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Research
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Effects of pre-storage calcium applications on physical and chemical attributes of potato*

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Abstract

Pre-storage applications are of considerable importance in reducing chemical and physiological changes occurring in potato tubers during prolonged storage. The objective of this study is to determine the effect of increasing doses of pre-storage applied calcium on physical and chemical properties of potato tubers. The experiment was carried out in a completely randomized design with three replications at cold storage with +4 °C temperature and 85-90% moisture. The potato tubers were soaked in three calcium solutions (5%, 10% and 15%) for one hour, along with the control (pure water). The calcium pretreatments showed significant ameliorative effects on all physical and chemical attributes of four months stored potato tubers. With calcium application, sprouting tuber rate and shooting length decreased by 15% and 42% as compared to the control, respectively. The pre-storage applications of calcium significantly reduced the losses occurring in total phenolic content and antioxidant activity during storage. In conclusion, the present study suggested that pre-storage calcium applications could reduce storage losses in potato tubers.

Key words: Antioxidant activity, *Solanum tuberosum*, shooting tuber, total phenolic content

Depolama öncesi kalsiyum uygulamalarının patatesin fiziksel ve kimyasal özellikleri üzerine etkisi

Öz

Depolama öncesi yapılan ön uygulamalar, uzun depolama süresi sırasında patates yumrularında meydana gelen kimyasal ve fizyolojik değişikliklerin azaltılmasında büyük öneme sahiptir. Bu çalışmanın amacı, depolama öncesinde uygulanan artan kalsiyum dozlarının patates yumrularının fiziksel ve kimyasal özellikleri üzerindeki etkisini belirlemektir. Araştırma, +4 °C sıcaklık ve %85-90 neme sahip soğuk hava deposunda 3 tekerrürlü olarak, tesadüf parselleri deneme desenine göre yürütülmüştür. Patates yumruları, kontrol (saf su) ile birlikte 3 farklı kalsiyum çözeltisine (%5, %10 ve %15) daldırılmıştır. Kalsiyum ön uygulamaları, dört aylık depolama süresi boyunca patates yumrularının incelenen tüm fiziksel ve kimyasal özellikleri üzerinde olumlu etkiler göstermiştir. Kalsiyum uygulaması ile sürgün veren yumru oranı ve sürgün uzunluğu kontrole göre sırasıyla %15 ve %42 oranında azalmıştır. Depolama öncesi kalsiyum uygulamaları, depolama sırasında toplam fenolik madde içeriği ve antioksidan aktivitede meydana gelen kayıpları önemli ölçüde azaltmıştır. Sonuç olarak, bu çalışma, depolama öncesi kalsiyum uygulamalarının patates yumrularında meydana

gelen depolama kayıplarını azaltabileceğini göstermiştir.

Anahtar kelimeler: Antioksidan aktivite, *Solanum tuberosum*, sürgün veren yumru oranı, toplam fenolik madde miktarı

Introduction

Potato is an important carbohydrate source with its starch storage attribute in its tubers. Stored starch molecules provide the energy source of the plant. The starch is transformed into sugar to provide the energy required for plant growth and development. It is of considerable importance that the starch stored during growing period reaches the next planting period with minimum loss after harvest. Potato tuber, with the breaking of dormancy, begins to convert the stored starch into sugar for shoot development. It is not desirable, however, to break the dormancy of seed tubers kept in storage until planting (Er and Uranbey, 2009; Alexopoulos et al., 2015). Storage temperature and humidity are important factors for regulating dormancy and sprouting. If the appropriate storage temperature is not provided, the dormant state of the tubers is short-term and the tubers, therefore, show early shoot development before planting. Sprouting of the tubers stored for fresh consumption reduces the market value of potatoes. Furthermore, sprouting tubers are not desirable for planting in potato cultivation. Effective control of sprouting is critically important for preservation of potato quality under storage conditions (Kara, 2004; Gomez et al., 2013). Various studies using several hormones and mineral elements have been carried out in order to complete the storage period with the least losses in stored tubers (Hernández-Muñoz et al., 2006; Akhtar et al., 2010). Calcium is one of the elements used for this purpose (Gonzales and Quevedo, 2017; Javed et al., 2018). Previous studies show that calcium plays a critical role in maintaining cell wall hardness and helps prevention of deteriorations of the tuber skin and damages in the walls of epidermal cells (Kassem et al., 2014, Madani et al., 2016). This research was intended with the thought that using certain calcium applications physiological and chemical changes occurring in potato tubers during storage could be kept to a minimum level so that economic losses in market value be prevented. The purpose of this study is to determine the effects of pre-storage calcium applications on changes in physiological and chemical characteristics of potato tubers during storage.

