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THE EDIBLE COATING TREATMENTS ON COLOR QUALITY FRESH-CUT LEEK DURING COLD STORAGE

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Abstract
This study was carried out to determine the effect of plant-based edible coating on color changes of fresh-cut leek during storage. For this aim 0.5, 1 and 2% solutions of tapioca-starch were prepared and 0,25% gelatine was added to each dose. The fresh-cut leek samples were dipped these solutions for 5 minutes, then dried, packaged and stored at 4 C and %85-90 RH for 28 days. The color values (*L*a*b** and h^o), discoloration rate (%), poliphenol oxydase (PPO) activity, total soluble solids (TSS) and weight losses of samples were determined in seven days intervals during storage. The results of the research shoved that, L values of coated samples were higher than that of the control group while the h^o values of control group were higher. PPO activity of samples increased in all treatment groups, but did not show evident differences among the treatments. The TSS of samples treated with 0,5% tapioca-starch edible coating were the lowes, whereas it remained the same for the other doses of edible coatings ofthe control group. The weight losses of the samples treated with 1% were the lowest among the treatment groups. Discoloration rate of samples treated with 2% edible coating, however, were found to the lowest. Therefore it could be said that, the coating with tapioca-starch of fresh-cut leek was found to be effective in preventing discoloration especially at the higher dose (2%).

Keywords: *Allium porrum*, browning, postharvest , starch-based coating, minimally processed.

Introduction
Edible coatings may be defined as a thin layer of material that covers the surface of the food and can be eaten as part of the whole product. The composition of edible coatings must therefore conform to the regulations that apply to the food product concerned (Guilbert et al. 1995). Polysaccharides are the most widely used components found in edible coatings for fruits (Kester and Fennema 1986; Krochta, 1997), as they are present in most commercially available formulations. Polysaccharides show effective gas barrier properties although they are highly hydrophilic and show high water vapor permeability in comparison with commercial plastic films. The main polysaccharides that can be included in edible coating formulations are starch and starch derivates, cellulose derivates, alginate, carrageenan, chitosan, pectin, and several gums (Vargas et al. 2008). Starch is the natural polysaccharide most commonly used in the formulation of edible coatings because it is inexpensive, abundant, biodegradable, and easy to use. Native granular starch is converted into a thermoplastic material by conventional methods in the presence of plasticizers, such as water and glycerol (Thire et al. 2003). Coatings made from starch become brittle in dry atmospheres and lose strength and barrier properties in high humidity (Peterson and Stading 2005). The addition of plasticizers overcomes their flexibility and extensibility (Mali et al. 2002). Leek (*Allium porrum* L.) is a popular vegetable due to its nutritional values. The white sheaths of leek contain on average 83-90% water, 1.5-2.0% protein, 0.3% lipids, 5.0-14.2% carbohydrates, and 1.8% fiber. Leeks also contain vitamin A, vitamin C, carotenoids, flavonoids; and the major flavor compounds of leek are nonprotein sulfur-containing amino acids (Nunes, 2009). Minimal processing of leek stalks includes root trimming, removal of outer damaged or decayed leaves and trimming to a desired length. Postharvest quality deterioration of minimally processed leeks includes inner leaf growth and discoloration of the cut surface, as well as fresh weight loss. Such deterioration is significantly reduced by storage at 0°C

temperature (Tsouvaltzis et al. 2008). On the other hand, storage at 0 C is practically inapplicable, since in commercial practice minimally processed produce is most commonly prepared, shipped, and stored at 5–10°C (Watada et al. 1996). The major cause of quality loss of minimally processed leeks is inner leaf growth and to a lesser extent dehydration and discoloration at the higher storage temperature. Therefore, the prevention of these changes of fresh-cut leek is important, and edible coating of fresh-cut fruit and vegetables delays such quality losses. Thus, the aim of this study is to determine the effect of starch-based edible coating on color quality of fresh-cut leeks.

