Effect of Low Molecular Weight Chitosan Coating on Physico-chemical Properties and Shelf life Extension of Pineapple (Ananas sativus)

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Abstract—Pineapple is perishable in fresh form and shelf life is limited, which leads subsequent post harvest loss every year in Bangladesh. The current study was conducted to investigate the effects of gamma irradiated and un-irradiated chitosan coating on different quality parameters (ripening, biochemical and organoleptic) and shelf life extension of pineapple over a storage period of 18 days at ambient environment (30 ± 1°C / RH). Preserved fruits maintained their eating quality during whole storage period without visual fungal growth. Dry matter content, total soluble solids, titratable acidity, reducing sugar, moisture content and ascorbic acid were also observed. All of the results were analyzed statistically and found to be significantly different. The overall results showed the superiority of irradiated chitosan (15 kGy) in extending the shelf life of pineapple and potentiality to be used on fresh produce to maintain quality and extending shelf life.

Index Terms — Chitosan coating; Pineapple; Irradiation; Shelf life extension; Natural fruit preservative

I. INTRODUCTION

Pineapple (Ananas sativus) is a non-climacteric fruit [1]. The annual production of pineapple in Bangladesh is 238000 metric ton [2] in which 43% pineapple was gone astray every year [3]. The higher loss of pineapples was mostly due to the excessive use of growth promoting chemicals. But physiological disorders, especially sunscald was observed to be the most serious problem in pineapple fruits which may cause damage by 100% [2]. Therefore, there is a need for substitute novel practices for preservation of fresh pineapple quality attributes during handling, distribution and retail sale.

Application of edible coatings is a promising alternative to improve the quality and extend shelf life of fresh and minimally processed produce [3]. Chitosan possesses biochemical properties, inherent antifungal properties, enzyme activity (chitinase), and elicitation of phytoalexins and due to excellent film forming ability of chitosan it is proved to be effective at extending the shelf life of fruits and vegetables [4-9]. The applications of chitosan are showing significantly positive effects in increasing yields of agricultural production in many countries. It is apparent that chitosan is being used in the preservation of fruits as a natural preservative [10]. It was shown that fruits like Oranges coated with both non-irradiated and irradiated chitosan oligomer solution showed extended shelf life. The effect of different radiation doses was observed and it was concluded that the shelf life was increased consistently by increasing the radiation dose [11].

These results were consistent with other scientists in case of mango, carrot and tomato [12-14]. Another study showed that chitosan extended shelf life of litchi [15]. Besides, chitosan coating was seen to delay fruit senescence of strawberry fruits stored at 10°C and 70 ± 5% relative humidity [16]. Shelf life of fruits increases here due to some specific reasons. Firstly, antifungal activity of chitosan is increased with the exposure of radiation. Besides increasing of anti-fungal activity, irradiation can modify chitosan to create chitosan solution having viscosity suitable with fruit coating due to its decrease of viscosity, coagulation and increase of solubility [17].

To date, use of this irradiated coating material has not yet been reported on fresh pineapple fruits in Bangladesh for maintaining quality and extending shelf life. Consequently, the objective of this study was to evaluate the efficiency of locally developed irradiated chitosan coatings for enhancing the shelf life and improving quality of pineapple.

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II. MATERIALS AND METHODS

1) Plant Material
Mature pineapple were obtained from a local market of Dhaka, Bangladesh and transported to the laboratory. Fruits of same variety were selected according to good appearance and free from infection and mechanical injuries.

2) Edible Coating Formulations and Irradiation
Chitosan was prepared in the laboratory of Institute of Radiation and Polymer Technology (IRPT), Bangladesh Atomic Energy Commission (BAEC) from prawn shell using chemical extraction method [17]. Degree of deacetylation of the chitosan was 83%. 20g of chitosan was dispersed in 980 ml of 2% acetic acid to prepare 1L 2% chitosan solution and subjected to 10, 15 and 20 kGy dose of gamma radiation. The gamma irradiation was carried out by 60Co gamma radiation source situated in IRPT, BAEC, Savar, Dhaka.

