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EXPERIMENTAL PAPER

Kinetic study on peroxidase inactivation and anthocyanin degradation of black cherry tomatoes (*Solanum lycopersicum* cv. OG) during blanching

HO THI NGAN HA^{1,2*}, NGUYEN MINH THUY³

¹Faculty of Agriculture and Natural Resources
An Giang University,
Vietnam

²Vietnam National University
Ho Chi Minh City, Vietnam

³Department of Food Technology, College of Agriculture
Can Tho University, Vietnam

*corresponding author: phone: 084 919965143; e-mail: htnha@agu.edu.vn

Summary

Introduction: Blanching is a necessary treatment stage in processing of tomato products to inactivate enzymes. However, it may cause the degradation of nutrients.

Objective: In this study, the kinetics of thermal peroxidase inactivation and anthocyanin degradation in black cherry tomatoes (cv. OG) were determined to predict the quality changes during the blanching.

Methods: Tomatoes were blanched at five levels of temperature (75–95°C) for five time periods (30–150 s).

Results: It was found that as the blanching temperature increased and the blanching time is prolonged, more peroxidase was inactivated and the greater number of anthocyanins was lost. The thermal peroxidase inactivation and anthocyanin degradation showed an apparent first-order reaction with the activation energy of 129.96 kJ/mol and 65.99 kJ/mol, respectively. Peroxidase and anthocyanin in black cherry tomatoes were found to be heat-sensitive.

Conclusion: These kinetic parameters were necessary to select and design appropriate blanching conditions for black cherry tomatoes on larger scale processing.

Key words: *anthocyanin, black cherry tomatoes, blanching, kinetic study, peroxidase, Solanum lycopersicum* cv. OG

Słowa kluczowe: *antocyjany, czarne pomidorki koktajlowe, blanszowanie, badania kinetyczne, peroksydaza, Solanum lycopersicum* cv. OG

INTRODUCTION

Black cherry tomatoes (*Solanum lycopersicum* L.) [1] are tomatoes with a purplish-brown color of skin [2]. They have been just grown in Vietnam in recent years and received great attention from consumers. In addition to the common bioactive compounds such as lycopene and vitamin C, black cherry tomatoes can also produce anthocyanin, predominantly in the skin and outer tissue that other tomato cultivars do not have [3].

Anthocyanin is a major group of flavonoids found in black tomatoes. The total anthocyanin content in the extract of purple tomatoes V118 (a non-GMO tomato variety) was 72.31 mg/100 g dried weight (DW), which included 50.18 mg/100 g DW of petunidin-3-O-(*p*-coumaroyl)-rutinoside-5-O-glucoside, 13.09 mg/100 g DW of malvidin-3-O-(*p*-coumaroyl)-rutinoside-5-O-glucoside, and 9.04 mg/100 g DW of petunidin-3-O-caffeoyl-rutinoside-5-O-glucoside [3]. A series of *in vitro* and *in vivo* studies have demonstrated that anthocyanin has health-promoting effects and plays an important role in reducing degenerative and chronic diseases [4]. Black cherry tomatoes with a high concentration of these phytochemicals may have greater antioxidant potential and therefore help to lower the risk of heart diseases and cancer better [3].

Due to their health benefits, black cherry tomatoes are commonly used as a fresh vegetable or processed into liquid products such as ketchup, puree, and sauce [1]. Tomato blanching is an essential step in the processing of these products to destroy enzymes which directly responsible for undesirable sensory and nutritional changes afterward [5]. Peroxidase (POD) is well-known as one of the most heat stable enzymes present in fruits and vegetables, therefore, it is often chosen as an indicator enzyme for blanching [6] because if POD is inactivated, other enzymes that cause quality problems will also be destroyed [7]. However, like other thermal treatment operations, blanching can cause a considerable loss of heat-sensitive bioactive compounds [8]. Particularly, in black cherry tomatoes, anthocyanin is synthesized in response to light, it is concentrated mainly in the outer peel, which makes the fruits look attractive but more easily exposed to harmful environmental factors during processing [9]. Moreover, this pigment is sensitive to high temperature [10], therefore, it may be suffered a lot of loss during the blanching which affected the color and biological value of fruits.

Kinetic modeling is a helpful method in quantitative analysis in which mathematical models include formulations that show the relationship between an

acquisition indicator (for example peroxidase activity, anthocyanin content) and investigated factors (such as temperature, time) [11]. It is a concise way to express physicochemical behavior in mathematical terms [11]. Knowledge of kinetic modeling consists of reaction order, the reaction rate constant and activation energy are necessary for predicting food quality changes and optimizing the processes, especially heat treatment [10, 12].

