Postharvest application of an edible coating based on chitosan and gum Arabic for controlling respiration rate and vitamin C content of chilli (Capsicum frustecens L.)

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Abstract. Chili (Capsicum frutescens L.) is the most important vegetable cum spice grown in tropical and sub tropical regions of the world. The post-harvest handling of chilli must be done well so that the quality is maintained. One way of handling post-harvest is to use edible coating such as chitosan and gum Arabic. The research was aimed to find out the effects of chitosan and gum Arabic coating to control of respiration rate and vitamin C content of post-harvest chilli. The research was conducted using a Completely Randomized Design (CRD) factorial consisting of two factors. The first factor consisted of various concentration of chitosan (0%, 1%, 1.5%, 2%) and the second factor consisted of various concentration of gum Arabic (0%, 5%, 10%, 15%) with three replications for each treatment. The coated fruits were then stored at room temperature (28°C) for 15 days. The observed data included respiration rate and vitamin C content. Data were analyzed using Analysis of Varians (ANOVA) and followed by Duncan’s Multiple Range Test (DMRT) at a 5% confidence level. The results showed that the application of chitosan and gum Arabic coating significantly affected the respiration rate and maintained vitamin C content.

1. Introduction
Chili (Capsicum frutescens L.) is the most important vegetable cum spice grown in tropical and sub tropical regions of the world. Chilli fruits are widely used as a flavoring and a spice throughout the world due to their color, taste, aroma and characteristic pungency [1,2]. The main factor associated with chilli postharvest shelf-life, particularly in tropical regions where the temperature is high, is increased respiration which results in faster fruit ripening and deterioration of fruit quality. The chilli fruits are usually used for fresh consumption and raw material for the food processing industry. Therefore, chilli fruits must be available in fresh condition at any time because it cannot be stored for a relatively long time. This causes demand and the need for chilli is always high at all times. The quality of chilli will drop after 2-3 days if stored at room temperature. Chilli can last for 10-20 days if stored in a cold temperature room (5-7 °C) and humidity 90-95% [3]. Storage of chilli fruits in cold temperatures will certainly require equipment that is not cheap, especially if it has to be marketed in areas far from the harvesting location. Therefore, post harvest handling is needed to extending postharvest life and keeping production costs low.

One of such promising postharvest treatment used for extending the market life of lively respiring horticultural produce is edible coating technology. Edible coatings indicate the application of commercial food grade waxes or films to protect the loss of natural glossiness during the postharvest...
period. The best part of the edible coating is that these are edible, healthy and biodegradable in nature, unlike other chemical postharvest treatments which leave a residue [4,5].

The use of edible coating is another safe method of prolonging storability of perishable crops [6]. Edible coatings are mostly derived from biological sources. Application of edible coating on fresh fruits is able to reduce quality changes and slow down quantity losses, for example, moisture loss by controlling and modifying the internal atmosphere of the individual fruits [7]. The edible coating material forms thin layer on the surface of food and gives a selective barrier against moisture, oxygen, and carbon dioxide [6]. If a film or coating with the appropriate permeability is chosen, a controlled respiratory exchange can be established and thus the preservation of fresh produce can be achieved [8]. Many materials such as polysaccharides, proteins, essential oils, may economically serve as edible coatings [9,10,11]. Chitosan and gum Arabic are classified as polysaccharides and can be used as an edible coating materials.

Chitosan has strong antimicrobial and antifungal activities that could effectively control fruit decay [12,13]. It could easily form coating on fruit and vegetable, and the respiration rate of fruit and vegetable was reduced by adjusting the permeability of carbon dioxide and oxygen [14]. Considering the superior properties of chitosan, it has been successfully used in many postharvest fruits and vegetables, such as grape, strawberries, jujube, fresh-cut lotus root and guava[11,15,16,17,18].

Gum Arabic is a soluble fiber obtained from acacia trees grown in sub-Saharan Africa (Acacia senegal (L.) Willd. or Acacia seyal Delile). Gum Arabic has been widely used as an emulsifier, thickening agent and film forming [19]. Coating with gum Arabic has been reported to be effective in increasing the shelf life of cucumber and tomatoes [20,21].