3) Coating Application
Pineapples were randomly distributed into five groups. Four groups were assigned each to one of four treatments whilst the fifth group provided untreated control. Samples were denoted by T1= Control, T2= Un-irradiated chitosan, T3= 10 kGy irradiated chitosan, T4= 15 kGy irradiated chitosan and T5= 20 kGy irradiated chitosan. Fruits were washed using distilled water, air dried at room temperature and then irradiated and un-irradiated chitosan solutions were sprayed. After the treatment, fruits were air dried and stored at ambient environment (30± 1°C / 75 ± 5% RH) up to complete damage of the control (18 days). Pineapples were analyzed for different parameters at a regular interval of 5 days.

4) Sensory Quality Evaluation
Sensory evaluation was done to evaluate taste, flavor and aroma of the preserved pineapple by using the Hedonic Scale suggested by Krum [18]. A panel of ten judges with age ranging from 25-40 years was selected on their consistency and reliability of judgment. Panelists were asked to rate the difference between samples by allotting the numbers from 0-9, where 0-2 represent dislike extremely, 3-5 for dislike, 6-8 for good and 9 for excellent aroma, taste and flavor.

5) Biochemical Analysis
Moisture content, Ash content, Acidity, total soluble solids (TSS) and pH were determined according to the official methods of analysis of the Association of Official Analytical Chemists (AOAC) [19]. For total soluble solids (TSS) determination hand refractometer, (Model: ATAGO 9099) was used and portable pH meter (Model: H1 98106) was used for pH determination. Ascorbic acid content was measured through methods of vitamin Assay (Methods of vitamin Assay 1966). Reducing sugar was determined using Nelson-Somogyi method.

6) Statistical Analysis
The experiments were arranged in completely randomized design, and each was comprised of five replicates. The data were subjected to one way ANOVA using SPSS software (17.5 version), while Duncan Multiple Range Test (DMRT) was used to compare differences between treatments at 95% confidence level of each variable.

III. RESULTS AND DISCUSSION

a. Physical appearance of pineapple at Ambient Environment
Quality of pineapple during storage has been tested by spoilage ratio and capability of ripening with color change. Pineapple with irradiated chitosan coating had no spoilage after 18 days of storage. Fungi could not be observed visually in chitosan treated fruits. At the preliminary stage of preservation (0 day) 60-80% fruits of each group were green. Treated Pineapples had strong texture compared to control. 15 kGy radiations showed best result as it had no visual fungal growth whereas untreated pineapple showed 60% visual fungal growth after 18 days of preservation period. Pineapple is a perishable fruit [12] but after application of irradiated chitosan solution as preservative the shelf life has extended.

b. Moisture Content, Total Soluble Solid (TSS) and Ash Content
Moisture content, Total Soluble Solid (TSS) and Ash content were performed at the beginning and end of the storage period. Table 1 represented the data set. From the table it was observed that moisture content was decreased significantly as the storage time proceeded. The minimum moisture loss occurred in fruits treated with Chitosan 15 kGy (T4) followed by the fruit treated with Chitosan 20 kGy (T5) as compared with untreated fruit (T1). The untreated fruits showed significantly lower moisture content than treated ones. Maximum moisture lost in untreated control might be due to high rate of respiration and transpiration [20].

