

Effect of storage temperature and time on potato cv. Innovator industrial quality

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ABSTRACT: Reducing the storage temperature delays sprouting and increases the storage period, prolonging the supply to the industry. However, it may cause enzymatic browning before frying and non-enzymatic browning over frying. Therefore, the objective of this study was to determine the effects of a reduction in the temperature and storage time on the quality of cv. Innovator intended for frying. Potato tubers were stored at 6, 7 and 8 °C for 150 days. This study analyzed the total soluble sugars (TSS), non-reducing sugars (NRS), reducing sugars (RS), post-frying coloring, fresh mass loss (FML), sprouting onset, peroxidase (POD) and polyphenoloxidase (PPO) activity. The TSS, NRS and RS contents were higher in tubers stored at 6 °C, classified in category 3, while at 7 and 8 °C, it was classified in category 2. Storage time affected sugar concentrations only in tubers at 6 °C. Also at 6 °C, the FML was lower and sprouting was delayed by 30 days. Regardless of temperature and storage time, there was no enzymatic darkening due to POD and PPO activity. It is concluded that reducing the storage temperature to 6 °C prolongs the dormancy period, reduces fresh mass loss, increases reducing sugar content and non-enzymatic browning.

Key words: maillard reaction; reducing sugars; *Solanum tuberosum* L.; sprouting

Efeito da temperatura e do tempo de armazenamento sobre a qualidade industrial da batata cv. Innovator

RESUMO: A redução da temperatura de armazenamento atrasa a brotação e aumenta o período de armazenamento, prolongando o fornecimento para a indústria. No entanto, pode ocasionar o escurecimento enzimático antes da fritura e não enzimático durante a fritura. Diante disso, o objetivo deste estudo foi determinar os efeitos da redução da temperatura e do tempo de armazenamento na qualidade dos tubérculos cv. Innovator destinados à fritura. Os tubérculos de batata foram armazenados a 6, 7 e 8 °C por 150 dias. Foram realizadas às análises de açúcares solúveis totais (AST), açúcares não redutores (ANR), açúcares redutores (AR), coloração pós-fritura, perda de massa fresca (PMF), início da brotação, atividade da peroxidase (POD) e polifenoloxidase (PPO). Os teores de AST, ANR e AR foram maiores nos tubérculos armazenados a 6 °C, sendo classificados na categoria 3, enquanto 7 e 8 °C, na categoria 2. O tempo de armazenamento teve efeito nas concentrações de açúcares apenas nos tubérculos a 6 °C. A 6 °C a PMF foi menor e a brotação foi retardada em 30 dias. Independente da temperatura e tempo de armazenamento não houve escurecimento enzimático, devido à atividade da POD e PPO. Conclui-se que a redução da temperatura de armazenamento para 6 °C prolonga o período de dormência, reduz a perda de massa fresca, aumenta o teor de açúcares redutores e o escurecimento não enzimático.

Palavras-chave: reação de Maillard; açúcares redutores; *Solanum tuberosum* L.; brotação

Introduction

The potato is the fourth most important agricultural crop in the world (Haan & Rodriguez, 2016), with a planted area in 2018 of 17,576,672 hectares and annual production of 368 million tonnes (FAO, 2020). In Brazil, in 2019, there was an increase of 0.5% in the production area potato compared to 2018, and the estimate for 2020 is an increase of 3.6% due to the expansion of the pre-fried potato processing industries (Hfbrasil, 2019/2020). Therefore, potato is among the most economically and socially important food due to high productivity, nutritional composition and versatility of processing (Evangelista et al., 2011).

For the constant supply of tubers to the processing industries and the reduction of summer production costs, especially in subtropical and tropical countries, prolonged refrigerated storage of the tubers is required.