Thermal inactivation kinetic studies in POD enzyme for different sources such as carrot [13], green asparagus [14], guava [15], zucchini [16], garlic [17], sweet corn and waxy corn [18], mangosteen [19], pumpkin [20] were observed in the wide range of 70 to 100°C. POD present in the tissues of fruits and vegetables as a combination of different isoenzymes with various thermal conditions [18]. Also, POD exists in plants both in soluble form – in the cell cytoplasm and insoluble form – when forming covalent and ionic bonds with the cell wall [21]. Thus, differences in the heat tolerance of POD vary significantly among fruit and vegetable cultivars, species, environmental conditions, and other factors [21].

Similarly, various kinetic parameters for anthocyanin degradation under heating were reported for the strawberry [22], raspberry [23], black rice [24], purple sweet potato [25], black carrot [26], mangosteen [12] and blackberry [27]. The degradation rate constant and activation energy during thermal treatment are dependent upon the stability of the anthocyanin which depends on structure, composition, physicochemical characteristics and presence of organic acids or other flavone in fruits [3].

The differences between kinetic parameters from several sources indicate the importance and necessity of kinetic analysis for individual fruits and vegetables because inappropriate values or small errors in the calculation of these parameters can greatly affect the prediction [21]. Currently, there is no published work concerning the thermal inactivation of POD and degradation of anthocyanin in whole tomato fruit, especially black cherry tomato. Therefore, the objective of the present study was a quantification of the effect of conventional blanching on POD inactivation and anthocyanin degradation of a new variety of black cherry tomato (*Solanum lycopersicum* cv. OG) cultivated in Vietnam in the whole fruit. Moreover, another novelty of this study was that black cherry tomatoes were vacuum-infiltrated before blanching to replace the gaseous components inside the fruits with water. This treatment helps the heat transfer process during blanching faster to avoid the loss of bioactive compounds, especially anthocyanins, which are mainly concentrated in

the outer skin. This may affect the kinetics of peroxidase inactivation and anthocyanin degradation upon blanching. The reaction kinetic approach was applied to be able to predict the quantity changes during blanching at different temperatures and exposure times and thereby selecting proper thermal processing conditions.

MATERIALS AND METHODS

Black cherry tomatoes

American black cherry tomato (cv. OG) seeds were provided from F1508 seed shop (Ho Chi Minh City, Vietnam) and grown in the greenhouse of Nam Long Business and Production Facility in Vinh Long province, Vietnam. Fruits were harvested at full ripening (32 days after fruit formation) with the fruit diameter of 25.11 ± 1.83 mm, the total soluble solid content and pH value of 6.17 ± 0.12 Brix and 4.43 ± 0.06 , respectively, the whole fruit firmness of 899 ± 45 g/cm². Tomatoes were packed into polyvinyl chloride plastic boxes and then put into cardboard containers. Both packages were perforated for ventilation. They were transported to the Food Technology Laboratory in Can Tho University, Vietnam within 1 to 2 h. Fruits were washed with tap water and then immersed in ozone-aerated water for 15 min using an ozone generator (Z755, 2-nozzle, Vietnam, ozone-generation capacity of 80.4 mg/h) to kill microorganisms on the surface. The tomato weight was 1500 g, the material and water ratio was 1:2. Then, the tomatoes were vacuum-treated in water using a vacuum generator (Rocker 400, Laftech, Australia) to replace gases inside the fruit pores with the liquid, thereby the thermal conductivity of fruits was increased during subsequent blanching. The vacuum level of 620 mmHg and the infiltration period of 22 min were selected, the ratio of tomatoes and distilled water was 1:1. After vacuum treatment, the mixture of tomatoes and water was brought to the atmospheric pressure and allowed to stand for an additional 15 min [28]. Then, fruits were removed from the water and drained until used as a raw materials for the blanching process. The initial anthocyanin content was 4.41 mgCE/100 g.

Tomatoes blanching process

Fruits were blanched at five temperature levels (75, 80, 85, 90, 95°C). At each temperature, fruits were blanched for five time periods (30, 60, 90, 120,

150 s). The blanching process was done by placing 1 kg of tomatoes in a rectangular stainless steel basket (25.5 cm long, 10 cm wide, 6.5 cm high, 0.5 cm square hole size) and then immersed in a thermostatic bath (Rex C-90, Memmert, Germany), in which the ratio of fruits and water was 1:2. After blanching, tomatoes were rapidly cooled by soaking in ice water (10°C) for 1 min to prevent further thermal decomposition. The experiment was performed in three replications.

