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Research
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The effect of post-harvest chitosan applications on some chemical changes of potatoes during storage*

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Abstract

Objective: The objective of this study was determination of effects of the chitosan application on changes at some chemical properties of potatoes such as dry matter rate, C vitamin amount, total soluble solids rates, total phenolic compounds and total antioxidant capacity.

Material and Method: In this research carried out in cold storage, 4 doses (control, 0.5%, 1% and 2%) of chitosan were applied to potato tubers by spraying method before storage.

Results: Among chitosan treatments, 1 % treatment was most effective in terms of preventing the increase dry matter rate (by 50%) and the decrease C vitamin content (by approximately 40%) during the storage. The increase of total phenolic compounds by 20% at the end of storage was prevented with chitosan applications compared to control.

Conclusion: Results show that the application of chitosan can reduce some chemical changes that occur in potatoes during storage.

Key words: Bioactive compounds, C vitamin, *Solanum tuberosum* L.

Hasat sonrasi kitosan uygulamalarının depo koşullarındaki patatesin bazı kimyasal değişimleri üzerine etkisi

Öz

Amaç: Bu çalışmanın amacı; kitosan uygulamasının patateste kuru madde oranı, C vitamin içeriği, toplam suda çözünür kuru madde oranı, toplam fenolik madde içeriği ve toplam antioksidan içeriği gibi bazı kimyasal özellikler üzerindeki etkisinin belirlenmesidir.

Materyal ve Yöntem: Soğuk hava deposunda gerçekleştirilen bu araştırmada, depolama öncesi patates yumrularına 4 doz (kontrol, %0.5, %1 ve %2) kitosan, püskürtme yöntemiyle uygulanmıştır.

Bulgular: Kitosan uygulamaları arasında %1 kitosan dozu, depolama sırasında kuru madde oranı artışını (%50) ve C vitamini içeriğinin azalışını (yaklaşık %40) önleme açısından en etkili olan doz olarak belirlenmiştir. Toplam fenolik bileşiklerin depolama sonunda kontrole göre %20 artması kitosan uygulamaları ile önlenmiştir.

Sonuçlar: Sonuçlar, kitosan uygulamasının, depolama sırasında pateteslerde meydana gelen bazı kimyasal değişiklikleri azaltabileceğini göstermektedir.

Anahtar kelimeler: Biyoaktif bileşikler, C vitamini, *Solanum tuberosum* L.

Introduction

Potato is an important plant food consumed all over the world. In addition to factors such as growing methods on the change of sensory structures and non-sensory chemical components in potatoes and variety of varieties, storage is also significantly effective (Blahovec and Lahodová, 2013). Tubers are grown by vegetative propagation and they are the storable parts of the potato.

Tubers have to enter dormancy after maturing period to be resistant to external factors, not to go into early sprouting state and especially reach the new growing period without losing nutrients during storage. Dormancy period of potato tubers stored for use as seed should not end early. Otherwise, it is possible that potatoes that give early shoots lose their physiologically necessary properties at the time of planting. Due to the early breaking of dormancy in freshly consumed potatoes, as a result of the loss of water and shoot extensions, the decrease in its quality both in terms of taste and structure decreases the market value considerably (Pinhero et al. 2009). With the breaking of the dormancy, the potato begins to transfer the nutrients contained in its tubers to the shoots. Increasing tuber respiration and water away from tuber surface accelerates nutrient transport to shoots.

It is seen that chemical and physical changes during the storage period of the tubers cause significant losses. Approximately 20% of tubers produced in our country are lost in the store conditions. Considering the amount of production, this rate means a great economic loss (Arıoğlu et al. 2006). Optimum storage temperature is 4-5 ^{o}C in order to minimize respiration in potato tubers. However, low temperature is not sufficient to keep respiration at a minimum level and prevent converting starch into sugar. In addition, a situation called the low temperature sweetening of the potato occurs in long-term storage. Especially in potatoes stored for chips production, darkening occurs during frying. This situation considerably reduces the quality and efficiency of chips.

Chemicals such as chloroform (isopropyl N- (3-chlorophenyl) carbamate; CIPC) are used to keep the potato without sprouting for a longer time after harvest. The use of such chemical, which was first used for pesticide purposes, has been reduced considerably in recent years due to the determination of its toxic effect and the high residual rate. In some countries, the use of the chemicals use is prohibited (Gómez-Castillo et al. 2013).