The results get support with conclusion of the group of scientists worked on the effect of irradiated (low molecular weight chitosan: LMWC) and un irradiated (high molecular weight chitosan: HMWC) chitosan on cut fruits and stated that irradiated chitosan retained much moisture content of fruit, so maintained fruit quality for longer time [21]. Irradiation increase degree of deacetylation and lowers the molecular weight of chitosan which in turn delayed internal changes of fruit and ultimately increase shelf life. In the other hand, not much delayed by un-irradiated chitosan because it has less degree of deacetylation and high molecular weight [22]. This is why maximum moisture in the fruits was retained in fruits treated with irradiated chitosan because it has ability to act on outside and inner side of the fruit.
Table 1: Effect of irradiated and non irradiated chitosan coating and storage at ambient environment (30 ± 1°C / 75 ± 5% RH) for 18 days on Moisture content, Total Soluble Solid (TSS) and Ash content of pineapple during storage (n=5); Means within columns with different letters are significantly different (P < 0.05)

<table>
<thead>
<tr>
<th>Storage days</th>
<th>Moisture content</th>
<th>Total Soluble Solid (TSS)</th>
<th>Ash content</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 day</td>
<td>86.2±0.61a</td>
<td>11.2±2</td>
<td>0.92±0.16a</td>
</tr>
<tr>
<td>18 day</td>
<td>77.5±0.94b</td>
<td>12.1±1.39b</td>
<td>1.53±0.09b</td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 day</td>
<td>85±0.42a</td>
<td>12.5±0.56a</td>
<td>0.98±0.18a</td>
</tr>
<tr>
<td>18 day</td>
<td>81.9±0.37a</td>
<td>13.2±0.31a</td>
<td>1.01±0.13a</td>
</tr>
<tr>
<td>T3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 day</td>
<td>86.1±2a</td>
<td>10.8±7a</td>
<td>0.97±0.09a</td>
</tr>
<tr>
<td>18 day</td>
<td>82.3±0.41a</td>
<td>13.4±0.56a</td>
<td>0.98±0.11a</td>
</tr>
<tr>
<td>T4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 day</td>
<td>86.11±0.17</td>
<td>11.6±0.88a</td>
<td>0.92±0.17a</td>
</tr>
<tr>
<td>18 day</td>
<td>84.4±0.27a</td>
<td>13.4±0.56a</td>
<td>0.98±0.11a</td>
</tr>
<tr>
<td>T5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 day</td>
<td>87.9±0.56a</td>
<td>11.2±0.63a</td>
<td>0.94±0.13a</td>
</tr>
<tr>
<td>18 day</td>
<td>83.43±0.43</td>
<td>13.3±0.64a</td>
<td>0.97±0.13a</td>
</tr>
</tbody>
</table>

n=5; Refer to Figure 1 for T1-T5

For all irradiated chitosan coated pineapple, there was a significant increase in TSS during storage compared with the un-irradiated chitosan treatment and control (Table 1). The pineapple treated with chitosan 15 kGy (T4) and chitosan 20 kGy (T5) showed statistically higher values of TSS followed by un-irradiated chitosan (T2) and control (T1). The higher levels of TSS in the fruit coated with irradiated chitosan might be due to protective O₂ barrier which in turns reduce oxygen supply on the fruit surface eventually respiration [23]. Further, it was observed that fruit treated with any chitosan had a high TSS content which suggests that the inhibitory effect is only due to the O₂ barrier but not for any internal change occurred by chitosan.

Ash content of different treatment varied from 1.53% -0.92% at the starting and ending days of preservation. Ash content increased significantly in untreated fruits as lower moisture content leads to higher density which responsible for higher ash content. Ash content decreased significantly as chitosan coating act as active moisture barrier.

b. Measurement of pH

The pH value increased within the range from 4.6 – 5.2 of different pineapple sample both treated and untreated ones (Figure 1). Uncoated fruits showed higher increasing rate than coated fruits but no significant difference was encountered. 15 kGy (T4) treated fruits showed better result 5.1 than other treatments. It was found that a small change in pH represents a large change in hydrogen ion concentration. The change in pH is associated with number of reasons; it might be due to the effect of treatment on the biochemical condition of the fruit and slower rate of respiration and metabolic activity [24] and the breakup of acids with respiration during storage.