Analytical methods

Peroxidase activity

The activity of peroxidase (POD) of tomatoes was defined according to the colorimetric method using guaiacol and hydrogen peroxide as the reaction substrate of Gonçalves *et al.* [13] and Morales-Blancas *et al.* [21] with some modifications. Tomato puree (20 g) was put in a 250 ml conical flask along with 100 ml of 1 M NaCl solution. The extraction was performed for 10 min with an assistance of a shaker (SK600, Lab Companion, Korea) at a speed of 180 rpm and centrifugation (Z323K, Hermle Labortechnik GmbH, Germany) was carried out afterwards at 7000×g for 10 min to separate the mixture. The substrate solution of POD included 0.1 ml of 99.5% guaiacol with 0.1 ml of 30% H₂O₂ and 99.8 ml of 0.1 M potassium phosphate buffer. The supernatant obtained after separation (0.12 ml) was added 3.48 ml of POD substrate solution and the absorbance was read at 470 nm after a period of 20 min by a UV-VIS Spectrophotometer (722N, Inesa, China). A blank was performed similarly by replacing the extract with 0.12 mL distilled water. The POD activity was expressed as U/g and calculated using equation 1.

$$\text{Peroxidase (U/g)} = \frac{\Delta A \times 100}{t \times 0.12 \times m}, \quad (1)$$

where ΔA – absorbance difference of the tomato and blank sample, t – reaction time (min), m – sample weight (g).

Anthocyanin content

The total anthocyanin content of tomatoes was determined using the spectrophotometric pH differential method of Lee *et al.* [29] with some modifications. The volume of 5 g tomato puree was increased to 50 ml with a mixture of ethanol and water

(volume ratio of 1:1) containing 1% of HCl. The extraction was performed in a shaker at 180 rpm for 60 min and then the mixture was centrifuged at 7000×g for 10 min. The supernatant was diluted with two buffers of 0.025 M potassium chloride with pH 1.0 and 0.4 M sodium acetate with pH 4.5. The absorbances of both dilutions were recorded at both 520 and 700 nm compared with the distilled water blank. The anthocyanin content was expressed as mgCE/100g with CE stand for cyanidin-3-glucoside equivalent and calculated by equation 2.

$$\text{Anthocyanin content (mgCE/100g)} = \frac{A \times M \times k \times V}{m \times \epsilon \times l} \times 100 \times 1000, \quad (2)$$

where $A - (A_{520\text{nm}} - A_{700\text{nm}})$ pH 1.0 - $(A_{520\text{nm}} - A_{700\text{nm}})$ pH 4.5, M - molecular weight of cyanidin-3-glucoside (449.2 g/mol), k - dilution factor, V - extract volume (ml), m - sample weight (g), ϵ - molar absorptivity coefficient of cyanidin-3-glucoside (26900 l/mol.cm), l - pathlength (1 cm).

Kinetic study

Previous studies [10, 30, 31] have shown that the thermal inactivation of POD and degradation of anthocyanin followed the simple first-order reaction kinetic (equation 3):

$$\frac{C_t}{C_o} = e^{-kt}, \quad (3)$$

where C_t - enzyme activity or anthocyanin content after blanching for time t , C_o - initial corresponding value, t - blanching time (s), k - rate constant of the POD inactivation or anthocyanin degradation reaction (s^{-1}).

From the regression curve constructed from the exponential equation, the coefficient k was determined.

The half-life time ($t_{1/2}$), i.e. the blanching time needed to cause the reduction of 50% of initial POD activity or anthocyanin content, was calculated by equation 4:

$$t_{1/2} = \frac{\ln(2)}{k} \quad (4)$$

The dependence of the reaction rate constant on the temperature was expressed by the activation energy (E_a) value and determined according to the Arrhenius formula (equation 5). Generally, the activation energy (E_a) is used to represent the energy that must

be provided to attain the transition state of a chemical reaction [32].

$$k(T) = k(T_{ref}) \exp \left[\frac{E_a}{R} \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right], \quad (5)$$

where T - absolute temperature (K), T_{ref} - absolute reference temperature (K), $k(T)$ and $k(T_{ref})$ - rate constants at temperatures T and T_{ref} respectively, E_a - energy of activation (kJ/mol), R - universal gas constant (8.314 J/mol.K). The reference temperature was the average of the range investigated (i.e., $T_{ref} = 85^\circ\text{C}$). Therefore, the E_a value was estimated from the slope of the linear regression equation obtained by Arrhenius plots of versus $1/T$.