Chitosan and gum Arabic coating can maintain the permeability of CO\(_2\) and O\(_2\) of banana which will form the desired modified atmosphere that can increase the shelf life [22]. The use of edible coatings combination of chitosan and gum Arabic has not been applied to chilli fruits yet. Therefore in the present study was mainly focused to examine the effect of treatment variations in chitosan and gum Arabic concentration to improving shelf life of chilli fruits, especially for controlling respiration rate and vitamin C content.

2. Materials and Methods

2.1 Plant material preparation

Chilli fruits (Capsicum frutescens L.) at commercial maturity were harvested from an agricultural nursery in Klaten, Central Java, Indonesia and transported to the Universitas Sebelas Maret within 2 hours. Chilli fruits that are of uniform in size, shape, and color and are also free from any blemish or defects were selected and then washed with distilled water.

2.2 Experimental design

The research was conducted using a Completely Randomized Design (CRD) factorial consisting of two factors. The first factor consisted of various concentration of chitosan (0%, 1%, 1.5%, 2%) and the second factor consisted of various concentration of gum Arabic (0%, 5%, 10%, 15%) with three replications for each treatment.

2.3 Preparation of edible coating

Edible coating solution from chitosan (1%, 1.5%, 2%) were prepared by dissolving 1 g, 1.5 g and 2 g of chitosan powder in 100 ml of 1% acetic acid. Edible coating from gum Arabic (5%, 10%, 15%) were prepared by dissolving 5 g, 10 g and 15 g of gum Arabic powder in 100 ml aquades. The solutions were stirred with low heat (40°C) for 60 minute on a magnetic stirrer, then filtered to remove any undissolved impurities using a vacuum flasks [22].
2.4 Application of chitosan and gum Arabic coating
The coating solution was applied uniformly on the whole surface of fruits. Chili fruits were dipped in the chitosan solution (0%; 1%; 1.5% and 2%) for 5 minutes and then allowed to dry for 30 min at room temperature (28°C). After the chilli fruits were dry, the fruits then dipped in the gum Arabic solution (0%, 5%, 10% and 15%) for 5 minutes. After that, the fruits were dried again to ensure that the coating material was applied thoroughly on surface of the fruits. The fruits were then stored at room temperature (28°C) for 15 days for further analysis.

2.5 Characterization of applied edible coating
2.5.1 Analysis respiration rate
The respiratory rate was determined using a Lutron GCH 2028 carbon dioxide analyzer (Lutron Electronic Enterprise Co., Ltd., Taipei, Taiwan). Three coated chilli fruits (approximately 30 g) were placed in glass jar and incubated at room temperature (28°C) for 1 h. The glass jar had air-tight screw caps and rubber septum to allow headspace sampling. Percentages of carbon dioxide were recorded when the readings were stabilized. The results were calculated and expressed as ml CO₂/kg day [23].

2.5.2 Analysis of vitamin C content
The vitamin C content of the samples was estimated based on absorbance in conjunction with spectrophotometer at 264 nm [24].

2.6 Statistical analysis
The data was expressed as the means value and standard deviations. The IBM SPSS software 17.0 was used to perform analysis of variance (ANOVA). Significance differences between the means were set at a 5% confidence level. Duncan’s Multiple Range Test (DMRT) was used to compare the mean values of multiple treatments.

3. Result and Discussion
3.1 Respiration Rate
Fruits and vegetables are living commodities and their rate of respiration is of key importance to maintenance of quality. It has been commonly observed that the greater the respiration rate of a fruit, the shorter the postharvest life [25]. In the present study, the respiration rate of chilli fruits decreased until the end of the storage day. Chitosan and gum Arabic treated chilli fruits exhibited a significantly lower respiration rate than control during the storage period (Table 1).

Edible coating has the potential of reducing respiration rate of fruits. This is associated with a decrease in the metabolic rate. At 15 day, respiration rate decreased until 40-62%. Application of chitosan as edible coating showed that the lowest decreased respiration rate occurred on the use of chitosan 1.5%, with respiration rate of 51.78% while application of gum Arabic showed that the lowest decreased respiration rate occurred on the use of gum Arabic 10%, with respiration rate of 41.38%.

In the combination of chitosan and gum Arabic as coating material, the lowest decrease in respiration rate occurred in the treatment of chitosan 1.5% and gum Arabic 10% with decreased in respiration rate of 40% that capable of producing thick and effective layers to reduce the respiration rate compared than other treatments. In the treatment of gum Arabic 10%, the results were not significantly different with those obtained in the use of chitosan 1.5% and gum Arabic 10%.