Tubers are usually stored at temperatures between 8-10 °C (Wiberley-Bradford et al., 2016). However, tubers stored at these temperatures show high sprouting and disease incidence (Wiberley-Bradford et al., 2016). Sprouts turn the tubers physically unsuitable for processing; in addition, the occurrence of sprouting may induce sweetening, resulting in a high sugar content, which is not adequate for processing (Xiao et al., 2018).

Lower temperatures can be used to delay sprouting (Xiao et al., 2018). However, storage below 8 °C, may increase the darkening after frying, induced by the sweetening of the tubers (Duarte-Delgado et al., 2016). Sweetening consists in the accumulation of reducing sugars (RS). The carbonyl or ketone group of the RS molecule reacts with the amino group of amino acids, such as asparagine, resulting in melanoidin pigments during frying by a non-enzymatic darkening reaction called Maillard (Wiberley-Bradford et al., 2016).

Furthermore, darkening may occur before frying caused by the action of peroxidase (POD) and polyphenoloxidase (PPO) (Singh & Wadhwa, 2017). That increase your activity in stress condition, such as a cold.

The objective of this study was to determine the effects of the reduction in temperature and storage time on the quality of cv. Innovator intended for frying.

Materials and Methods

Tubers from cv. Innovator was obtained from the commercial production area of Perdizes, Minas Gerais, Brazil (19° 21' 10" S, 47° 17' 34" W and 1000 m). The tubers were planted in May and hand-harvested in September. The curing was performed at 15 °C for 15 days, followed of the store to 6 (UR 90% ± 2), 7 (UR 85% ± 3) and 8 °C (UR 90% ± 2) in the absence of light for 150 days.

Sprouting onset was determined visually at the buds on the tubers.

The tubers loss of the accumulated fresh mass (FML) was obtained by the difference between the tubers weight at the beginning of storage and in each evaluation period. The result was expressed as a percentage.

To analyzes total soluble sugars (TSS), reducing sugars (RS), non-reducing sugars (NRS), five grams of tuber were diluted in 80% ethanol at 100 °C. The solution was triturated and centrifuged three times for 10 minutes at 1500 g. The samples were filtered at each centrifugation and the volume of the combined filtrates (extract) (Dubois et al., 1956).

The reaction of TSS was composed of 250 µL of the extract, 250 µL of 5% phenol and 1.25 mL of sulfuric acid. Subsequently, the reaction was placed in a thermostatic bath at 30 °C for 20 min. TSS were quantified by spectrophotometer (Genesys- 10 UV) at 490 nm and the results were expressed in % of fresh weight. Sucrose 1% was used as a standard (Dubois et al., 1956).

RS were determined by the dinitrosalicylic acid (DNS) (Gonçalves et al., 2010), using 0.2% fructose to determine the standard curve. The reaction was composed of 500 µL of DNS solution and 500 µL of the sample, subsequently placed in a thermostatic bath at 100 °C and after 5 min, 4 mL of distilled water was added. The readings were performed in spectrophotometer (Genesys- 10UV) at 540 nm and results expressed in % of the fresh weight.

NRS was calculated by the difference between TSS and RS and expressed in percentage.

To evaluate the post-fry color, the tubers were cut French fries using a manual cutter and fried in an electric fryer, with capacity for 3 L (Model: Ford®) for 3 min at 180 °C. The color of the post-fry potatoes was visually determined based on the grading scale recommended by the 'United States Standards for Grades of Frozen French Fried Potatoes' (USDA, 1967) and the fast-food industry color grading chart from 1 to 5.

The POD and PPO extract and proteins were obtained from 5 g of plant material and 15 mL of extraction buffer (0.1 M potassium phosphate buffer, pH 6.5). The material was ground, filtered with layers of gauze and centrifuged at 17000 g for 30 min at 4 °C (Lagrimini et al., 1997).

