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Regeneração da periderme de dano dos tubérculos de batata como resultado da temperatura de cura

Regeneration of the damage periderm of potato tuber as a result of the temperature of curing

Regeneración del daño peridérmico de los tubérculos de papa como resultado de la temperatura de curado

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Resumo

Reconhece-se que os danos mecânicos são uma das principais causas de perdas pós-colheita dos tubérculos de batata e a cura é um processo indispensável para aumentar a resistência à escoriação. Além disso, é necessário o uso de temperaturas de cura mais baixas para manter a qualidade e prolongar a durabilidade dos tubérculos. No entanto, podem não permitir a regeneração adequada da periderme de dano, além desse efeito ser variável entre os genótipos. O presente estudo avalia os resultados histológicos na periderme decorrente do dano mecânico através de uma simulação de escoriação, uma vez que é o mais comum durante as etapas de colheita e pós-colheita. Portanto, o objetivo deste estudo foi determinar o efeito da redução da temperatura de cura no número de camadas e na espessura da periderme de dano de tubérculos de batata da cv. Innovator. A análise histométrica do súber, do felogênio, da feloderme e da periderme total dos tubérculos foi realizada no software Image-Pro Plus (MediaCybernetics), após 15 dias de cura. O número de camadas e a espessura de cada camada estrutural da periderme foram determinados a partir de seis medições para cada repetição. Após a cura, não houve formação do súber e da feloderme nos tubérculos a 8 °C sob o tratamento de escoriação, enquanto todos os componentes da periderme foram formados a 14 e 20 °C. A 8 e 14 °C, o felogênio diferenciou-se da mesma forma em tubérculos conduzidos nos tratamentos de controle e danos mecânicos, enquanto a 20 °C a espessura não diferiu em nenhum componente da periderme. O felogênio a 14 e 20 °C não diferiu no número de camadas e espessura. O aspecto visual das lesões dos tubérculos a 14 e 20 °C enfatizou a regeneração. Conclui-se que a redução da temperatura de cura para 8 °C proporcionou uma regeneração celular mais lenta. No entanto, é possível realizar o procedimento de cura a 14 °C, sem comprometer a formação do periderme de dano. A cultivar Innovator possui rápida regeneração celular em temperaturas de cura mais altas, portanto, recomenda-se que os tubérculos desta cultivar sejam curados a 14 ou 20 °C. O

estudo avalia o dano mecânico por meio de uma simulação do dano por escoriação. Entretanto, para uma melhor compreensão da formação da periderme do dano, é interessante que outros estudos avaliem diferentes tipos de dano, como impacto, compreensão e abrasão, a fim de avaliar a capacidade de regeneração de acordo com o dano dessa cultivar.

Palavra-chave: Felogênio; Súber; Feloderme; Número de células.

Abstract

It is acknowledged that mechanical damage is a major cause of post-harvest losses of potato tubers and the curing is an indispensable process to increase resistance to excoriation. Furthermore, the use of lower curing temperatures is required to maintain the quality and prolong the durability of the tubers. However, they may not allow adequate regeneration of the damage periderm, besides this effect being variable among genotypes. The present study evaluates histological outcomes in the periderm derived from the mechanical damage through a simulation of excoriation, as it is the most common during the harvest and post-harvest stages. Therefore, the objective of this study was to determine the effect of reducing the curing temperature on the number of layers and on the thickness of the damage periderm of potato tubers of cv. Innovator. Histometric analysis of the cork, phellogen, phelloderm and the total periderm of tuber, was performed using the Image-Pro Plus software (MediaCybernetics) after curing for 15 days. The number of layers and thickness of each periderm structural layers were determined from six measurements for each repetition. After curing, there was no formation of the cork and phelloderm in the tubers conducted at 8 ° C under the excoriation treatment, while all components of the periderm were formed at 14 and 20 °C. At 8 and 14 °C, the phellogen differentiated similarly in tubers conducted at control and mechanical damage treatments, while at 20 °C the thickness did not differ in any component of the periderm. The phellogen at 14 and 20 °C did not differ in the number of layers and thickness. The visual aspect of the tuber injuries at 14 and 20 °C emphasizing the regeneration. It is concluded that the reduction of the curing temperature to 8 °C provided slower cell regeneration. However, it is possible to conduct the curing procedure at 14 °C, without compromising the formation of the damage periderm. The cultivar Innovator has rapid cell regeneration at higher curing temperatures, therefore it is recommended that the tubers of this cultivar be cured at 14 or 20 ° C. The study evaluates the mechanical damage through a simulation of the damage by excoriation. The however, for a better understanding of the formation of the damage periderm, it is interesting that other studies evaluate different

types of damage, such as impact, comprehension and abrasion, in order to assess the regeneration capacity according to the damage of this cultivar.