The coating materials which play more important role in inhibiting the respiration rate of chilli fruits is application of chitosan 1.5% and gum Arabic 10%. The presence of these coating materials were able to maintain the surface of the chilli fruits so that the outside air cannot enter through the chilli pores. Similar report has showed that the application of gum Arabic 10% in coating of tomato fruits has been found to delay the ripening process by slowing down the rate of respiration. The other result from Scanning Electron Microscope (SEM) observations on bananas showed that coating material such as chitosan and gum Arabic can cover the cuticle and block pores on the surface of the fruits. Therefore,
the amount of oxygen that can be accessed by cells to be reduced and the amount of cabondioxide increases so that the respiration process can be inhibited [21]. Reduction of the respiration rate as a result of chitosan coating also has been reported in longan fruits [26] and plum fruits coated [27].

Table 1. The effect of different edible coating combinations of chitosan and gum Arabic on respiration rate of chilli fruits.

| Treatment | Concentration of chitosan (%) | Concentration of gum Arabic (%) | Respiration rate (ml CO2/kg day) | Decreased respiration rate (%) |
|-----------|-------------------------------|---------------------------------|---------------------------------|-------------------------------|
|           | Day 0                         | Day 15                          |                                 |                               |
| 0         | 0                             | 93.43±e                         | 36.23±3.13                      | 60.75±4.09                    |
|           | 5                             | 96.35±e                         | 43.24±2.37                      | 55.12±2.46                    |
|           | 10                            | 95.32±e                         | 55.87±4.62                      | 41.38±4.85                    |
|           | 15                            | 102.09±ab                       | 40.51±3.73                      | 60.31±3.65                    |
| 1         | 0                             | 101.98±ab                       | 38.35±2.48                      | 62.40±2.45                    |
|           | 5                             | 102.22±ab                       | 43.29±0.65                      | 57.66±0.64                    |
|           | 10                            | 94.26±e                         | 43.53±1.43                      | 53.82±1.52                    |
|           | 15                            | 95.09±e                         | 40.88±2.15                      | 57.01±2.27                    |
| 1.5       | 0                             | 95.29±ab                         | 45.95±4.25                      | 51.78±4.46                    |
|           | 5                             | 101.85±ab                       | 46.13±2.80                      | 54.70±2.83                    |
|           | 10                            | 94.11±e                         | 55.92±4.97                      | 40.57±5.46                    |
|           | 15                            | 99.96±bc                        | 42.30±0.85                      | 57.68±0.84                    |
| 2         | 0                             | 94.38±e                         | 41.74±0.44                      | 55.77±0.47                    |
|           | 5                             | 110.13±bc                       | 40.77±1.29                      | 61.61±8.22                    |
|           | 10                            | 95.59±e                         | 47.50±4.05                      | 50.31±4.21                    |
|           | 15                            | 102.04±ab                       | 54.93±2.08                      | 46.17±2.04                    |

Note = Different lowercase letter indicates significant difference at p < 0.05 in each storage day; different uppercase letter indicates significant difference at p < 0.05 in each treatment.

3.2 Effect of chitosan and gum Arabic coating on vitamin C content

Vitamin C, also known as ascorbic acid, is easily destroyed by oxidation especially at high temperature and easily lost during processing for preservation. Based on the results of ANOVA, various variations of chitosan and gum Arabic treatment effect on vitamin C content significantly (table 2). A continuous decline in ascorbic acid of chilli fruit throughout the storage period was observed during storage time. After 15 days storage, vitamin C content was decreased until 72-98%.