Figure 1: Effect of irradiated and non irradiated chitosan coating on pH value, acidity, reducing sugar content and ascorbic acid of Pineapple at ambient environment (30 ± 1°C / 75 ± 5% RH).

d. Measurement of Acidity

The results showed that acidity percentage was decreased along with the storage period in both coated and uncoated fruits (Figure 2) and then increased and there was no significant differences found. Results also suggested that treated pineapples had a slower decreasing trend than control. 70% acidity was found in 15 kGy (T4) treated fruits where control (T1) showed 98% acidity. Titratable acidity is directly related to the concentration of organic acids present in the fruits. The decreasing acidity at the end of storage might be due to the metabolic changes in fruits or due to the use of organic acid in respiratory process that is compatible with other scientists. Increased activity of citric acid during ripening or reduction in acidity may be due to their conversion into sugars and their further utilization in the metabolic processes of the fruit [20]. The effect of chitosan coatings on longan fruit was also reported and found that titratable acidity decreased during storage [25]. As, chitosan coating can lead to develop oxygen barrier on the fruit surface and thus reduce metabolic rate so, treated fruits showed less decreasing trend of titratable acid. Further, increase in acidity at higher storage period might be due to the conversion of macromolecules into titrable acids.
e. **Measurement of Reducing Sugar**

The chitosan treated fruits showed gradual increase in reducing sugar content (Figure 3) and the results showed significant differences between treated and untreated fruits. The reducing sugar content of control (T1) is 2 where 15 kGy (T4) treated fruits showed 5 which means treated fruits has slow ripening process than untreated ones.

Generally, reducing sugar content of fruits increases with the breakdown of non-reducing sugar. The gradual increase in reducing sugars in coated pineapple as compared to control treatment might be attributed slow ripening process [26].

The related result also found in mango fruits where the effectiveness of crab and shrimp chitosan along with radiation doses was studied [20]. Maximum amount of reducing sugars in treated fruits might be due to gradual conversion of starch to sugars, moisture loss and decrease in acidity by physiological changes during storage. Besides, less bacterial or fungal growth on treated pineapple can be another reason for higher reducing sugar content. Further decrease of reducing sugar in higher storage period may be due to utilization of sugars by bacteria or fungus.

However the rate of decrease in ascorbic acid was higher in untreated control (T1) fruits as compared with coated fruits. Among the treated fruits 15 kGy (T4) fruits showed superior result. Present studies showed that vitamin C was mostly high in mature but unripe pineapple fruits and it decreased as the ripening progressed. The reason for high vitamin C content in coated fruit can be attributed to slow ripening rate of chitosan treated fruit. Oxidation of ascorbic acid may be caused by several factors including exposure to oxygen, metals, light, heat and alkaline pH [28]. The results congregate with the findings of Jiang & Li who narrated that ascorbic acid content decreased when longan fruit was coated with chitosan at low temperature 2°C [25].

f. **Measurement of Ascorbic acid (V-C)**

The Vitamin C of samples increased until 15th day of storage and thereafter started to decline. (Figure 4) and there was no significant differences found. The results are strongly supported by other scientists worked on apricot [27].

g. **Sensory Quality Evaluation**

The taste scores of stored pineapples were varied from 5.3 to 4.0 during storage period. 15 kGy (T4) treated fruits showed better performance, scored 5 where untreated fruits (T1) scored 4 after 18 days of storage. Therefore, the results showed decreasing trend significantly (Table 2). It might be due to fluctuations in acids, pH and sugar/acid ratio [29].
Although there are many different tastes, they primarily represent four dominant chemical sensations; sweet, sour, bitter and salty in which sweet and sour predominate. This small variation of taste scores of treated pineapples was for chitosan coating, which maintained taste and retained the quality of fruit until 18 days of storage. Besides, chitosan retained fruit quality and no off flavor was developed than control sample.