Keywords: Phellogen; Cork; Phelloderm; Number of layers.

Resumen

Se reconoce que el daño mecánico es una causa importante de pérdidas posteriores a la cosecha de tubérculos de papa y el curado es un proceso indispensable para aumentar la resistencia a la abrasión. Además, el uso de temperaturas de curado más bajas es necesario para mantener la calidad y prolongar la durabilidad de los tubérculos. Sin embargo, es posible que no permitan una regeneración adecuada de la peridermis dañada, y este efecto varía entre genotipos. El presente estudio evalúa los resultados histológicos en la peridermis debido al daño mecánico a través de una simulación de excoriación, ya que es el más común durante las etapas de cosecha y post cosecha. Por lo tanto, el objetivo de este estudio fue determinar el efecto de reducir la temperatura de curado en el número de capas y el grosor de la peridermis del daño a los tubérculos de papa del cv. Innovador. El análisis histométrico del suber, felógeno, felodermo y la peridermia total del tubérculo se realizó utilizando el software Image-Pro Plus (MediaCybernetics), después de 15 días de curado. El número de capas y el grosor de cada capa estructural de la peridermis se determinaron a partir de seis mediciones para cada repetición. Después del curado, no hubo formación de suber y felodermo en los tubérculos a 8 °C bajo tratamiento de excoriación, mientras que todos los componentes de la peridermis se formaron a 14 y 20 °C. A 8 y 14 °C, el fenógeno difería de la misma manera en los tubérculos realizados en los tratamientos de control y daño mecánico, mientras que a 20 °C el grosor no difería en ningún componente de la peridermis. El felógeno a 14 y 20 °C no difirió en el número de capas y grosor. El aspecto visual de las lesiones tuberculosas a 14 y 20 °C enfatizó la regeneración. Se concluyó que la reducción de la temperatura de curado a 8 ° C proporcionó una regeneración celular más lenta. Sin embargo, es posible realizar el procedimiento de curado a 14 ° C, sin comprometer la formación del daño periderm. La variedad Innovator tiene una rápida regeneración celular a temperaturas de curado más altas, por lo que se recomienda que los tubérculos de esta variedad se curen a 14 o 20 ° C. El estudio evalúa el daño mecánico a través de una simulación del daño por excoriación. Sin embargo, para una mejor comprensión de la formación de la peridermia del daño, es interesante que otros estudios evalúen diferentes tipos de daños, como el impacto, la comprensión y la abrasión, con el fin de evaluar la capacidad de regeneración de acuerdo con el daño de este cultivar.

Palabras clave: Felógeno; Suber; Felodermo; Número de células.

1. Introduction

Mechanical damage is a major cause of reduced durability and quality of products (Gao et al., 2016) although inevitable in the harvest and post-harvest stages of potato tubers.

In the damaged tuber area, a traumatic phellogen is formed, which gives rise to a damage periderm (Jin et al., 2018). This periderm is composed of three acknowledged layers, cork, phellogen and phelloderm, which formation is influenced by the genotype (Lulai et al., 2007).

Some cultivars are considered unacceptable for commercial production, as they present excessively slow periderm development (Lulai et al., 2007), while tubers with greater resistance to damage, in addition to better physical appearance, have less water loss and infection by pathogens and reduced respiratory activity (Jin et a., 2018), what may be associated with dry matter loss and possible influence on tuber quality, it is important to select cultivars with greater resistance to excoriation.

Innovator is a cultivar obtained by crossing the North American variety Shepody with a Dutch clone (RZ-84-2580) (HZPC, 2017) and has a size, shape and color suitable for the potato processing industry. It is already used by several companies, as in the McCain factory in Argentina, in which 50% of the processed potato is from this cultivar (ABBA, 2017). However, its ability to regenerate the periderm under conditions of mechanical damage is unknown.