Material and methods

Plant Material

Leeks (*Allium porrum* L. cv. İnegöl) were obtained from Kocaeli Wholesale Distribution Center and immediately brought to the laboratory. The leeks were screened for uniformity such as being free from any mechanical damages and diseases, and being at a similar stage of maturity. The 3-4 cm diameter leeks were used forthis study. The outer, yellowed leaves of leeks were hulled, and the compressed roots were cut. Then, the yellow leaves of leeks were cut with a sharp knife at the length of 10 cm, and washed with tap water.

Preparation of starch-based edible coating

For purposes of this research, tapioca starch which is extracted from cassava root (*Manihot esculenta*) was used as polysaccharide material. The tapioca starch-solution at the doses of 0.5% (5 g/L) , 1% (10 g/L) and 2% (20 g/L) were prepared. Since starch did not form gel at the low temperature, solution was heated until 65^{o}C temperature. For providing flexibility of coating, gelatin was added into all starch-solutions at the 2.5 g/L (0.25%) doses. After the solutions were prepared, the leek samples were dipped into the solutions at the 40^{o} temperature for 3 min. Then all samples were dried at room temperature for fifteen minutes.

Packaging and Storage Conditions

200 g of fresh-cut leek of each replicate was placed in a plastic box (polyethylene terephthalate (PET)) with cover and 110x110x50 mm in size. All treated samples were stored in a cold room at 5 ±1°C and a relative humidity of 85-90% for 28 days.

Color measurements

Color measurements (L*, a*, and b* values) were performed using a chromometer CR-400 (Konica Minolta, Inc. Osaka, Japan) equipped with illuminant D65 and 8 mm aperture of the instrument for illumination and measurement. The instrument was calibrated with a white reference tile (L* = 97.52, a* = −5.06, b* = 3.57) prior to measurements. The L* (0 = black, 100 = white), a* (+ red, − green), and b* (+ yellow, − blue) color coordinates were determined according to the CIELab coordinate color space system (Radzevičius et al. 2014). Hue angle (ho = tan-1 (b*/a*) when a* > 0 and b* > 0 or ho=180o+ tan-1 (b*/a*) when a*< 0 and b > 0) was calculated from the a* and b* values (Lancester et al. 1997)

Polyphenol oxidase activity (PPO)

To measure polyphenol oxidase activity, 5 g of homogenized fresh-cut leek was extracted with 0.1 M phosphate buffer, pH 7 containing 5 g of polyvinylpyrrolidone using magnetic stirrer for 15 min. The homogenate was filtered through Whatman No. 1 filter paper, and the filtrate collected as an enzyme extract. PPO activity was determined by a spectrophotometric method based on an initial rate of increase in absorbance at 410 nm (Soliva et al. 2000). Phosphate buffer pH 7 (0.1 M, 1.95 mL), 1 mL of 0.1 M catechol (substrate) and 50 µL of the enzyme extract were pipetted into a test tube and mixed thoroughly. The mixture was rapidly transferred to a cuvete of path lenght 1-cm. The absorbance at 410 nm was recorded continuously at 25°C for 5 min using ultraviolet-visible (UV-

VIS) spectrophotometer (UV Mini 1240, UV-VIS Spectrophotometer, Shimadzu, Japan) (Arnnok et al. 2010)

Discoloration Rate (%)
In each analysis period, the number of color-changing samples was calculated as a ratio to the total number of samples and expressed as (%).

Total soluble solids (TSS)
TSS were determined for each sample fruit in three replications using an Atago DR-A1digital refractometer (Atago Co. Ld., Japan) at 20 °C and expressed as percentage value (%) (Kasım and Kasım 2015)

Weight losses
The weight of each sample with three replications of each treatment group was recorded on the day of the harvest and on the sampling dates. Cumulative weight losses were expressed as percentage loss of original weight.

Statistical analysis
Experiments were conducted in an aentirely randomized design with a minimum of-three replications per storage treatments per sampling date. Data wasanalyzed by ANOVA and differences among means were determined by the Duncan's multiple range test with significance level at p<0.05.