Data analysis and model evaluation

Microsoft Excel software was used to calculate and draw graphs. Data analyses were carried out by the Statgraphics Centurion software (version XV, U.S.A.). The quality of the model was evaluated by the coefficient of determination (R^2).

Ethical approval: The conducted research is not related to either human or animal use.

RESULTS AND DISCUSSION

POD inactivation kinetic

The results demonstrated that both blanching temperature and time significantly affected the POD activity ($p < 0.05$). The thermal inactivation of POD in black cherry tomatoes at temperatures of 75, 80, 85, 90, and 95°C was indicated in figure 1. From the chart, it could be seen that the POD activity remarkably declined with the increase of time and temperature. However, the investigated temperature and time range was not enough to inactivate the total enzyme activity. At the highest temperature and the longest time (95°C , 150 s), the POD activity remained 1.27% of the initial value. And kinetic analysis indicated that the POD inactivation followed the strong first-order model apparently with R^2 higher than 0.95 at all five temperatures (tab. 1). This was further illustrated by the plot of remaining POD activities (P_t/P_o) vs. blanching time was reasonably fitted to the curves over most of the time (fig. 1).

This result had a good agreement with studies of Anthon *et al.* (2002) [30] and Ercan and Soysal [31]. These authors also reported an absolute first-order

Table 1.

The parameters of the first-order model to represent the inactivation of POD and degradation of anthocyanin

Temperature [°C]	$k \times 10^3$ [s ⁻¹]	$t_{1/2}$ [s]	R^2	E_a [kJ/mol]
POD inactivation				
75	$3.00 \pm 0.19^{**}$	231.67 ± 14.70	0.9701 ± 0.0052	129.96 ± 2.57
80	6.80 ± 0.41	102.12 ± 6.09	0.9727 ± 0.0075	
85	14.74 ± 0.48	47.06 ± 1.52	0.9809 ± 0.0015	
90	26.29 ± 0.59	26.37 ± 0.59	0.9697 ± 0.0009	
95	31.91 ± 0.70	21.73 ± 0.48	0.9502 ± 0.0084	
Anthocyanin degradation				
75	0.250 ± 0.020	2784.49 ± 223.47	0.9149 ± 0.0099	65.99 ± 1.98
80	0.420 ± 0.010	1650.97 ± 39.32	0.9558 ± 0.0026	
85	0.543 ± 0.015	1276.40 ± 35.58	0.9588 ± 0.0091	
90	0.850 ± 0.030	816.15 ± 28.82	0.9701 ± 0.0064	
95	1.377 ± 0.025	503.61 ± 9.24	0.9950 ± 0.0035	

Notes: *Mean; **STD – standard deviation, k – rate constant, $t_{1/2}$ – half-life time, R^2 – determination coefficient, E_a – activation energy

Figure 1.

Thermal inactivation of POD at temperatures of 75 to 95°C. Notes: P_o – initial POD activity, P_t – POD activity after blanching, the curves represented the prediction according to the first-order kinetic model

POD thermal inactivation in both tomato crude extract and tomato juice. The first-order kinetic equation is not often obtained for the POD inactivation in most plant materials because of the presence of many POD isozymes. But tomato fruit has been proven to contain only one isozyme of POD [31] that would explain the simple kinetics we attained here. However, at the highest blanching temperatures (95°C), there was a slight deviation from the curves ($R^2=0.9502$). This could be accounted for the high temperature causing fruit cracking, resulting in the faster heat transfer into the fruit and the easier inactivation of the POD in the first stages.

From the predicted curves, the constants of inactivation (k) were determined based on the exponential regression equation and showed in table 1. It was observed that when the blanching temperature increased from 75 to 95°C, the rate of POD inactivation was also raised indicated by the growth of the k values from 3.00×10^{-3} to $31.91 \times 10^{-3} \text{ s}^{-1}$. The obtained k values were then used to plot of $\ln k$ versus $1/T$ (Arrhenius plot) (fig. 2) indicating a sample linear fit ($R^2=0.9630$).

