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].

Table 1. Changes in titratable acidity, ascorbic acid content and total soluble solid (% Brix) of MP vegetables

Variety	Titratable acidity (%)			Ascorbic acid (mg/25 g)			Total Soluble Sugar (% Brix)		
	2	4	6	2	4	6	2	4	6
Carrot	3.019 a	2.627 a	2.457 a	5.528 b	5.104 b	4.932 b	8.581 a	8.184 a	7.962 a
Potato	1.171 b	1.059 b	0.983 b	9.441 a	9.125 a	8.035 a	6.991 b	5.792 b	4.762 b
CV (%)	12.5	5.43	5.43	14.4	3.56	3.38	1.69	2.22	3.31
LSD (0.05)	0.119	0.047	0.0448	0.489	0.119	0.117	0.0592	0.073	0.099
Level of Sig.	**	**	**	**	**	**	**	**	**

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

Treatment	Titratable acidity (%)			Ascorbic acid (mg/25 g)			Total soluble sugar (% Brix)		
	2	4	6	2	4	6	2	4	6
T ₀	1.320 fg	1.117 f	1.101 f	5.203 de	5.6389 i	5.109 f	6.498 m	5.791 j	4.950 j
T ₁	1.415 fg	1.390 e	1.215 h	6.652 cd	6.032 h	5.408 ef	6.750 l	5.917 i	5.267 i
T ₂	1.593 fg	1.425 de	1.260 h	7.065 b-d	6.308 gh	5.682 de	7.300 k	6.517 h	5.717 h
T ₃	1.687 fg	1.403 e	1.313 h	7.163 b-d	6.582 fg	5.963 d	7.398 jk	6.760 g	5.850 gh
T ₄	1.845 e-g	1.630 c-e	1.537 g	7.293 b-d	7.108 e	6.563 c	7.537 ij	6.863 fg	6.262 f
T ₅	1.922 d-g	1.708 b-e	1.597 g	7.257 b-d	7.147 de	6.823 a-c	7.628 hi	6.955 ef	6.420 ef
T ₆	1.983 c-f	1.817 a-d	1.720 f	5.902 d	7.228 de	6.800 bc	7.717 gh	7.085 de	6.535 cde
T ₇	2.062 c-e	1.912 a-c	1.838 de	7.537 bc	7.307 c-e	6.825 a-c	7.845 fg	7.033 de	6.483 def

T ₈	2.482 ab	1.993 a-c	1.923 cd	7.725 bc	7.443 b-d	6.918 ab	7.928 ef	7.150 cd	6.733 bcd
T ₉	2.203 b-d	2.033 a-c	1.978 bc	7.745 bc	7.562 a-c	6.940 ab	8.057 de	7.300 bc	6.750 bc
T ₁₀	2.257 b-d	2.082 ab	2.020 bc	7.775 bc	7.578 a-c	6.970 ab	8.115 cd	7.383 ab	6.850 ab
T ₁₁	2.318 bc	2.137 a	2.065 ab	7.900 a-c	7.677 ab	7.070 ab	8.217 bc	7.433 ab	6.833 ab
T ₁₂	2.437 a	2.202 a	2.140 a	8.138 ab	7.840 a	7.142 a	8.393 a	7.567 a	7.017 a
CV (%)	12.5	5.43	5.43	14.4	3.56	3.38	1.69	2.22	3.31
LSD (0.05)	0.304	0.116	0.109	1.249	0.293	0.288	0.151	0.179	0.243
Level of Sig.	**	**	**	**	**	**	**	**	**