Decrease in vitamin C content can be caused due to the occurrence of oxidative processes and the ongoing process of respiration. Decrease in vitamin C content because oxidative processes can occur due to stimulation by light, oxygen, heat, peroxide and enzymes [28]. The higher the oxidative process takes place, the more vitamin C is damaged. In this study, degradation of vitamin C was caused by the presence of contact with surrounding air. The mechanism is the presence of oxygen molecules causing ascorbic acid monoanion to produce ascorbic anion radicals and H2O followed by dehydro formation of ascorbic acid and hydrogen peroxide. Dehydro of ascorbic acid (L-dehydroascorbate acid) is a form of oxidation of L-ascorbic acid which still has activity as vitamin C. L-dehydroascorbate acid which is very unstable can change to 2.3-L-diketogulonat (DKG) which has no activity vitamin C again. If DKG has been formed, it will reduce and even eliminate the vitamin C content available [29]. The process of respiration that is still ongoing during storage in chilli fruits also causes a decrease in vitamin C content.
The process of respiration will produce water then water evaporates from the fruit tissue. Evaporation of water causes the cell structure that originally intact to wither so that the enzyme ascorbate oxidase will be released by direct contact with ascorbic acid. As a result, vitamin C content is damaged [30]. Similar reports have been published for other horticultural crops (such as banana, green peppers, red peppers, etc) indicate that loss of vitamin C is also accelerated by longer storage time [31]. Our results are also indicated that concentration of vitamin C in chilli fruits declined gradually during storage at room temperature (28 °C) and with increasing duration of storage time after 15 days storage. The gradually declining ascorbic acid in coated fruit with gum Arabic suggests that the coating slowed down but did not prevent the synthesis of ascorbic acid during ripening [5,21]. Similar gradually slowing down of ascorbic acid content during ripening has been reported in the the application of chitosan as coating of strawberry fruits after 9 days of storage, longer than uncoated fruits [32].

Table 2. The effect of different edible coating combinations of chitosan and gum Arabic on vitamin C content of chilli fruits.

| Treatment | Vitamin C content (mg/100ml) | Decreased Vitamin C content(%) |
|-----------|-----------------------------|-------------------------------|
| Concentration of chitosan (%) | Concentration of gum Arabic (%) | 0 Day | 15 Day |                               |
| 0         | 0                           | 15.30<sup>b</sup> | 1.54 ± 0.000 | 89.88<sup>b</sup> ± 0.10 |
|           | 5                           | 14.82<sup>ab</sup> | 0.88 ± 0.000 | 94.06<sup>ab</sup> ± 0.02 |
|           | 10                          | 14.96<sup>ab</sup> | 0.57± 0.011 | 96.17<sup>ab</sup> ± 0.11 |
|           | 15                          | 15.10<sup>ab</sup> | 1.82± 1.020 | 88.49<sup>ab</sup> ± 6.78 |
| 1         | 0                           | 15.30<sup>b</sup> | 0.18± 0.029 | 98.88<sup>b</sup> ± 0.19 |
|           | 5                           | 15.00<sup>ab</sup> | 2.78± 0.000 | 81.47<sup>b</sup> ± 0.03 |
|           | 10                          | 14.98<sup>ab</sup> | 3.65± 0.135 | 75.63<sup>ab</sup> ± 0.88 |
|           | 15                          | 14.79<sup>a</sup> | 6.76± 0.000 | 54.29<sup>a</sup> ± 0.03 |
| 1.5       | 0                           | 15.04<sup>ab</sup> | 4.19± 0.111 | 72.12<sup>a</sup> ± 0.10 |
|           | 5                           | 14.99<sup>ab</sup> | 6.09± 0.000 | 59.37<sup>ab</sup> ± 0.05 |
|           | 10                          | 15.02<sup>ab</sup> | 2.47± 0.009 | 83.55<sup>ab</sup> ± 0.05 |
|           | 15                          | 15.10<sup>ab</sup> | 5.30± 0.040 | 64.31<sup>ab</sup> ± 1.15 |
| 2         | 0                           | 14.79<sup>a</sup> | 2.92± 0.011 | 80.27<sup>a</sup> ± 0.02 |
|           | 5                           | 14.85<sup>ab</sup> | 0.98± 0.061 | 93.38<sup>a</sup> ± 0.43 |
|           | 10                          | 15.00<sup>ab</sup> | 0.87± 0.058 | 94.17<sup>a</sup> ± 0.36 |
|           | 15                          | 14.79<sup>b</sup> | 2.99± 0.029 | 79.80<sup>b</sup> ± 0.18 |

Note = Different lowercase letter indicates significant difference at p < 0.05 in each storage day; different uppercase letter indicates significant difference at p < 0.05 in each treatment

4. Conclusion
The application of chitosan and gum Arabic as edible coating combination could be an alternative in the preservation of fruits and vegetables. The combination of chitosan and gum Arabic has been able to maintain respiration rate and gradually slowing down vitamin C content of chilli fruits for 15 day storage.