Results and discussion
L values

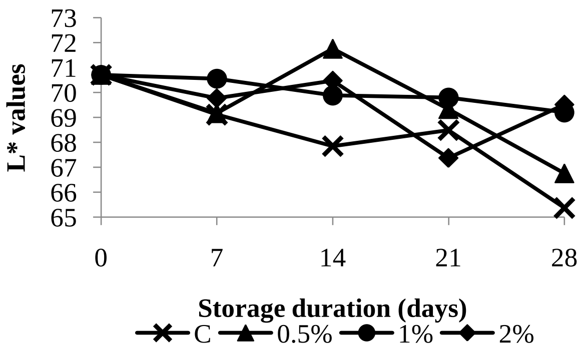

Figure 1. *L** values of fresh-cut and coated leeks.

L values of fresh-cut leeks in all samples decreased during the storage. But this decrease was minimum in the leek samples coated with 1% tapioca-starch (TS), and the differences among the treatments were found to be significant statistically at the level of p<0.05. Furthermore, no evident changes were obtained up to 14. days of stage, but after that time L values of samples in all treatments decreased. Therefore, it can be said that coating fresh-cut leek with 1% TS was effective to retain white color and also to bring brightness to the samples. But neither lower (0.5%) nor higher (2%) doses of coating were effective on white color of samples. Also, with extending storage duration, the coating material lost its protective effect, and the L color of samples decreased. In green vegetables, the senescence process usually leads to a yellow coloration of the tissues, normally considered the major consequence of chlorophyll degradation (Toivonen and Brummell, 2008). Also, in some minimally processed green vegetables, the synthesis of pheophytin, an olive-colored pigment, appears when the chlorophyll loses its bond with the magnesium atom and substitutes it with a hydrogen atom. The maintenance of a low temperature and a high relative humidity, combined with atmospheres lowered in O2 and moderately rich in CO2, are shown to be the main advisable techniques to delay this disorder (Artes et al. 2007). So, in the present study, the tapioca starch-based edible coating materials is providing high relative humidity on the surrounding ofthe product, but also barrier to gas penetration. Therefore the L values of fresh-cut leeks with coated edible films is found to be higher than that of the control group.

Color a, b* and hue (h^o) angle*

The a* values of fresh cut and coated with TS leeks, shown at Fig. 2. According to the Fig. 2, a* values of samples is -12.5 in all samples at the beginning of the storage, but this values decreased during storage, and it varied between -6.5 and -7.8 at the end of the storage. However, differences among the coating treatments did not find significant statistically ($p<0.05$).

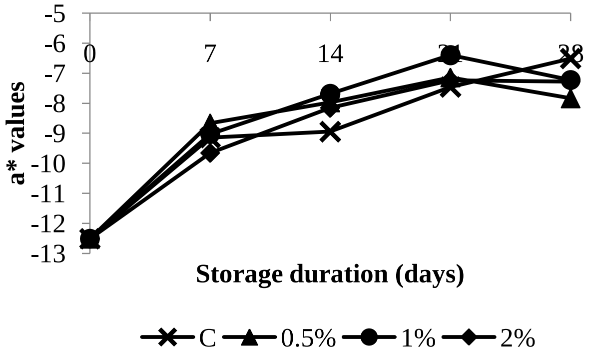

Figure 2. *a** values of fresh-cut and coated leeks.

b* values of coated fresh-cut leek pieces was high at initial measurement (41.6, Fig.3), while after that time these decreased until the end of the storage, like a* values. But, the differences between the samples coated with 2% and the other treatments were significant at the level of $p<0.05$. According to this result, it was suggested that 2% TS coating maintained the color of samples compared to that of the other treatments. Whereas, when the hue angle values are examined, it was seen that the hue angles values of samples in control were higher than the other treatments (Fig.4). The differences among the treatments, however, were not significant, statistically ($p<0.05$). Similar results were obtained by (Kerdchoechuen et al. 2011), the authors found that the hue angle of surface color of minimally processed pummelo coated with the two starches did not differ from the control. Also, Riberio et al. (2007) studied that the ability of polysaccharide-based (starch, carrageenan and chitosan) coatings to extend the shelf-life of strawberry fruit (*Fragaria ananassa*) and found that the edible coating did not cause significant colour differences.