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

Interaction treatment	Titratable acidity (%)			Ascorbic acid (mg/25 g)			Total soluble sugar (% Brix)			
	2	4	6	2	4	6	2	4	6	
V ₁	T ₀	1.566ij	1.809i	1.733 h	4.127	4.010 k	3.425 h	6.819 m	6.1462 hi	5.894 g
	T ₁	2.287 i	2.073 i	1.800 h	4.260	4.023 k	3.833 g	7.133 lm	6.500 j	6.333 h
	T ₂	2.343 hi	2.080 i	1.823 h	5.000	4.500 j	4.230 fg	8.100 i	7.567 i	7.100 fg
	T ₃	2.440 g-i	2.010 i	1.933 h	5.150	4.993 i	4.630 f	8.217 hi	7.920 gh	7.433 f
	T ₄	2.610 g-i	2.307 h	2.233 g	5.300	5.157 hi	5.060 e	8.387 gh	8.127 fg	8.023 e
	T ₅	2.753 f-i	2.440 gh	2.340 fg	5.260	5.190 ghi	5.347 de	8.483 fg	8.277 ef	8.173 de
	T ₆	2.807 e-h	2.550 fg	2.453 ef	5.450	5.270 ghi	5.200 de	8.580 e-g	8.370 d-f	8.270 c-e
	T ₇	2.917 d-g	2.660 ef	2.553 de	5.587	5.343 fgh	5.250 de	8.690 d-f	8.367 d-f	8.267 c-e
	T ₈	3.733 ab	2.780 de	2.657 cd	5.700	5.420 fgh	5.337 de	8.757 c-e	8.433 c-e	8.333 b-e
	T ₉	3.167 c-f	2.847 cd	2.737 bc	5.753	5.483 fgh	5.380 de	8.893 b-d	8.600 b-d	8.500 a-d
	T ₁₀	3.247 c-e	2.913 cd	2.810 bc	5.883	5.567 fgh	5.473 de	8.930 bc	8.700 a-c	8.700 ab
	T ₁₁	3.337 b-d	2.993 bc	2.883 ab	6.000	5.643 fg	5.540 d	9.097 ab	8.800 ab	8.633 a-c
T ₁₂	3.553 a	3.097 a	2.990 a	6.290	5.753 f	5.650 d	9.287 a	8.933 a	8.833 a	
V ₂	T ₀	1.017 j	0.532 q	0.464n	8.07	7.625f	6.575 d	6.1534s	5.167 q	3.856 p
	T ₁	1.143 jk	0.707 p	0.630 m	9.043	8.040 e	6.983 c	6.367 r	5.333 p	4.200 o
	T ₂	0.843 k	0.770 o	0.697 lm	9.130	8.117 e	7.133 c	6.500 qr	5.467 op	4.333 no
	T ₃	0.933 jk	0.797 no	0.693 lm	9.177	8.170 e	7.297 c	6.580 p-r	5.600 n-p	4.267 o
	T ₄	1.080 jk	0.953 mn	0.840 kl	9.287	9.060 d	8.067 b	6.687 o-q	5.600 n-p	4.500 m-o
	T ₅	1.090 jk	0.977 m	0.853 kl	9.253	9.103 d	8.300 ab	6.773 op	5.633 no	4.667 l-n
	T ₆	1.160 jk	1.083 klm	0.987 jk	6.353	9.187 cd	8.400 ab	6.853 no	5.800 l-n	4.800 j-m
	T ₇	1.207 jk	1.163 jkl	1.123 ij	9.487	9.270 bcd	8.400 ab	7.000 mn	5.700 m-o	4.700 k-n
	T ₈	1.230 jk	1.207 jkl	1.190 i	9.750	9.467 abc	8.500 ab	7.100 lm	5.867 l-n	5.133 ij
	T ₉	1.240 jk	1.220 jkl	1.220 i	9.737	9.640 abc	8.500 ab	7.220 lm	6.000 kl	5.000 i-l
	T ₁₀	1.267 jk	1.250 jk	1.230 i	9.667	9.590 abc	8.467 ab	7.300 kl	6.067 kl	5.000 i-l
	T ₁₁	1.300 jk	1.280 j	1.247 i	9.800	9.710 ab	8.600 a	7.337 kl	6.067 kl	5.033 i-l
T ₁₂	1.320 jk	1.307 j	1.290 i	9.987	9.927 a	8.633 a	7.500 j	6.200 k	5.200 i	
CV (%)	12.5	5.43	5.43	14.4	3.56	3.38	1.48	1.69	2.22	
LSD (0.05)	0.430	0.163	0.155	1.766	0.414	0.408	0.242	0.213	0.253	
Level of Sig.	**	**	**	Ns	**	*	**	**	**	