Material and Methods

This research was carried out in a cold storage using 85-90% relative humidity and 4 °C temperature at Agricultural Faculty of Ordu University. Agria, a certified variety obtained from a private seed company, was used as the plant material. The experiment was carried out in completely randomized design with three replications. Before the application process, potato tubers were kept in solution containing 10% sodium hypochlorite for 5 minutes and passed through pure water. Calcium chloride ($CaCl_2$) was used as calcium source. The tubers were then treated with the solutions containing 5%, 10% and 15% calcium and the tubers in the control group was treated with pure water. After dipping in solutions for one hour, the tubers were dried on blotting papers and placed in storage medium using storage boxes. Tuber samples were taken every 45 days for analyzes. The shooting rate and shoot length observations were taken at the end of the 135th day. For total sugar rate, 500 µL from each potato supernatant was diluted with 500 µL distilled water and 500 µL phenol solution and 2.5 ml sulfuric acid were added to the flasks. Absorbance values were determined at 760 nm. The absorbance values were evaluated according to the glucose standard and expressed as percentage (Dubois et al., 1956). For total phenolic content, 1000 µL from each potato supernatant was diluted with 3.6 mL distilled water and 100 µL Folin–Ciocalteu reagents were added to 300 µL Na_2CO_3. Absorbance values were determined at 760 nm. The standard was Gallic acid. The values were evaluated as milligrams (mg) of gallic acid equivalents (GAE) per grams (g) of fresh weight (fw) (Beyhan et al., 2010). DPPH (1,1-diphenyl-2-picryl-hydrazil) solution was prepared for DPPH analysis by modifying the method of Brand-Williams et al. (1995). It was added 1 ml of DPPH solution with a concentration of 0.26 mM to 1000 µL tuber extract and 2000 µL of ethyl alcohol, followed by 30 min. kept in the dark. Absorbance values were determined at 517 nm. The values were evaluated as a fresh weight (TE g^{-1} fw) of 100 g^{-1} equivalents to µmol Trolox. SAS-JMP-5.01 package program was used for the significant difference test. LSD-test (least significance difference test) was applied for multiple comparison.

Results and Discussion

According to the results of this study, shooting rate decreased with increasing calcium doses (Fig. 1). Shooting rates were obtained from the control, 5%, 10% and 15% calcium as 97.1%, 83.93%, 83.6 % and 80.93%, respectively. It was determined that shooting rate of 5% calcium application was 7% lower than that of the control. The lowest shooting rate was obtained from 15% calcium application. At the end of the storage, the shoot lengths were found to be as 24.3 mm, 11.16 mm, 8.16 mm and 11.8 mm at the control, 5%, 10% and 15% calcium doses, respectively (Fig. 2). Calcium doses, except for the control, were statistically in the same group. Calcium application of 10% decreased shoot length by approximately 67% compared to the control. It is known that the application of calcium reduces continuing respiratory rate after harvest of stored plants such as apples, radishes, broccoli and melons (Kou et al., 2015; Ranjbar et al., 2018). Reduction of respiration may prevent the breakdown of polysaccharides within the storage organ (Öztürk et al., 2016). The disintegrated polysaccharides are transported to shoots. It can be thought that the shoot formation and development of potato tuber may be due to increased respiration (Benkeblia et al., 2008). In view of the results of this study, it was thought that calcium could prevent early shoot formation and development by decreasing the amount of respiratory rate during storage.

The minimum sugar content was obtained from the tubers treated with the 10% calcium dose at the storage period of 45, 60, and 135 days (Fig. 3-4). The mean minimum increase in the amount of sugar was obtained as 15% from the 10% calcium dose. This increase was 31% in non-treated tubers. It is generally stated that the amount of sugar contained in potato tubers increases with increasing duration in long-term storage (Kaul et al., 2010; Bhattacharjee et al., 2014). The sugars formed by the breakdown of polysaccharides can easily be used for shoot formation in potato tubers. Thus, it is undesirable to increase sugar content in potatoes, especially at low temperatures, during the desired storage time. Previous studies have shown that pre-storage applications of potato tubers can prevent the increase in sugar content during storage (Lester and Grusak, 2004; Kaur et al., 2012; Foukaraki et al., 2014). As far as we know, there is no study about the effects of calcium on above mentioned parameters of potato. Lara et al. (2004) and Jagadeesha et al. (2015) reported that the increases in sugar ratio of bananas and strawberry treated with calcium chloride were lower than those in the control fruits.