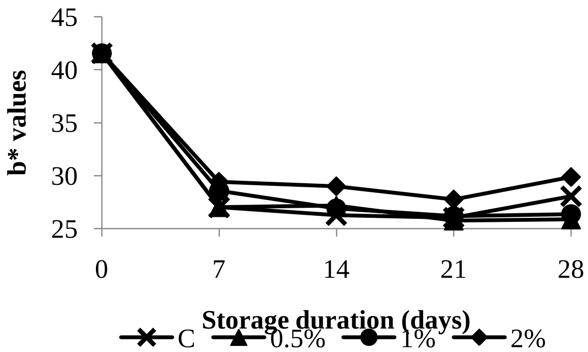

Figure 3. *b** values of fresh-cut and coated leeks.

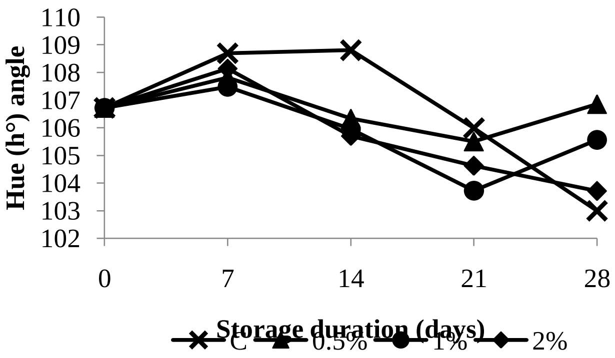

Figure 4. Hue (h^o) angle values of fresh-cut and coated leeks.

Polyphenol Oxidase (PPO) Activity

The PPO activity of samples in all treatments groups increased throughout the storage (Fig. 5). The first 7 days of storage, the PPO activity of control and 0.5% TS was lower compared to the other treatments, but after that time it was increased in all treatments. However, no significant differences among the treatments were determined ($p<0.05$). The PPO activity of treatments was 0.83%, 0.88%, 0.95% and 0.93% for C, 0.5% TS, 1% TS and 2% TS, respectively, at the end of the storage duration. Polyphenol oxidase is an enzyme that naturally found in many fruit cells and responsible for enzymatic browning on the wounded tissues (Alandes et al. 2009). During peeling and cutting process, an undesirable brown color is produced as a result of enzymatic browning reaction due to intermixing of polyphenol oxidase with phenolics compounds. In the present study starch-based edible coating was not effective on decreasing PPO activity. However, there was no darkening observed on the cut surface of the fresh-cut leeks, but the discoloration of cut surface only occured depending on dehydration.

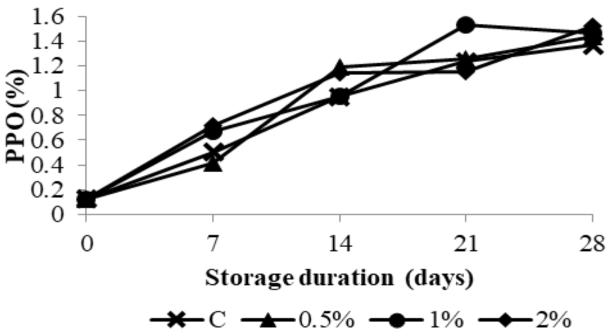

Figure 5. The PPO activity of fresh-cut and coated leeks.

Discoloration Rate (%)

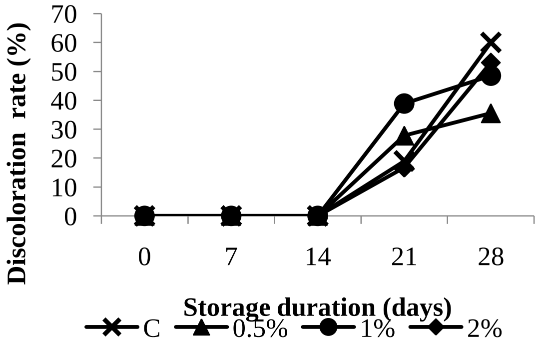

Figure 6. Discoloration rate of fresh-cut and coated leeks.