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References

[1] Barbero GF, Liazid A, Azaroual L, Palma M and Barroso CG 2014 Int. J. Food Prop. 19 485–493
[2] Giuffrida D, Dugo P, Torre G, Bignardi C, Cavazza A, Corradini C and Dugo G 2014 Food Res. Int. 65 163–170
[3] Syukur M, Yunianti R and Dermawan R 2016 Cultivation of Chilli Fruits, Harvesting Every Day (Jakarta : Penebar Swadaya) [in Indonesian]
[4] Kumar R and Kapur S 2016 Int. Journ. of Sci. Tech. Eng. 2 (11) 694-697.
[5] K Prasad K, Guarav AK, Preethi P and Neha P 2018 Acta Scientific Agriculture 2 (5) 55-64.
[6] Dhall RK 2013 Critical Reviews in Food Science and Nutrition 53 (5) 435–450.
[7] Turhan KN 2009 International Controlled and Modified Atmosphere Research Conference 876 299-305
[8] Ayranci E and Tunc S 2003 Food Chemistry 80 (3) 423–431
[9] Vanzela ESL, Nascimento PD, Fontes EAF, Mauro MA and Kimura M 2013 Food Sci. Technol. 50 420–425.
[10] Lima MA, Cerqueira MA, Souza BWS, Santos ECM and Teixeira JA 2010 J. Food Eng. 97 101-109.
[11] Santos NSD, Aguiar AJA, Oliveira CED, Sales CVD and Silva SDM 2012 Food Microbiol. 32 345-353.
[12] Aider M 2010 Food Sci. Technol-LEB 43 837-842
[13] Shiekh RA, Malik MA, Al-Thabaiti SA and Shiekh MA 2013 Food Sci. Technol. Res. 19(2) 139-155.
[14] Elsabee MZ and Abdou ES 2013 Eng C Mater. Biol. Appl. 33 1819-41
[15] Perdones A, Sánchez-González L, Chiralt A and Vargas M 2012 Postharvest Biol. Tech. 70 32-41.
[16] Yu YW, Zhang SY, Ren YZ, Li H and Zhang XN 2012 J. Food Eng. 113 408-414
[17] Xing Y, Li X, Xu Q, Jiang YH and Yun J 2010 Innov. Food Sci. Emerg. 11 684-689
[18] Hong K, Xie J, Zhang L, Sun D and Gong D 2012 Scientia Horticulturae 144 172-178
[19] Motlagh S, Ravines P, Karamallah KA and Ma Q 2006 Food Hydrocolloids 20(6) 848-854
[20] Al-Juhaimi F, Ghafoor K and Babiker EE 2012 Pakistan Journal of Botany 44(4) 1439–44.
[21] Ali A, Maqbool M, Anderson PG and Zahid N 2013 Postharvest Biol.Tech. 76 119-124
[22] Maqbool M, Ali A, Alderson PG, Zahid N and Siddiqui Y 2011 J. Agric. Food Chem. 59 5474-82
[23] Azarakshn N, Osman A, Ghazali HM, Tan CP and Mohd Adzahan N 2012 Int. Food Res. J. 19(1) 279-285
[24] AOAC (Association of Official Analytical Chemist) 1990 Official Method of Analyst (15th Ed) (Washington DC : AOAC)
[25] Aked J 2002 Maintaining the Postharvest Quality of Fresh Fruits and Vegetables Fruit and Vegetable Processing: Improving Quality ed W Jongen (Cambridge : Woodhead Publishing) pp 119-149
[26] Lin MG, Lasekan O, Saari N and Kahirunniza-Bejo S 2017 Journal of Food Quality 2017 1-11
[27] Bal E 2013 J. Agr. Sci. Tech. 15 1219-30
[28] Chitravathi K, Chauchan OP and Raju PS 2015 Food Packaging and Shelf Life 45 1-9
[29] Sine HMC 2013 Partner 20(2) 165-171 [in Indonesian]
[30] Rahayu ES and Pribadi P 2012 Biosaientifikasi 4(2) 89-97 [in Indonesian]
[31] Lee SK and Kader AA 2000 Postharvest Biology and Technology 20 207-220
[32] Petriccione M, Mastrobuoni F, Pasquariello MS, Zampella L, Nobis E, Capriolo G and Scortichini M 2015 Foods 2015, 4, 501-523