Note: ** significant at $p < 0.01$

V₁: Carrot

T₀: Control

T₃: 10% Aloe Gel + 1.5% NaHCO₃

T₆: 20% Aloe Gel + 1% NaHCO₃

T₉: 30% Aloe Gel

T₁₂: 30% Aloe Gel + 2% NaHCO₃

V₂: Potato

T₁: 10% Aloe Gel

T₄: 10% Aloe Gel + 2% NaHCO₃

T₇: 20% Aloe Gel + 1.5% NaHCO₃

T₁₀: 30% Aloe Gel + 1% NaHCO₃

T₂: 10% Aloe Gel + 1% NaHCO₃

T₅: 20% Aloe Gel

T₈: 20% Aloe Gel + 2% NaHCO₃

T₁₁: 30% Aloe Gel + 1.5% NaHCO₃

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].

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 T₁₁ 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.

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.

Table 4. Effect of vegetable species on changes in reducing sugar, non-reducing sugar content and pH of MP vegetables

Variety	Reducing sugar			Non-reducing sugar			pH		
	2	4	6	2	4	6	2	4	6
Carrot	1.682 a	1.415 a	1.262 a	1.250 a	1.049 a	0.914 a	5.190 a	4.755 a	4.612 a
Potato	1.271 b	1.101 b	0.982 b	0.3213 b	0.309 b	0.290 b	4.866 b	4.572 b	4.302 b
CV (%)	4.47	10.2	9.9	102.37	14.11	37.57	9.4	2.41	2.89
LSD (0.05)	0.028	0.059	0.051	0.458	0.044	0.106	0.214	0.053	0.061
Level of Sig.	**	**	**	**	**	**	**	**	**

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

Variety	Reducing sugar			Non-reducing sugar			pH		
	2	4	6	2	4	6	2	4	6
T ₀	1.001 l	0.763 i	0.689 g	0.301 d	0.307 j	0.233 ef	3.599g	3.801 k	3.725 h
T ₁	1.075 jk	0.910g	0.815g	0.472 c	0.427 i	0.317 e	4.247 f	4.083 j	3.887 g
T ₂	1.043 k	0.977fg	0.887 fg	0.478 c	0.445 i	0.388 de	4.502 ef	4.212 ij	4.040 fg
T ₃	1.128 j	1.018 fg	0.883 fg	0.520 c	0.492 hi	0.417 c-e	4.528 ef	4.310 hi	4.127 f
T ₄	1.253 i	1.048 fg	1.008 ef	0.582 c	0.515 ghi	0.720 a-c	4.687 d-f	4.405 gh	4.292 e
T ₅	1.338 h	1.133 ef	0.828 g	0.714	0.570 fgh	0.488 c-e	4.792 d-f	4.533 efg	4.337 de
T ₆	1.398 gh	1.205 de	1.058 de	0.697 b	0.618 efg	0.518 b-e	4.837 c-f	4.633 ef	4.477 cd
T ₇	1.447 fg	1.272 cde	1.172 cd	0.762 bc	0.675 def	0.570 b-e	5.593 ab	4.662 e	4.517 c
T ₈	1.510 ef	1.347 bcd	1.220 bc	0.817 b	0.733 cde	0.650 a-d	5.015 b-e	4.870 d	4.635 c
T ₉	1.562 de	1.360 bcd	1.257 bc	0.873 b	0.788 bcd	0.712 a-c	5.148 b-d	4.947 cd	4.820 b
T ₁₀	1.632 c	1.437 b	1.343 ab	0.942 ab	0.805 bc	0.722 a-c	5.267 a-d	5.013 c	4.825 b
T ₁₁	1.790 b	1.588 a	1.463 a	0.985 ab	0.873 ab	0.800 ab	5.422 a-c	5.152 b	5.003 a
T ₁₂	1.950 a	1.662 a	1.443 a	1.033 a	0.952 a	0.887 a	5.505 a	5.295 a	5.055 a