Chitosan, one of the most important naturally occurring polysaccharides after cellulose, has been reported in previous studies to have the potential to be an alternative for pre-storage applications (Petriccione et al. 2015). Chitosan is a natural carbohydrate polymer produced from chitin that can be used to extend the shelf life of fruits that are not harmful to the environment and humans (Kaviani et al. 2015). It has been reported in previous studies that chitosan applied externally to plants can increase the activities of many enzymes related to the defense mechanism in plants, such as phenylalanine ammonia-lyase (PAL), chitinase (CHI) and 1,3-glucanase (Shao et al. 2015). Chitosan is a natural polymer that is safe for human and environmental health, non-toxic, can bind to microbial cells and has a fungistatic structure. Chitosan is also biodegradable. An important reason why chitosan is used to cover the surface of fruits and vegetables in storage and extend their shelf life is that it is edible. It has been revealed in researches that it is very safe for human health (Du et al. 1997; Zhu et al. 2008). In the literature reviews, it was found that chitosan prevented statistically significant some losses in the storage of fruits and vegetables (El-Anany et al. 2009; Jinasena et al. 2011; Shiri et al. 2013). However, there has not been enough research about its effects on potatoes.

In this study, it was aimed to determine the applicability of chitosan, a natural polymer source, to potatoes before storage, and effects of chitosan on some chemical changes such as increasing the dry matter ratio and decreasing the vitamin C ratio that may occur in potatoes during storage.

Material and Method

The research was carried out in cold storage with 5 ° C and approximately 80% relative humidity belong to laboratories of Ordu University Faculty of Agriculture in 2018. Certified potatoes (Agria) obtained from the seed company were used as the material. 15 days after harvest, the tubers applied were placed in boxes made of hard plastic at cold storage. The experimental design was randomized complete parcel design with three replications. In the study, chitosan solutions were prepared as 4 doses (control, 0.5%, 1% and 2%). Preparation of chitosan solutions; 0.5 g for a 0.5% dose, 1 g for a 1% dose and 2 g for a 2% dose were added to the solutions. The solution prepared contained 2 ml of 0.5% glacial acetic acid. Then, the pH of each solution was adjusted to 5.5. Tween 80 was added to each solution as 0.1ml / 100ml (Bautista-Banos et al. 2003). The prepared solutions were applied to the tubers with the help of a spray. Tubers dried at room temperature were taken into boxes with ventilation holes and removed into the storage. 60 tubers were placed in each box. Tubers in the control group only contained pure water and Tween 80 added in the same amount as the solutions of the other doses. The properties of tuber samples such as total soluble solids (%), Vitamin C (Ascorbic acid) amount (mg / 100g fresh tuber), dry Matter ratio (%), Total phenolic compounds (μg) and total antioxidant capacity (μg TE g^{-1}) taken every 30 days for 3 periods were examined.

Dry matter rate (%) was determined by cutting the tubers into thin slices and drying them in an oven at 78°C until they reached a steady weight approximately 48h. Dry matter ratio (%) was calculated in result of the ratio of dry weights to wet weights and it was expressed as a percentage. The amount of vitamin C (Ascorbic acid) in fresh tubers was determined according to AOAC (1984) and the results obtained were determined as mg per 100 g fresh tubers. Total soluble solids (%) values were found by hand refractometer. Total phenolic compounds were determined using Folin-Ciocalteu chemical. Initially, 400 μL of fresh tuber sample extract was taken and 4.2 mL of distilled water was added on it. Then, 100 μL of Folin-Ciocalteu reagent and 2% sodium carbonate (Na_2CO_3) were added and left for 2 hours incubation. After incubation, the solution, which acquired a bluish color, was measured in a spectrophotometer at 760 nm and the results were calculated in gallic acid, and expressed as μg GAE g-1 fresh weight. (Beyhan et al. 2010). 0.26 mM DPPH solution was prepared for DPPH (1,1-diphenyl-2-picryl-hydrazyl) analysis (total antioxidant capacity). After adding 2700 μL ethyl alcohol and 1 ml DPPH solution to 300 μL tuber sample extract and vortexing for 30 minute kept in the dark environment. After the incubation of the samples, absorbance values were determined at 517 nm in a spectrophotometer. The absorbance values obtained were expressed as μmol Trolox equivalent g-1 fresh weight (μg TE g-1 fw) (Özgen et al. 2006). The significant differences were calculated using the least significance difference (LSD) with the help of SAS-JMP-5.01 and the differences were evaluated statistically significant at P≤0.01 level.

Result and Discussion

Dry matter rate

Regardless of the production purpose, the amount of dry matter in the tuber can be considered as one of the most important characteristics determining the quality of the potato (Zgórska and Grudzińska, 2012; Rukundo et al. 2013). It is known that dry matter content determines the taste of potatoes, the consistency of fresh and processed tubers and their resistance to mechanical damages (Wierzbicka, 2012; Baranowska, 2018). Immediately after harvest, potato tubers contain about 80% water and 20% dry matter (Lommen, 1993). However, with the storage of potatoes, the rate of tuber dry matter increases and changes (Ozturk and Polat, 2016). It is known that application of various methods and different materials to post-harvest potato tubers can prevent changes in dry matter ratio during storage (Kırlı et al. 2019; Krochmal-Marczak et al. 2020). The dry matter rates obtained are shown in Table 1. The dry matter rates increased with increasing storage time. In the tubers that are not applied, the increase in dry matter ratio is approximately 5% compared to the beginning of storage. With the application of 1% chitosan, it was observed that this increase was prevented by 50% at the end of the 60th day and decreased to 2.5%. In the application of 2% chitosan, it was determined that the increase in the dry matter ratio was 8% more than the control.