The activity of POD was composed of 100 µL enzyme extract, 0.5 mL of guaiacol (1.7%), 1.5 mL of 0.1 mol L⁻¹ potassium phosphate buffer (pH 7.0) and 0.5 mL of hydrogen peroxide (1.8%). POD activity was determined in a spectrophotometer at 470 nm and the data expressed in units of absorbance (UA) min⁻¹ mg⁻¹ protein (Lagrimini et al., 1997).

The activity of PPO was composed of 100 µL enzyme extract, 1.5 mL of 0.1 mol L⁻¹ potassium phosphate buffer (pH 7.0), 0.5 mL catechol and 0.9 mL of distilled water. Changes in absorbance were determined at 420 nm and expressed in UA min⁻¹ mg⁻¹ protein (Kavrayan & Aydemir, 2001).

Total protein was determined by the method of Bradford (1976) using bovine serum albumin (BSA) as standard.

The experiment was conducted in split-plot design, where the plots were the temperatures (6, 7 e 8 °C) and in the subplots, the storage times (30, 60, 90, 120 e 150 days). It was used as a completely randomized design, with six replications, each repetition consisting of two tubers. The data were analyzed using the boxplot. stats procedure (R Core Team, 2017). For the analysis of variance, interaction, and regression (p > 0.05) unfolding, the R version 1.1.2 was used (Ferreira et al., 2013).

Results and Discussions

The Innovator cultivar stored at 7 and 8 °C the sprouting occurred at 120 days of storage, while at 6 °C it started at 150 days (Figure 1). The acceleration of sprouting at higher storage temperatures is due to the effect of temperature on the physiological aging processes of tubers that reduce dormancy (Muthoni et al., 2014).

Tubers stored at 6 °C had the lowest FML (2.29%) and tubers stored at 7 and 8 °C caused PMF of 8.51 and 6.65% at 150 days, respectively (Figure 2). FML occurs due to carbohydrate consumption by the respiratory process and water loss through transpiration, factors mainly determined by temperature and water content in storage chambers (Chitarra & Chitarra, 2005). As the storage chamber at 7 °C remained at lower RH (80% ± 3) than the chambers at 6 and 8 °C (RH 90% ± 2), the FML was higher. Afek et al. (2000) demonstrated the effect of RH on FML in potato tubers stored for six months at 10 °C, where RH of 96-98% caused weight loss of 2%, while in RH of 92 – 94%, the loss was 7%, and if reduced to 82 - 86%, the loss is 12%. The lower FML of tubers at 6 °C is due to prolongation of the sprouting period (Figure 1), due to respiratory activity that is increased with sprout growth (Bisognin et al., 2008).

The refrigerated storage time did not influence the sugar contents of the tubers stored at 7 and 8 °C for 150 days. The mean values of TSS, NRS and RS at 7 °C were 0.18, 0.16 and 0.05%, respectively, and at 8 °C were 0.13, 0.12 and 0.02%, respectively. At 6 °C the tuber NRS content decreased from 0.27 to 0.15% in 150 days of storage, while the RS increased from 70 days of storage, indicating that from this period there was conversion of NRS to RS, raising the RS content to 0.11% at 150 days, which led to an increase in TSS concentration from 127 days to 0.23% at 150 days (Figure 3).

Tuber TSS, NRS and RS contents decreased with increasing temperature from 6 to 8 °C at 30 and 90 days of storage (Figure 4 A and B). The lower the storage temperature, the higher