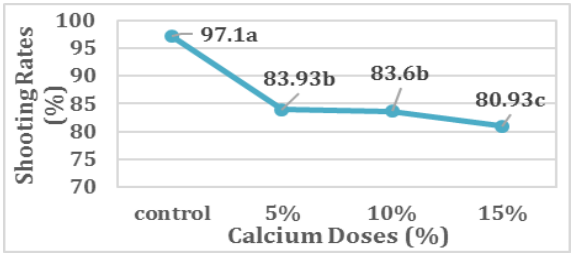

Figure 1. Shooting rate (%) of potato with applied calcium before storage at the end of the storage

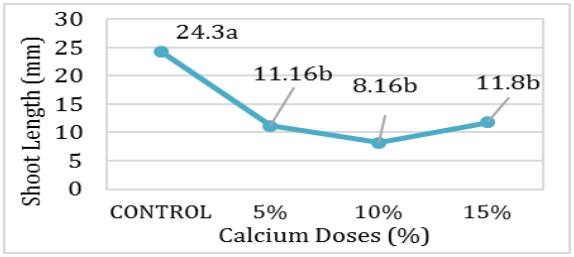

Figure 2. Shoot length (mm) of potato with applied calcium before storage at the end of the storage

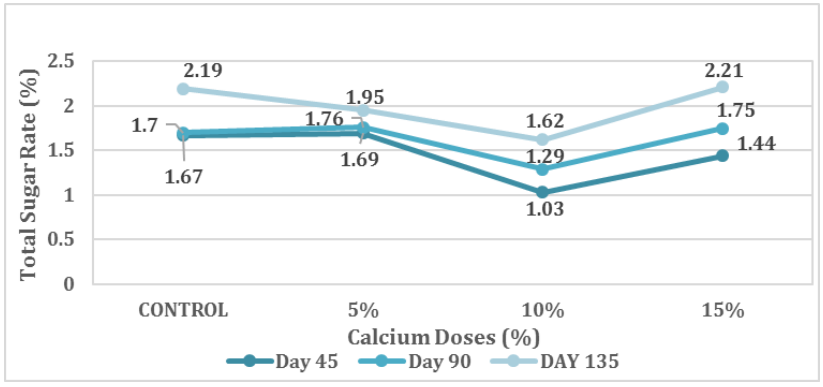

Figure 3. Total sugar rates of potato with applied calcium before storage for day 45, day 90 and day 135 during storage

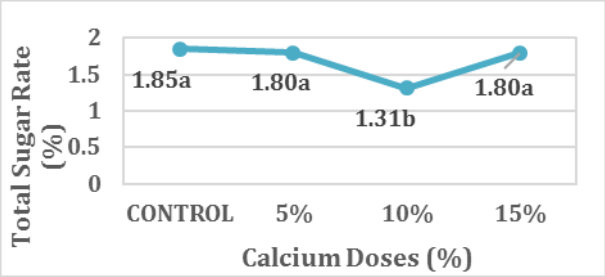

Figure 4. Total sugar average values of potato with applied calcium before storage at the end of the storage

As a result of this study, it was observed that the amount of total phenolic content (TPC) decreased with increasing storage time (Fig. 5). This is the same for DPPH used to determine antioxidant activity (Fig. 7). It is well-known that there is a positive correlation between total phenolics and antioxidant activity (Ay et al., 2018). The greatest values of total phenolic content and the highest antioxidant activity values were obtained from the tubers treated with 15% $CaCl_2$ compared with the control (Fig. 6-8). The tubers treated with 5% and 10% $CaCl_2$ were found to have more TPC and more antioxidant activity than the control after storage. Phenolic compounds and antioxidants in plants can protect cells against oxidative injury by destroying free radicals (Jiménez-Zamora et al., 2016; Huyut et al., 2017). In previous studies, it was determined that pre-harvest and post-harvest applications of calcium could provide a high rate of total phenolics and antioxidant activity in the stored part of the plant compared to the control (Shafiee et al., 2010; Madani et al., 2016). Bagheri et al. (2015) reported that total phenolic contents and antioxidant activities of persimmon fruits treated with calcium at the end of storage were more than that of the control.