The healing of the tubers has an effect on the formation of the periderm, as it promotes the thickening of the cell walls of the phellogen causing greater adherence of the cork and the suberization of the cells of the periderm, thus promoting greater resistance to excoriation (Sabba and Lulai, 2002; Sabba and Lulai, 2005; Wiltshire and Peters, 2006; Lulai, 2007).

The curing temperature used determines the speed of formation of the periderm, since the suberization rate increases approximately three times between 5 and 10 ° C, and another three times between 10 and 20 °C, being higher at 25 °C (Artschwager, 1927; Wigginton, 1974; Dean, 1989; Morris et al., 1989).

Therefore, the most common curing temperature is 20 °C, however exposure to high temperatures despite accelerating the formation of the periderm of damage promotes a reduction in the durability and quality of the tubers, therefore it is necessary to determine

whether it is possible to reduce the curing temperature without excessively reducing the formation of the periderm.

This reduction should be between 20 and 8 °C, because below this temperature there is a non-enzymatic browning, due to the Maillard reaction between reducing sugars and amino acids, such as asparagine, during the frying of the tubers destined to the potato processing industry (Amy et al., 2016), reducing commercial acceptance.

Therefore, the objective of this study was to determine the effect of reducing the curing temperature on the number of layers and on the thickness of the damage periderm of potato tubers of cv. Innovator.

2. Methodology

Potato tubers (*Solanum tuberosum* L.) cultivar Innovator were obtained from the commercial production area of the region of Perdizes-MG (19º 21 '10 "S, 47º 17' 34" W and 1 000 m). The tubers were planted in May and harvested manually in September 2017. The treatments consisted of tubers with mechanical damage and control (without mechanical damage). The damage (excoriation) was carried out with the aid of metallic sandpaper on one side of the tuber until the peel was removed. Subsequently, the tubers were placed in acclimatized chambers at 8, 14 and 20 ° C (RH 90% ± 3) for 15 days to cure.

Samples of approximately 3 x 5 mm, contemplating the surface of tubers, injured or not, conducted at different curing temperatures were fixed in FAA50 (formalin, acetic acid, ethanol 50%; 5: 5: 90 v/v), for 24 h, and subsequently stored in ethanol 70% until processing. The samples were dehydrated in ethylic series and included in metacrylate (Historesin, Leica). The tuber samples were cross sectioned (8 µm thick) in an automatic advance microtome (RM 2155, Leica). The sections were stained with Toluidine Blue pH 4.0 (O´BRIEN; MCCULLY, 1981) for 10 min, and mounted with synthetic resin (Permount, Fisher). The photographic documentation of representative cross sections of tuber samples for the quantitative histometric analysis were performed with a light microscope (Olympus AX70) equipped with U-Photo system. The mean thickness (µm) and the number of cells was determined for the periderm and its three acknowledged regions, to date: phelloderm, phellogen and phellem (cork).

The analysis of the periderm and its regions was performed with the Image-Pro Plus software (MediaCybernetics). Six measurements, each from different selected cross sections

of the same sample, were performed for each selected section for each repetition, consisted of two tubers.

The experimental design used was completely randomized, in subdivided plots, with curing temperatures (8, 14 and 20 ° C) in the plots and in the subplots the tubers without and with mechanical damage, with 5 repetitions, each repetition consisting of two tubers. The data were submitted to analysis of variance ($p < 0.05$) using the statistical software SAEG 9.1 - System of Statistical Analysis and Genetics (SAEG, 2007).

3. Results and Discussion

At 8 °C, the number of layers of the damaged tubers' phellogen differed from the control, however, the thickness of this layer did not differ, indicating that this layer regenerated after curing (Table 1) although at different rates. However, the cork and phelloderm layers were not observed in the damaged tubers (Table 1), the temperature reduction delayed the differentiation of these layers, and it was not possible to verify them after 15 days of curing. Thus, when evaluating the periderm, there was a smaller number of layers and thickness in the tubers with damage compared to the control ones (Table 1).

At 14 °C all cell layers were formed in the periderm, the cork and phelloderm of the damaged tubers showed fewer layers and thickness than those of the control (Table 1). The differentiation process of the phellogen occurred faster, although did not differ in the number of layers and thickness (Table 1). However, the periderm, due to the slower differentiation of cork and phelloderm cells, had fewer layers and thickness (Table 1).