Table 1. Dry matter rate means of potatoes with chitosan applied before storage

	Beginning of storage	30 Days	60 Days	Mean
Control	17.50 i	18.38 d	18.53 c	18.13
0.5%	17.50 i	18.25 e	20.03 b	18.59
1%	17.50 i	17.69 g	17.96 f	17.72
2%	17.50 i	17.54 h	20.18 a**	18.41
Mean	17.50	17.97	19.17	18.21

**Means with the same letters in the same row and column are not significantly different from each other (P < 0.01).

As a result of the literature reviews, we could not find any information about the direct effect of post-harvest chitosan applications on potato dry matter rate. But considering the relationship between tuber weight loss and water loss, it can be mentioned about the research of Saha et al. (2014) about chitosan application prevented tuber weight loss occurring in potatoes during storage. Sivakumar et al. (2005), Meng et al. (2010) and Petriccione et al. (2015) reported that weight losses were statistically significantly lower with chitosan application before storage in papaya, grapes and strawberries, respectively, compared to control.

Vitamin C (Ascorbic acid)

This change, like other chemical properties, is desired to be minimal during storage. In previous studies, it is known that different applications have been made to prevent the loss of vitamin C during storage.

Vitamin C values obtained are shown in Table 2. It is observed that the amount of vitamin C decreases with increasing storage time. It was determined that tubers in the control group lost more vitamin C compared to other applications and the vitamin C amount was 10.80 mg / 100 g at the beginning but it decreased to 9.56 mg / 100g at the end of 60 days. The decrease in the amount of vitamin C in untreated tubers is approximately 11.4% compared to the beginning. With the 1% chitosan application, it was determined that this decrease was prevented by approximately 40% at the end of the 60th day and up to 7,7%.

Table 2. Vitamin C content means of potatoes with chitosan applied before storage

	Beginning of storage	30 Days	60 Days	Mean
Control	10.80 a**	10.29 f	9.56 ı	10.22
0.5%	10.80 a	10.35 d	10.10 h	10.42
1%	10.80 a	10.68 c	10.30 e	10.59
2%	10.80 a	10.77 b	10.20 g	10.59
Mean	10.80	10.52	10.04	10.45

**Means with the same letters in the same row and column are not significantly different from each other (P < 0.01)

Saha et al. (2014) reported that potato tubers applied chitosan at the end of storage lost statistically significant, less vitamin C compared to control. Bal, (2013), Kibar and Sabir, (2018) and Kumar et al. (2017) stated that there is less loss of vitamin C at the end of storage in plums, tomatoes and plums applied chitosan by dipping method, respectively, compared to control.

Total soluble solids

It is known that insoluble starch in water becomes soluble as starch turns into sugar with the increase in storage time (Zhang et al. 2014; Saha et al. 2014; Nazarian-Firouzabadi and Visser, 2017). It is desired that changes of total soluble solids are minimal as The amount of vitamin C, also known as ascorbic acid, in potato tubers begins to decrease with increasing storage time (Keijbets and Ebbenhorst-Seller, 1990; Abong et al. 2011; Hajilou and Fakhimrezaei, 2013). undesirable changes that occur in other tuber properties during storage.

Total soluble solids values obtained are shown in Table 3. In the control group tubers, the initial increase in the total soluble solids is about 57%. It was determined that this increase decreased to approximately 28% at the end of the 60th day with 1% chitosan application. It was determined that tubers in the control group increased more than other applications and the total soluble solids were 4.20% at the beginning, increased up to 6.60 at the end of 60 days. It was determined that 2% chitosan application was effective in preventing the increase in the total soluble solids rate after 1% chitosan application.

Table 3. Total soluble solids means of potatoes with chitosan applied before storage

	Beginning of storage	30 Days	60 Days	Mean
Control	4.20 h	5.25 e	6.60 a**	5.35
0.5%	4.20 h	5.24 e	6.06 b	5.17
1%	4.20 h	5.09 g	5.41 d	4.90
2%	4.20 h	5.15 f	5.90 c	5.09
Mean	4.20	5.19	5.99	5.13

**Means with the same letters in the same row and column are not significantly different from each other (P < 0.01)

Unlike the spray method used in this study, Saha et al. (2014) reported that the increase in the total soluble solids ratio at chitosan application with dipping method was prevented compared to the control at the end of 60 days. Badawy et al. (2017) and Eshetu et al. (2019) stated that chitosan application by immersion prevented the increase in total soluble solids ratio in strawberries and mango, respectively, compared to control.