The half-life time ($t_{1/2}$) and the activation energy (E_a) were also given in table 1. In contrast to the parameter k , the $t_{1/2}$ values decrease with the increase of blanching temperature. The 50% reduction in the activity of POD was observed for 231.67, 102.12, 47.06, 26.37, and 21.73 s of blanching at 75, 80, 85, 90, and 95°C, respectively.

Figure 2.

Arrhenius plot of the thermal inactivation of POD ($T_{ref} = 85^\circ\text{C}$)

90, and 95°C, respectively. Meanwhile, a longer half-life time was found for POD from other sources. Deylami *et al.* (2016) [12] showed that a 50% POD activity reduction in mangosteen pericarp for 547.8 s and 349.2 s of blanching at 80 and 90°C, respectively. In another work, it was observed that the POD activity decreased 65% and 52% after heating grape peel extract and grape pulp extract at 75°C for 360 s [33]. Three principal processes have been thought to be related to the thermal POD inactivation including (1) conformational change of the protein part of an enzyme (apoenzyme); (2) removal of the pseudo-group (heme) from the haloenzyme (enzyme active site); and/or (3) degradation or modification of the pseudo-group [31].

After plotting of $\ln(k)$ by $1/T$, the value of E_a was simply calculated from the slope of the linear regression equation and found as 129.96 kJ/mol. Similar results were obtained for the activation energies of POD inactivation in carrot as 151.40 kJ/mol [34], tomato crude extract as 149 kJ/mol [30], sweet corn as 114.36 and waxy corn as 119.72 kJ/mol [18]. However, several reports indicated higher values of E_a for POD from other materials. For a typical example, Anthon *et al.* (2002) [30] found that the activation energies of POD from two tomato varieties of CXD 199 and BOS 3155 were 546 and 557 kJ/mol, respectively.

Although POD is often considered as an indicator for blanching of fruits and vegetables because of its high thermal stability, results of the half-life time and activation energy in this work showed that the POD in black cherry tomatoes (cv. OG) was less heat-stable than POD extracted from other plant sources and was readily inactivated at temperatures of 75–95°C but not total inactivated. The differences between study results could be due to a series of factors, including variety, maturity, pretreatment as well as an experimental methodology [31]. The pre-processing of these tomatoes by vacuum impregnation helped to increase the heat transfer capacity due to the substitution of gases by the water [35] which could contribute to the easily POD inactivation during blanching afterward. Martinez-Monzó *et al.* (2000) [36] proved that the impact of the gas replacement in the apple pores with the isotonic liquid led to a considerable increase of thermal conductivity (15–24%). This was also demonstrated in our previous study, the black cherry tomatoes which not vacuum infiltrated had remaining POD activity of 29.78% and anthocyanin content of 63.69 mgCE/100g DW after blanching at 90°C for 60 s, meanwhile, these two responses were obtained lower values

(12.24% and 62.70 mgCE/100 DW, respectively) in fruits infiltrated at the optimum vacuum condition (620 mmHg, 22 min) before blanching [37].

Anthocyanin degradation kinetic

The results also showed the significant effect of both blanching temperature and time on the anthocyanin loss ($p < 0.05$, data not shown).

A kinetic study was carried out by plotting the residual anthocyanin content (A_t/A_0) as an exponential function of exposure time for different temperatures (fig. 3). It could be observed from this graph that the degradation rate of black cherry tomatoes anthocyanin increased as the temperature increased. And the sample first-order model of anthocyanin thermal degradation obtained at five temperatures (the R^2 values in table 1 were all greater than 0.91) was similar to previous studies [27, 38]. However, at three low blanching temperatures (75, 80, and 85°C), the residual anthocyanin content after blanching of 30 s had a slightly higher deviation compared to the regression curves leading to the lower R^2 value. The reason was that when heated at low temperatures for a short time, anthocyanin not only decreased but also increased a little. This could be due to the interconversion of anthocyanin isomers [39]. In contrast, when blanched at high temperatures (90 and 95°C), anthocyanin lost very quickly by both the thermal degradation and dissolution in blanched water due to the cracking of the fruits.

Figure 3.

The thermal degradation of anthocyanin at temperatures of 75–95°C. (Notes: A_0 – initial anthocyanin content; A_t – anthocyanin content after blanching; the curves represented the prediction according to the first-order kinetic model)

The rate constants (k) obtained from the first-order equations were fitted to an Arrhenius-type plot (fig. 4) to establish the effect of temperature on the rate of anthocyanin degradation in black cherry tomatoes. And regression analysis showed that blanching temperature and k values had a strong linear dependence ($R^2=0.9847$).