At 20 ° C, the excoriated tubers had fewer layers of periderm cells compared to those of the control. However, the thickness did not differ, indicating that there was a complete regeneration of the damage periderm after excoriation (Table 1) or that regeneration of the periderm is an ongoing process and newly formed cells might still be submitted to mold.

Table 1: Number of cell layers and thickness (µm) of periderm, phellem (cork), phellogen and phelloderm of the control and tubers with damage after curing for 15 days at 8, 14 and 20 °C.

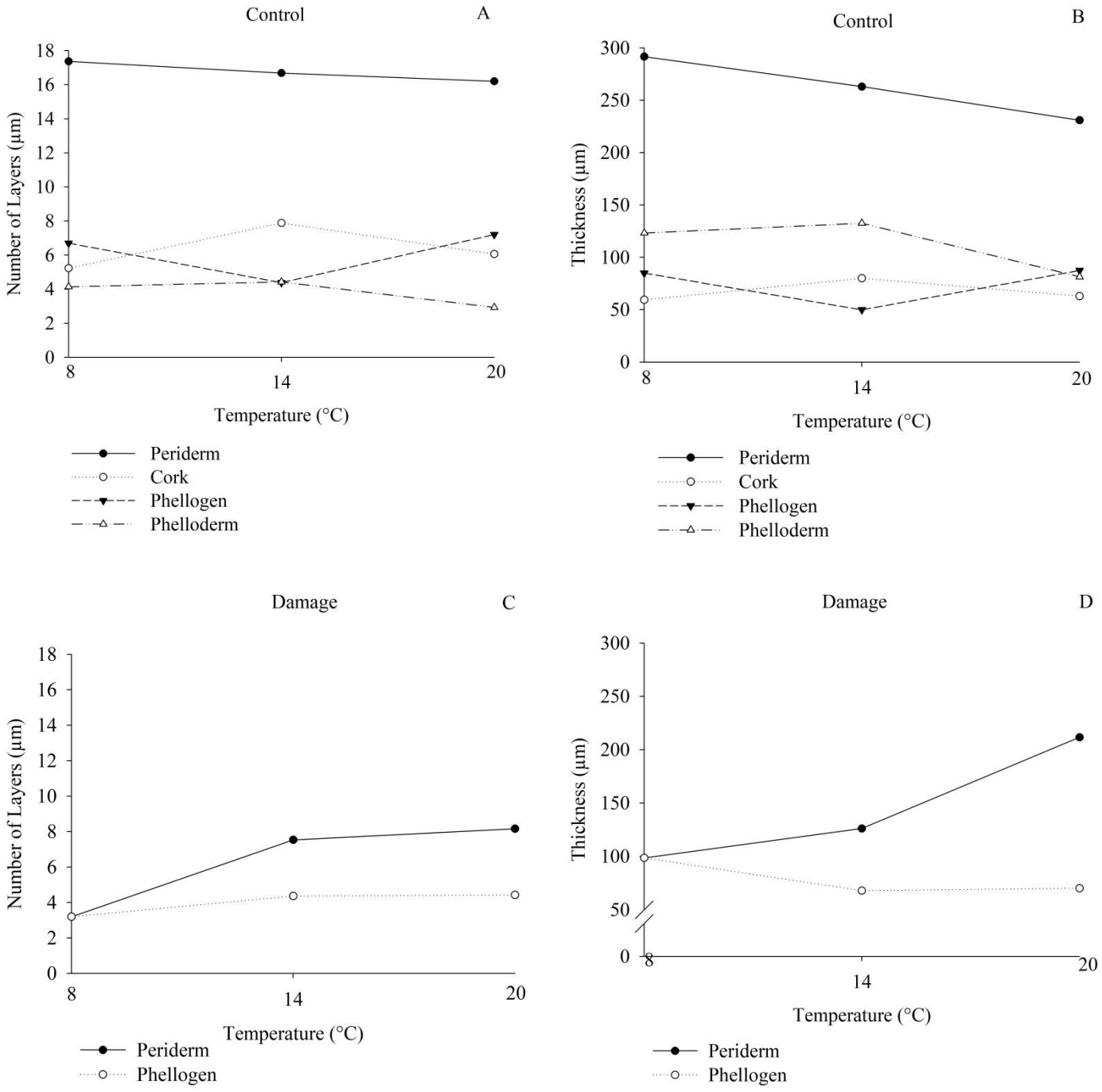
	Number of Cell Layers				Thickness (µm)		
	8 °C	14 °C	20 °C		8 °C	14 °C	20 °C
Periderm							
Control	17.37 a	16.68 a	16.2 a	Control	291.71 a	263.02 a	230.99 a
Damage	3.2 b	7.53 b	8.16 b	Damage	98. 56 b	126.13 b	211.69 a
Cork							
Control	5,23	7.88 a	6.06 a	Control	59,28	79.98 a	62.96 a
Damage	-	2.53 b	2.90 b	Damage	-	42.68 b	55.94 a
Phellogen							
Control	6.70 a	4.38 a	7.20 a	Control	84.9 a	49.8 a	87.4 a
Damage	3.20 b	4.36 a	3.43 b	Damage	98.5 a	67.9 a	70,1 a
Phelloderm							
Control	4.14	4.42 a	2.93 a	Control	123.12	132.50 a	81.32 a
Damage	-	0.63 b	1.83 b	Damage	-	15.53 b	85.59 a