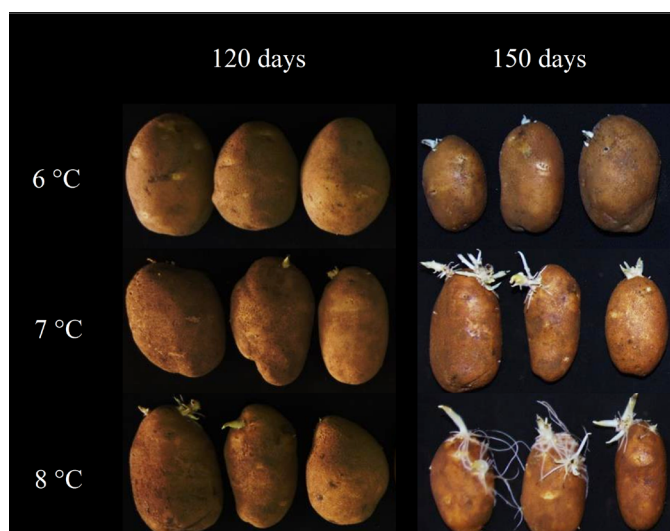
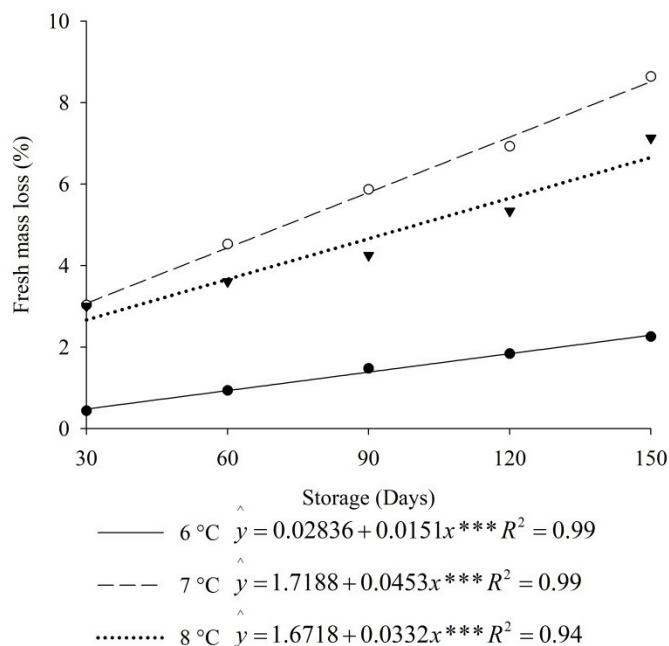
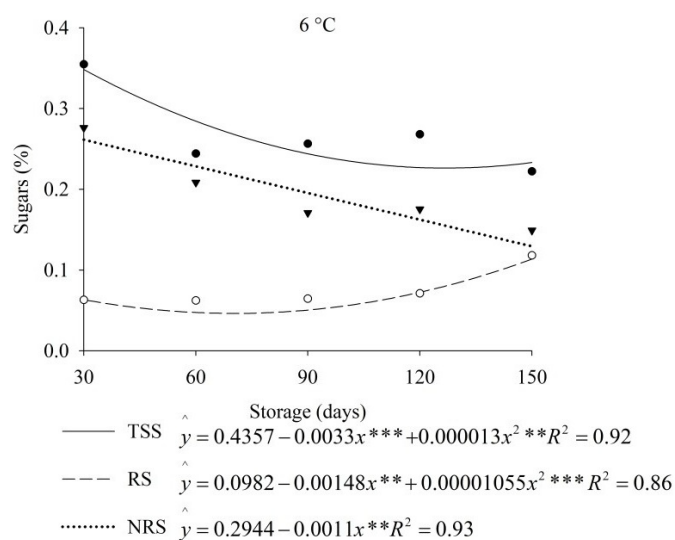


Figure 1. Sprouting onset of the tubers of cv. Innovator stored at 6, 7 and 8 °C at 120 and 150 days of storage.



***, significant to 0.001%.

Figure 2. Regressions of the fresh mass loss (FML) of tubers of cv. Innovator stored at 6, 7 and 8 °C throughout the storage.