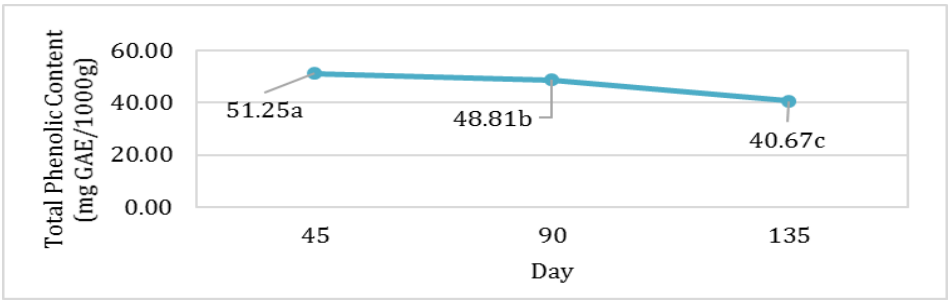

Figure 5. Total phenolic content of potato day 45, day 90 and day 135 at storage

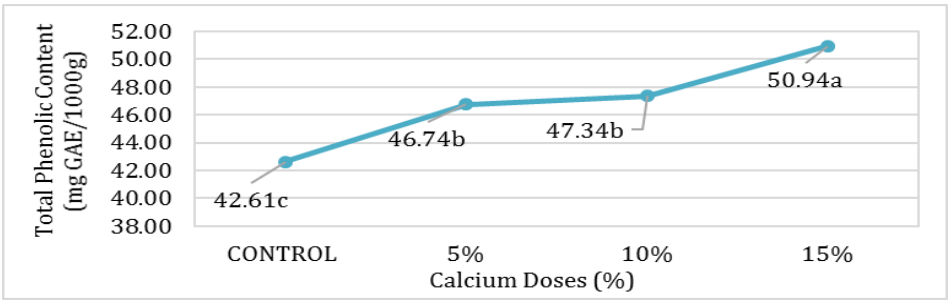

Figure 6. Total phenolic content of potato with applied calcium before storage at the end of the storage

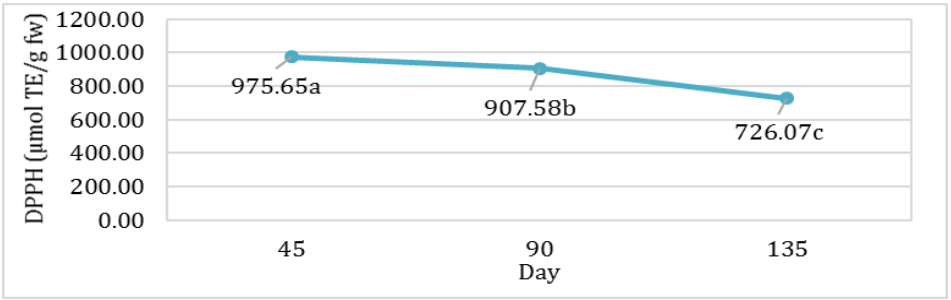

Figure 7. DPPH of potato with applied calcium before storage for day 45, day 90 and day 135 at storage

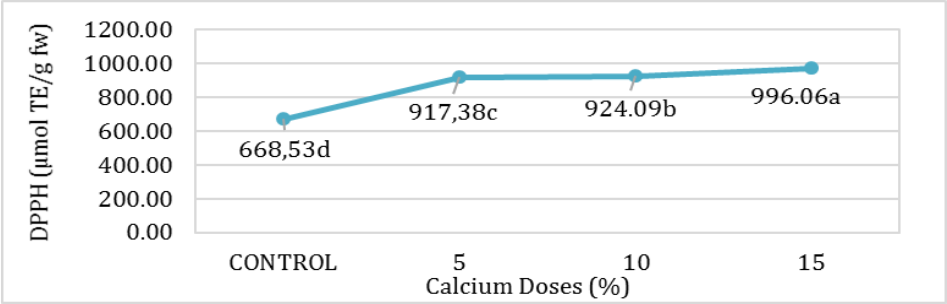

Figure 8. DPPH of potato with applied calcium before storage at the end of the storage

Conclusion

The results of this study revealed that postharvest calcium application was effective on inhibiting or slowing down the increase in sugar rate. It can be concluded that dipping potato tubers in $CaCl_2$ solutions may help prolong postharvest life of the potato tubers in cold storage. The dipping application of calcium played an important role at preventing of early shooting during cold storage. In addition, as a result of this study, it is thought that it is possible to prevent the decrease of phenolic compounds and antioxidants in stored potato tubers by calcium pre-applications.

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