Discoloration rate (DR) of samples that obtained by visual scoring increased the last two weeks of storage (Fig 6). That is, for the first two week no external discoloration was observed in the samples. The DR of samples in control and 2% TS was found lower than the other treatments at the day of 21, whereas, after that time it increased in all treatment groups. But, the differences among the treatments were not significant statistically (p<0.05). Edible films are commonly used to protect perishable food products from deterioration by slowing dehydration, providing a selective barrier to moisture, oxygen and carbon dioxide, improving textural quality, reducing microbial growth (Fan et al., 2009). In the present study, with the usage of apioca starch-based edible coating, the discoloration of the leek was retarded for two weeks of storage. But after that time this preservative effect of edible coating was not enough the prevent color changes.

Total Soluble Solids (TSS, %)

The TSS (%) values of samples measured as 7.0% at the initial stage of storage (Fig. 7), however, they decreased in all treatment groups during the storage. Meanwhile, the most decreasing was found in 0.5% TS treatment for the first two weeks of storage. But no significant differences were found among the treatments (p<0.05). Therefore it can be concluded that, the coating treatments did not effect the TSS content of samples.

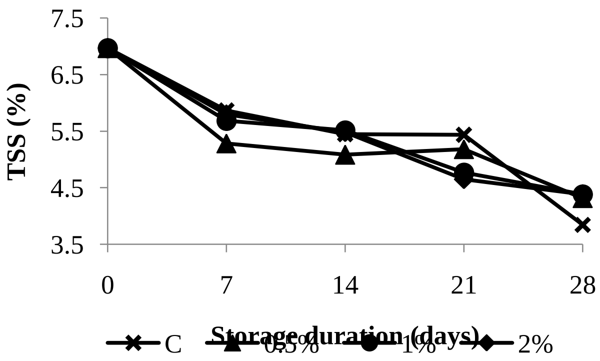

Figure 7. TSS values of fresh-cut and coated leeks.

Weight Loss

Weight losses of samples in all treatment groups increased during storage as seen in Fig 8. Weight loss of fresh cut leek decreased by 1% TS significantly (p<0.05), compared to control and 2% TS, throughout storage. But, the weight losses of samples varied between 0.64%-0.77%, and did not exceed 1%. So, the fresh-cut leek samples did not lose their weight too much according to initial weight, although, the TS treatment at the 1% dose was found effective to maintain the weight of leeks, more than the other treatments. It was previously found that, the starch-based edible coating of minimally processed pummelo had a lower weight loss of 4.8–7.7% compared to the control (Kerdchoechuen et al. 2011). The results of present study is compatible with this finding.

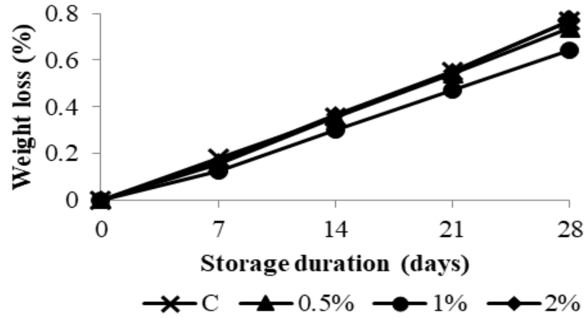

Figure 8. Weight loss of fresh-cut and coated leeks.

Conclusions

The present study aimed to, evaluate the effect of the tapioca starch-based edible coating on the color and the other biochemical characteristics of fresh-cut leek pieces. For this purpore,s three different starch-based edible coating were used, and the color L* a* b* and hue angle values, PPO activitity, discoloration rate, TSS and weight losses of samples were calculated in weekly intervals during storage. According to the results, the tapioca starch-based edible coatings has no evident effect on the color values; however the brightness of samples as measured by L values, was found to be higher in all coating treatments. Similarly, using edible coating did not decrease PPO activity. Despite that, discoloration rate of samples in 2% the TS was lower than the other treatments. TSS values of samples in all coating treatments was not show significant changes depends on edible coating treatment, so it could be concluded that the coating treatment did not effect on TSS values. But, the 1% tapioca starch-based edible coating decreased the loss of weight. In conclusion, it could be said that the 1% and 2% doses of edible coating is found to be succesful in the preservation of color quality of fresh cut leek pieces.

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