Jiang & Li [25] reported that chitosan treated longan fruit had good eating quality even after 30 days of storage at 20°C. These results tally with Munoz et al. [30] who reported the influence of the chitosan on strawberries stored at 20°C for 4 days showing better maintenance of eating quality. It was observed from the results that the flavor scores were increased significantly from 4.1 to 5.2. Similarly, the maximum aroma score was observed in case of the fruits treated with 15 kGy (T4) irradiated chitosan. It seemed that the biochemical changes were slower and conversion of organic compounds into smaller compounds like esters, aldehydes, acids, alcohols, ketones etc. did not take place that contributed significantly to flavor and aroma of the fruits [31]. Whereas in control, flavor and aroma score was lowest than treated pineapple and started spoiling after 15 days. It might be due to the production of volatile compounds. Doreyappa & Huddar [32] reported that flavor of mangoes after ripening showed significantly decreasing trend as the storage period proceeded when stored at 32 to 35°C. It might be due to fluctuations in acids, pH and sugar/acid ratio24. Pineapple without chitosan coating did not develop flavor while chitosan coated fruits showed best results significantly. Desirable flavors may be produced by loss of organic acids during senescence. Untreated control fruits had lowest flavor scores. It might be due to the change in carbohydrates, proteins, amino acids, lipids and phenolic compounds that can influence the flavor of fresh fruits. The texture score significantly varied from 4.6 to 5.6 and highest value was observed in 15 kGy (T4) irradiated chitosan treated pineapple as chitosan coating created modified atmosphere.

The overall sensory evaluation showed significant differences between treated and untreated pineapple which prove that chitosan extend the shelf life of pineapple without deteriorating any physical, chemical and sensory properties.

IV. CONCLUSION

The treatment of irradiated (15 kGy) chitosan had extended shelf life of pineapple which is statistically proved. Treated pineapples showed best behavior throughout storage period with minimum loss of moisture, shrivel, increased ascorbic acid content and able to conserve better sensory characteristics. Irradiated chitosan coating also protected pineapple fruits from visual fungal growth. So, this study recommends chitosan as a very promising edible coating material that is very effective and safer way in maintaining the overall quality of pineapple.

REFERENCES


Table 2: Effect of irradiated and non irradiated chitosan coating on sensory quality of Pineapple at ambient environment (30± 1°C / 75 ± 5% RH); Means within columns with different letters are significantly different (P < 0.05)

<table>
<thead>
<tr>
<th>Treatement</th>
<th>Color</th>
<th>Flavor</th>
<th>Texture</th>
<th>Appearance</th>
<th>Taste</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>3.2±1.65&lt;sup&gt;a&lt;/sup&gt; 4.1±1.48&lt;sup&gt;c&lt;/sup&gt; 4.6±1.5&lt;sup&gt;c&lt;/sup&gt; 4.0±1.30&lt;sup&gt;d&lt;/sup&gt; 4.0±0.89&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>4.6±1.52&lt;sup&gt;b&lt;/sup&gt; 4.2±0.84&lt;sup&gt;c&lt;/sup&gt; 5.1±1.58&lt;sup&gt;b&lt;/sup&gt; 4.6±1.52&lt;sup&gt;d&lt;/sup&gt; 4.6±1.67&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>4±2.24&lt;sup&gt;c&lt;/sup&gt; 4.6±1.95&lt;sup&gt;b&lt;/sup&gt; 4.8±2.0&lt;sup&gt;c&lt;/sup&gt; 4.8±2.18&lt;sup&gt;b&lt;/sup&gt; 4.7±2.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>5.6±0.89&lt;sup&gt;d&lt;/sup&gt; 5.2±0.45&lt;sup&gt;b&lt;/sup&gt; 5.6±1.34&lt;sup&gt;b&lt;/sup&gt; 5.6±0.89&lt;sup&gt;a&lt;/sup&gt; 5.4±1.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T5</td>
<td>4±1.41&lt;sup&gt;c&lt;/sup&gt; 4.8±0.84&lt;sup&gt;b&lt;/sup&gt; 5±1.22&lt;sup&gt;b&lt;/sup&gt; 4.6±0.89&lt;sup&gt;a&lt;/sup&gt; 5.3±1.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
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</table>

n=5; Panelists=10; Refer to Fig. 1 for T1-T5