CV (%)	4.47	10.2	9.9	102.37	14.11	37.57	9.4	2.41	2.89
LSD (0.05)	0.073	0.146	0.126	0.169	0.109	0.261	0.547	0.132	0.151
Level of Sig.	**	**	**	**	**	**	**	**	**

Table 6. Interaction effect of species and edible starch along with NaHCO₃ on changes in total soluble sugar and reducing sugar of MP vegetables

Variety		Reducing sugar			Non-reducing sugar			pH		
		2	4	6	2	4	6	2	4	6
V ₁	T ₀	1.129 l	0.733 jk	0.817 o	0.700 ef	0.467 j	.413 i	3.927	3.641 p	3.523 m
	T ₁	1.233 k	1.100 f-j	1.027 g-l	0.733 ef	0.633 i	0.467 e-h	3.973	3.817 o	3.660 l
	T ₂	1.100 mn	0.900 jk	0.793 m-o	0.727 ef	0.647 i	0.593 e-h	4.603	4.123 n	3.913 k
	T ₃	1.217 kl	1.067 g-k	0.893 j-o	0.800 ef	0.707 hi	0.653 d-g	4.633	4.297 mn	4.100 jk
	T ₄	1.397 j	1.100 f-j	1.100 f-j	0.897 e	0.747 hi	0.647 d-g	4.820	4.397 j-m	4.303 f-j
	T ₅	1.490 ij	1.233 d-g	0.723 o	1.930 a	0.830 gh	0.757 c-f	4.947	4.550 h-k	4.407 e-h
	T ₆	1.580 hi	1.333 c-f	1.137 f-h	1.100 de	0.920 fg	0.810 c-e	4.953	4.690 f-i	4.570 c-e
	T ₇	1.653 gh	1.433 cd	1.333 de	1.187 de	1.030 ef	0.887 b-e	6.433	4.733 f-h	4.623 b-e
	T ₈	1.763 ef	1.533 bc	1.400 cd	1.277 d	1.123 de	1.027 a-d	5.197	5.100 cd	4.833 b
	T ₉	1.877 d	1.533 bc	1.433 b-d	1.353 cd	1.240 cd	1.140 a-c	5.287	5.247 bc	5.193 a
	T ₁₀	2.000b c	1.667 ab	1.567 a-c	1.483 c	1.270 cd	1.137 a-c	5.420	5.237 bc	5.130 a
	T ₁₁	2.097 ab	1.833 a	1.573 a	1.587 bc	1.393 bc	1.293 ab	5.620	5.360 ab	5.260 a
	T ₁₂	2.187 a	1.833 a	1.600 a	1.677 bc	1.533 ab	1.433 a	5.660	5.443 a	5.337 a
V ₂	T ₀	0.867q	0.636 l	0.553 o	0.200 h	0.190 j	0.133 gh	4.327	4.100 m	3.827 m
	T ₁	0.917 p	0.853 k	0.747 no	0.210 h	0.220 j	0.167 h	4.520	4.350 k-m	4.113 jk
	T ₂	0.987 op	0.920 i-k	0.837 l-o	0.230 h	0.243 j	0.183 h	4.400	4.300 mn	4.167 h-j
	T ₃	1.040 no	0.970 h-k	0.873 k-o	0.240 h	0.277 j	0.180 h	4.423	4.323 l-n	4.153 ij
	T ₄	1.110 l-n	0.997 g-k	0.917 i-o	0.267 h	0.283 j	0.793 c-e	4.553	4.413 j-m	4.280 f-j
	T ₅	1.187 k-m	1.033 g-k	0.933 h-n	0.277 h	0.310 j	0.220 gh	4.637	4.517 i-l	4.267 g-j
	T ₆	1.217 kl	1.077 g-k	0.980 h-m	0.293 h	0.317 j	0.227 gh	4.720	4.577 g-j	4.383 e-i
	T ₇	1.240 k	1.110 e-i	1.010 g-l	0.337 g	0.320 j	0.253 gh	4.753	4.590 g-j	4.410 e-h
	T ₈	1.257 k	1.160 e-i	1.040 g-l	0.357 g	0.343 j	0.273 gh	4.833	4.640 f-i	4.437 e-g
	T ₉	1.247 k	1.187 e-h	1.080 g-k	0.393 g	0.337 j	0.283 gh	5.010	4.647 f-i	4.447 e-g
	T ₁₀	1.263 k	1.207 d-h	1.120 f-i	0.400 g	0.340 j	0.307 gh	5.113	4.790 e-g	4.520 d-f
	T ₁₁	1.483 ij	1.343 c-e	1.193 e-g	0.383 g	0.353 j	0.307 gh	5.223	4.943 de	4.747 b-d
	T ₁₂	1.713 f	1.490 bc	1.287 d-f	0.390 g	0.370 j	0.340 f-h	5.350	5.147 c	4.773bc
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