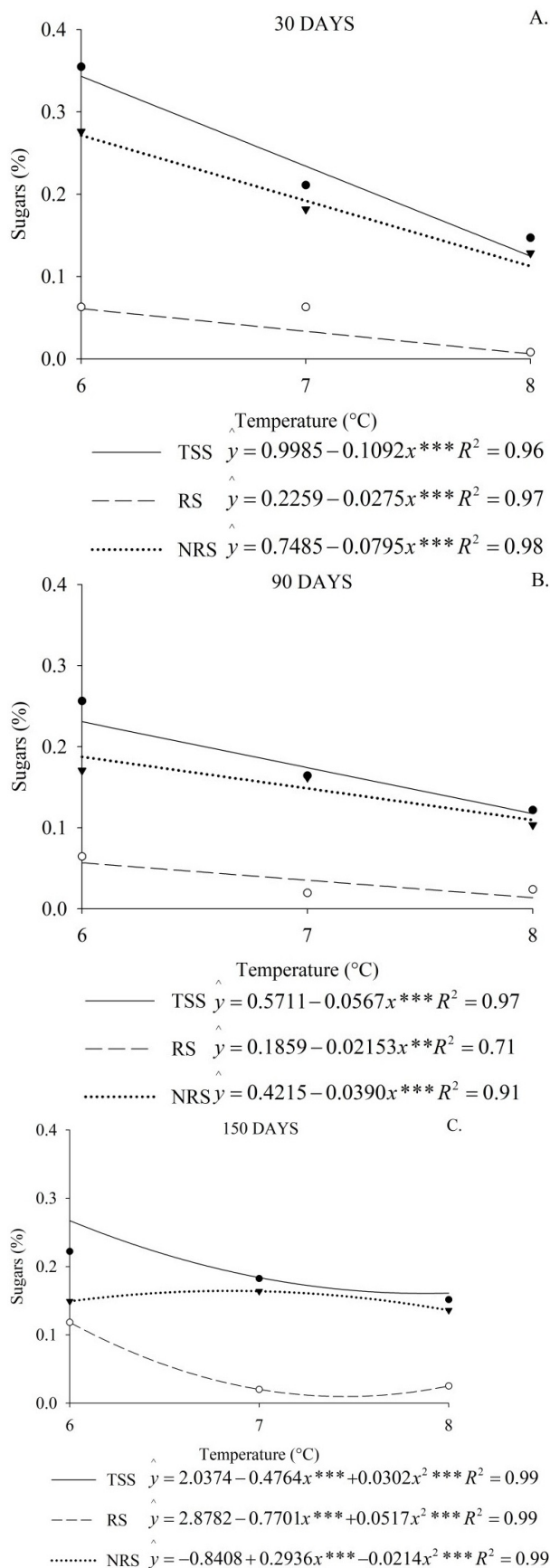


, * significant to 0.01% and 0.001%, respectively.

Figure 3. Regressions of total soluble sugars (TSS), reducing sugars (RS) and non-reducing sugars (NRS) of potato cv. Innovator stored at 6 °C by 150 days.

the stress condition in the tubers, consequently the higher the sugar accumulation, as observed at 6 °C for cv. Innovator, because sugars act as cryoprotectants of biological tissues against damage caused by cold is considered a mechanism of adaptation of the culture (Stitt & Hurry, 2002).

At 150 days, the TSS and RS decreased with increasing temperature from 6 to 7 °C, while the increase from 7 to 8 °C caused a decrease in NRS and an increase in RS, indicating that there was a conversation between them, which led to increasing in TSS (Figure 4C). The consumption of NRS with the temperature increase from 7 to 8 °C was due to the occurrence of sprouting, in which at 8 °C the size of the shoots



, * significant to 0.01% and 0.001%, respectively.

Figure 4. Regressions of total soluble sugars (TSS), reducing sugars (RS) and non-reducing sugars (NRS) of potato cv. Innovator stored at 6, 7 and 8 °C for 30 (a), 90 (b) and 150 (c) days.

was larger (Figure 1). For bud growth and development there is the hydrolysis of starch in NRS that is converted to RS to provide carbon and energy to the buds (Bisognin et al., 2008).