Figure 4.

Arrhenius plot of the thermal degradation of anthocyanin ($T_{ref}=85^\circ\text{C}$)

Kinetic parameters, including degradation rate constant (k) and half-life time ($t_{1/2}$) for anthocyanin, were determined from the coefficient of the exponential regression equation obtained from the curves in figure 3 and presented in table 1. As a fact, the k values increased (from 0.250×10^{-3} to $1.377 \times 10^{-3} \text{ s}^{-1}$) with temperature (from 75 to 95°C), meaning that higher blanching temperatures results in a greater and more rapid loss of anthocyanin than the use of low blanching temperatures. Temperature rise induces the loss of the glycosyl moieties of the anthocyanins by hydrolysis of the glycosidic bond. This leads to further loss of anthocyanin, since the aglycones are much less stable than their glycosidic forms. It is postulated that the formation of a chalcone is the first step in the thermal degradation of anthocyanins [40].

The calculated $t_{1/2}$ values were 2784.49, 1650.97, 1276.40, 816.15 and 503.61 s at 75, 80, 85, 90 and 95°C , respectively. These $t_{1/2}$ values were notable lower than the results of Martynenko and Chen [32] who reported the half-life time of anthocyanin in the blueberry puree as 11238 and 4836 s at 80 and 95°C . The energy of activation (E_a) was also an important parameter to evaluate the degradation of anthocyanin. The calculated E_a value was 65.99 kJ/mol, which is much lower than the reported value of 81–94 kJ/mol for anthocyanin degradation in blackcurrant, maqui berry and blueberry [41]. The higher

E_a indicated that anthocyanin in black cherry tomatoes (cv. OG) was more susceptible to degradation by exposure to blanching temperatures increasing as compared to blueberry. The reason was that anthocyanin in black cherry tomatoes concentrated in the outer skin and tissue, while anthocyanin in other fruits (such as blueberry) was distributed throughout the fruit.

From the above results, it was observed that the higher the blanching temperature and the longer the blanching time is, the higher is the loss of peroxidase and anthocyanin. However, the goal of blanching was to inactivate as much POD as possible while retaining maximum anthocyanin content. At 90°C , the remaining POD activity after blanching for 30, 60, 90, 120 and 150 s was 40.36%, 16.10%, 7.45%, 3.70% and 2.83%. Meanwhile, at 95°C , the remaining POD activity was 27.15%, 8.38%, 4.64%, 2.18% and 1.27%, respectively. Similarly, the remaining anthocyanin content was 97.96%, 95.37%, 93.33%, 91.18%, 86.85% after blanching at 90°C for 30, 60, 90, 120, 150 s, respectively and 95.92%, 92.74%, 87.76%, 84.58%, 81.63% after blanching at 95°C for the corresponding times. Blanching at high temperatures for a long time (90°C for 120–150 s and 95°C for 90–150 s) significantly reduces the POD activity but causes cracking of the fruit, which was also a contributing factor to the reduction of POD activity by dissolving in blanched water, but in parallel, nutrients were also significant losses. Therefore, the two blanching conditions that inactivated a maximum POD and did not cause cracking were 90°C for 90 s and 95°C for 60 s, inactivating 92.55% and 91.62% POD, respectively. However, blanching at 95°C for 60 s causes more anthocyanin loss than blanching at 90°C for 90 s (7.26% compared to 6.67%). Therefore, suitable blanching temperature and time for black cherry tomatoes were 90°C for 90 s.

CONCLUSION

The present work evaluated the effect of blanching parameters, including temperature and exposure time, on the inactivation of POD and degradation of anthocyanin in black cherry tomatoes (cv. OG). Kinetics of these two processes followed the first-order equation with activation energies of 129.96 and 65.99 kJ/mol. Results indicated that POD and anthocyanin in black cherry tomatoes in this study were more sensitive to temperature than several other fruits. It was due to the differences in structure and blanching conditions used such as blanching temperature and time,

and also vacuum impregnation used before blanching. This mathematical modeling could be used in estimating the remaining POD activity or anthocyanin content after blanching from the temperature-time profile and kinetic parameters. Moreover, in order to inactivate the POD as much as possible while maintaining the maximum anthocyanin content in black cherry tomatoes, the best temperature and blanching time was chosen to be 90°C for 90 s. Further prospective studies at a larger scale should be carried out for application in industrial production.

Conflict of interest: Authors declare no conflict of interest.

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