T₀: Control

T₃: 10% Aloe Gel + 1.5% NaHCO₃

T₆: 20% Aloe Gel + 1% NaHCO₃

T₉: 30% Aloe Gel

T₁₂: 30% Aloe Gel + 2% NaHCO₃

V₂: Potato

T₁: 10% Aloe Gel

T₄: 10% Aloe Gel + 2% NaHCO₃

T₇: 20% Aloe Gel + 1.5% NaHCO₃

T₁₀: 30% Aloe Gel + 1% NaHCO₃

T₂: 10% Aloe Gel + 1% NaHCO₃

T₅: 20% Aloe Gel

T₈: 20% Aloe Gel + 2% NaHCO₃

T₁₁: 30% Aloe Gel + 1.5% NaHCO₃

Microbial changes of minimally processed vegetables

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.

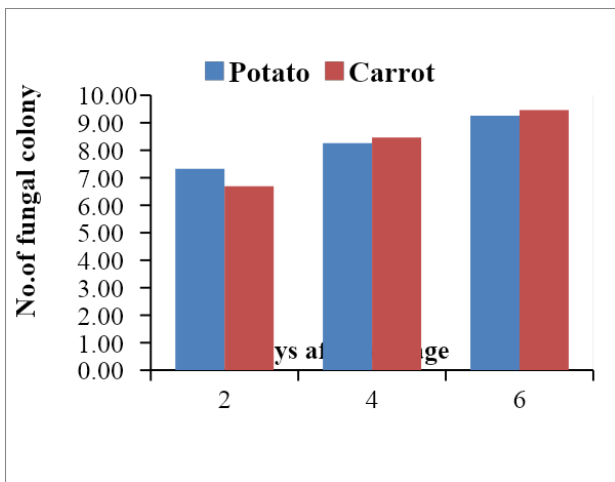


Fig. 1. Effect of vegetable species on growth of fungal colony on PDA media at different DAS of MP vegetables