Total phenolic compounds

There are various phenolic compounds in different amounts and forms in plants. There are few phenolic compounds in potatoes compared to other plants. Although the studies are limited, it is known that the amount of phenolic compounds in the tuber changes during storage, as in other chemical properties (Külen et al. 2013; Galani et al. 2017).

Total phenolic compounds values obtained are shown in Table 4. It was observed that the total amount of phenolic compounds decreased with increasing storage time. It was determined that tubers in the control group lost more total phenolic compounds than other applications, and the total phenolic compounds were 40.62 µg GAE g^{-1} at the beginning, which decreased to 25.83 µg GAE g^{-1} in control at the end of 60 days. With the application of 2% chitosan, it was determined that this decrease was prevented by 20% at the end of the 60th day compared to the control.

Table 4. Total phenolic compounds means of potatoes with chitosan applied before storage

	Beginning of storage	30 Days	60 Days	Mean
Control	40.62 a**	32.58 c	25.83 f	33.01
0.5%	40.62 a	32.78 c	28.45 e	33.95
1%	40.62 a	33.49 b	28.67 de	34.26
2%	40.62 a	33.37 b	28.82 d	34.27
Mean	40.62	33.05	27.94	33.87

**Means with the same letters in the same row and column are not significantly different from each other (P < 0.01).

As a result of the literature reviews, no study has been found on the effect of chitosan applications on the total phenolic content of potatoes. Hosseini et al. (2018) reported that the decrease in total phenolic compounds of bananas content was prevented after 20 days of storage with chitosan application using the dip method. Petriccione et al. (2015) and Huynh and Nguyen, (2020) reported that chitosan applied before storage in strawberries and pumpkin prevented the decrease in total phenolic compounds amounts occurring at the end of storage. In this study, similar to the findings of the researchers, it was determined that chitosan application prevented the decrease in the total phenolic compounds that occurred as a result of storage in potatoes.

Total antioxidant capacity

In addition to the phenolic compounds contained in potatoes, the antioxidant capacity has also been emphasized in recent years (Singh et al. 2004; Brown, 2005). It is known that the antioxidant activity of potatoes decreases with the increase of storage time as in the total phenolic compounds and there are limited number of studies on the effects of pre-storage applications on the changes that occur in potatoes during storage (Külen et al. 2013; Galani et al. 2017).

Total antioxidant capacity values obtained are shown in Table 5. It was observed that the total antioxidant capacity decreased with increasing storage time. It was determined that the total antioxidant capacity was 772.6 µg at the beginning, which decreased to 532.1 µg at the end of 60 days in untreated tubers. The loss in total antioxidant capacity at the end of storage is 31% in untreated tubers. It was determined that total antioxidant capacity in tubers treated with chitosan did not change statistically significantly compared the control. As a result of the literature reviews, no study was found on the effects of chitosan application on total antioxidant activity of potatoes during storage. Petriccione et al. (2015), Zhang et al. (2015) and Kou et al. (2014) stated in their studies on strawberry, cucumber, pears respectively that the antioxidant activity amounts of unapplied fruits decreased faster than fruits coated with chitosan during storage.

Table 5. Total antioxidant capacity means of potatoes with chitosan applied before storage

	Beginning of storage	30 Days	60 Days	Mean
Control	772.6	658.7	532.1	654.5
0.5%	772.6	656.7	571.1	666.8
1%	772.6	673.5	596.9	681.0
2%	772.6	671,7	596.7	680.3
Mean	772.6 a**	665.2 b	574.2 c	670.6

**Means with the same letters in the same row and column are not significantly different from each other (P < 0.01).

Conclusions

Our results showed that chitosan can reduce storage losses in potatoes, which is applied by spray method which is easier to apply than other methods. 1 % chitosan treatment was more preventive on losses in dry matter rate, C vitamin content, total soluble solids than other doses. With the increase in storage time, total phenolic compounds and total antioxidant capacities values decreased. While 2 % chitosan treatment prevented the decrease by 20% in total phenolic compounds, none of the chitosan doses had an effect on total antioxidant capacities. This research has shown that chitosan, which is safe, edible and biodegradable in terms of human health, can be an alternative source for pre-storage applications in potatoes.

Conflicts of interest

The authors declare no conflicts of interest.

Author Contribution Statement

ÖD: Establishing of the resarch and evaluating the results, AK: Establishing, conducting, analyzing of the resarch and writing of the article, NY: Establishing of the resarch and evaluating the results, FÖ: Article editing

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