Lower case letters in the same column do not differ by the 5% t test. Source: Authors.

When evaluating the effect of temperature on the periderm layers of the control tubers, it was observed that there was a tendency to reduce the thickness of the periderm with increasing temperature and this effect was almost null in the number of cells (Figure 1A and B). There was also a tendency for a greater number of layers and thickness of the cork and phelloderm at 14 °C, while the phellogen showed the opposite behavior (Figure 1A and B).

The effects on damaged tubers were observed, there was a tendency for a greater number of layers and periderm thickness at 14 and 20 ° C in tubers with damage compared to 8 °C, and at 20 °C, the greatest thickness of the periderm (Figure 1C and D). Phenogen at 8 °C should have a tendency to have fewer layers and greater thickness than at 14 and 20 °C, which showed no apparent difference (Figures 1C and D).

Figure 1: Number of layers and thickness (µm) of the periderm, cork, phellogen and phelloderm of the control tubers (A and B) and with damage (C and D) after curing for 15 days at 8, 14 and 20 °C.



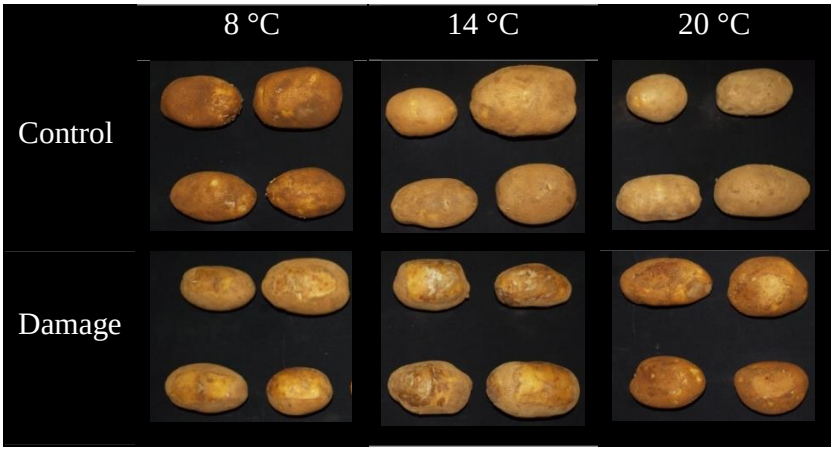
Source: Authors.

The visual aspect of the tubers at 14 and 20 °C shows better appearance of regeneration of the injured region, with the better appearance in the tubers at 20 °C, different

from that observed at 8 ° C, in which the lesions are very apparent after 15 days of healing (Figure 2).

The present study evaluates the mechanical damage through a simulation of the damage by excoriation, as it is the most common during the harvest and post-harvest stages. Further approach of mechanical damage, such as impact, comprehension and abrasion, might provide different outcomes in the context of the regeneration capacity of potato cultivars.

Figure 2: Images of control tubers with mechanical damage after 15 days of curing at 8, 14 and 20 °C.



Source: Authors.

4. Final Considerations

The reduction of the curing temperature to 8 °C provided slower cell regeneration. However, it is possible to conduct the curing procedure at 14 °C, without compromising the formation of the damage periderm. The cultivar Innovator has rapid cell regeneration at higher curing temperatures, therefore it is recommended that the tubers of this cultivar be cured at 14 or 20 °C.

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