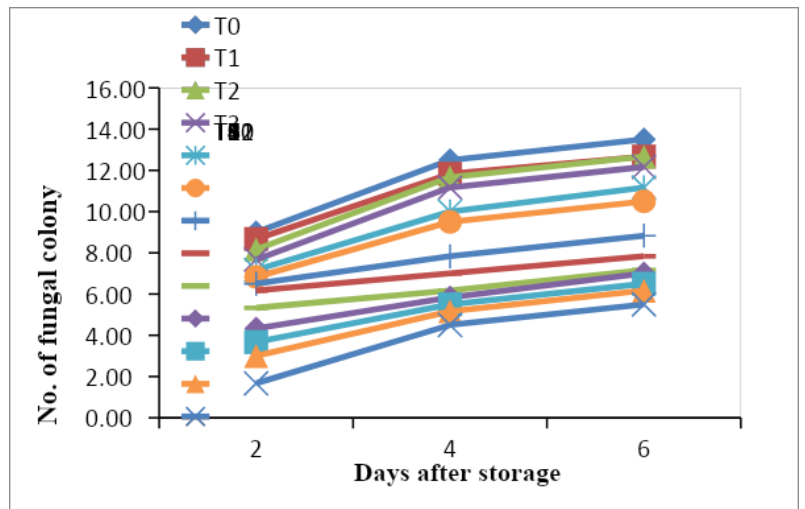


Fig. 2. Effect of edible starch along with NaHCO₃ on growth of fungal colony on PDA media at different DAS of MP vegetables

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 fungal colony (0.667, 3.00 and 4.00, respectively). However, treatment T₁₁ (30% Aloe gel + 1.5% NaHCO₃) 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% NaHCO₃ had more effective to reduced

microbial growth while aloe gel has inhibited the growth of both gram positive and gram negative bacteria.

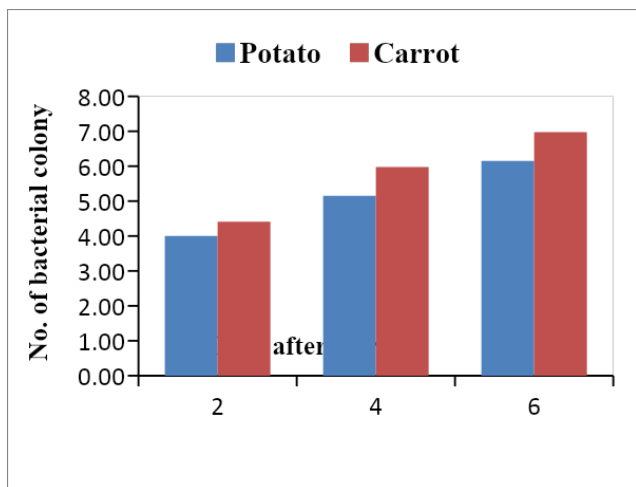


Fig. 3. Effect of vegetable species on growth of bacterial colony on NA media at different DAS of MP vegetables

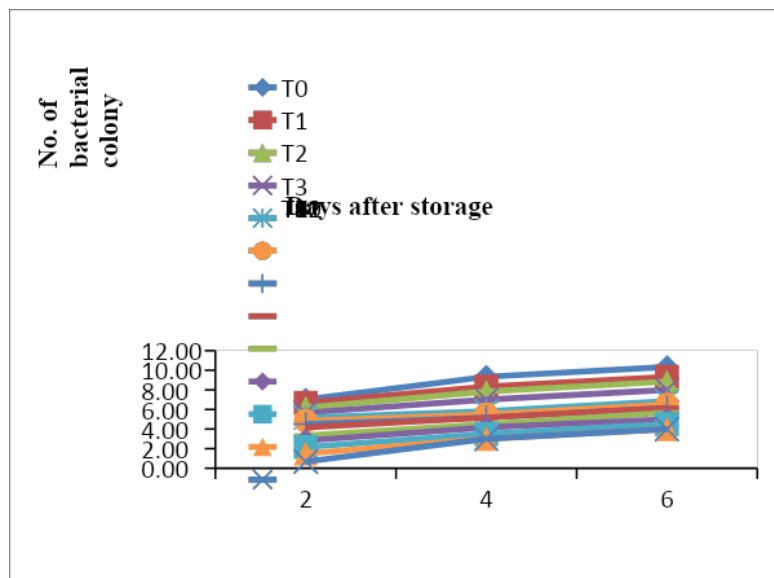


Fig. 4. Effect of edible starch along with NaHCO₃ on growth of bacterial colony on NA media at different DAS of MP vegetables

CONCLUSION

In case of vegetable species, all the characters 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 NaHCO₃ (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.

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