RS contents were in the range of 0.06 to 0.12%; 0.02 to 0.03%; 0.006 to 0.03% in tubers stored at 6, 7 and 8 °C, respectively, below that indicated for the potato processing industry, 0.12% of the fresh mass (Stark et al., 2003). NRS is in the range of 0.27 to 0.15%; 0.19 to 0.17%; 0.11 to 0.14% in tubers stored at 6, 7 and 8 °C, respectively, also below industry recommendations, 0.33% of the fresh mass (Chapper et al., 2002).

The Innovator potatoes frying stored at 6 °C were classification in category 3, while the tubers at 7 and 8 °C in category 2 (Figure 5). The processing industries require potatoes category 1, 2 and 3. Low sugar levels resulted in light coloration after frying. The correlation between RS and browning during frying was also observed in Asterix, Sminia793101-3 and Missaukee cultivars, which presented higher RS and browning values at lower storage temperatures (4, 8, 12 and 25 °C) (Freitas et al., 2012). Russet Burbank, Ranger Russet and Umatilla cultivars when stored at 6 and 7 °C also maintained acceptable levels of RS for processing for up to 230 days (Knowles et al., 2009).

POD and PPO concentrations were not influenced by temperature and storage time. The activity of POD and PPO remained in the range of 0.10 to 0.29 UA min⁻¹ mg⁻¹ protein and 0.50 to 1.44 UA min⁻¹ mg⁻¹ protein, respectively. Low

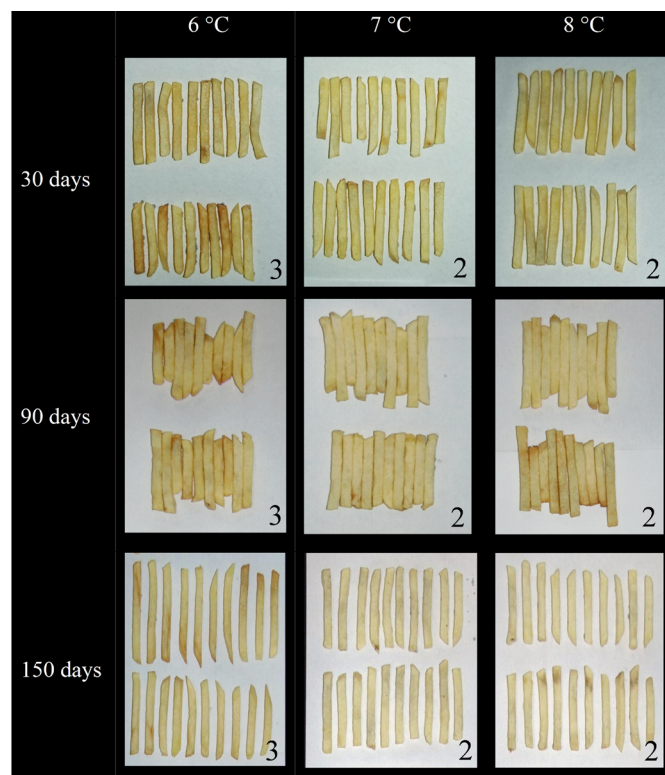


Figure 5. Post-fry coloring of potato sticks cv. Innovator after storage at 6, 7 and 8 °C for 30, 90 and 150 days. The numbers below each photo represent the classification according to USDA and the fast-food industry color grading chart from 1 to 5.

storage temperatures may have made it difficult for enzymes to contact their substrate by reducing the kinetic energy of molecules (Lee et al., 1995). As the variation between temperatures is small, it was not sufficient to cause changes in enzymatic activity. As well as the storage time, which could attenuate the cold stress condition and increase the enzymatic activity, which was not observed.

Conclusion

That reducing the storage temperature to 6 °C prolongs the dormancy period, reduces fresh mass loss, increases reducing sugar content and non-enzymatic browning.

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