OPTIMIZATION OF BLANCHING PROCESS FOR CARROTS

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ABSTRACT

Investigations were carried out to study the effects of selected blanching treatments on the quality of carrots over a temperature range of 80–100C. The blanching treatments selected were steam, water, 0.05 N acetic acid solution and 0.2% calcium chloride solution. These blanching treatments were evaluated with respect to the inactivation time of peroxidase (POD) and catalase, and the process was optimized on the basis of the maximum yield of carrot juice and minimum loss of vitamin C and β-carotene. The most effective blanching treatment was 5 min in hot water at 95C. At this time–temperature combination, POD and catalase were completely inactivated and the yield of carrot juice and vitamin C and β-carotene contents were found to be 55%, 8.192 mg/100 g and 3.18 mg/100 g, respectively. The kinetics of thermal inactivation of POD in carrot juice using various enzyme inactivation models available in the literature was critically evaluated. The Weibull distribution model provided a good description of the kinetics of the inactivation of POD in carrot juice over the temperature range of 80–100C.

PRACTICAL APPLICATIONS

Blanching is an important unit operation before processing fruits and vegetables for freezing, pureeing or dehydration. The findings of this study

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would be useful in determining the process parameters for blanching carrots with maximal retention of nutrients. The enzyme residual activity curve indicates the destructive effect of heat on the affected enzymes. A successful modeling will enable the processors to modulate their process according to different time–temperature combinations.

INTRODUCTION

Carrots (*Daucus carota*), one of the important root vegetables, are known for their nutrient contents viz. β-carotene besides appreciable amount of vitamins and minerals (Walde *et al.* 1992). Carrots are well known for their sweetening, antianemic, healing, diuretic and sedative properties. The enzymes commonly found to have deteriorative effects in carrots are peroxidases (PODs) and catalase. In order to minimize deteriorative reactions, fruits and vegetables are heat treated or blanched to inactivate the enzymes. Blanching of fruits and vegetables are done either in hot water, steam or selected chemical solutions (Luna-Guzmán and Barret 2000; Severini *et al.* 2004a,b). Blanching in calcium chloride solution is used to increase the firmness of fruits and vegetables, because of the activation of pectinmethylesterase when immersed in hot calcium chloride solution (Quintero-Ramos *et al.* 2002).

The inactivation of POD is usually used to indicate blanching sufficiency as POD is ubiquitous and considered to be among the most heat-resistant plant constitutive enzymes (Ganthavorn *et al.* 1991). While blanching leads to some favorable factors, like the inactivation of enzymes, expelling trapped air in the intracellular regions and reducing any initial infections, it also causes loss of nutritional quality (Ramesh *et al.* 2002). Therefore, the optimization of the blanching process with respect to nutrient retention (β-carotene, vitamin C loss) and product yield should be considered along with the inactivation of enzymes. The variables, such as temperature and time of treatment, and concentration and nature of the acid or salt in the blanching solution, determine the effectiveness of the blanching process (Quintero-Ramos *et al.* 2002; Severini *et al.* 2004a).

Over the years, low-temperature longtime blanching, compared to the conventional high-temperature short-time blanching for better quality retention, has been emphasized. Low-temperature longtime blanching, in comparison to high temperature short time, enhances the firmness and reduces the nutritional and flavor losses of the product (Taylor *et al.* 1981; Canet and Hill 1987).

Mathematical modeling of enzyme inactivation in heated foods is essential to estimate the residual activity of enzymes from the temperature–time profile and enzyme inactivation kinetics. The potential benefits of modeling

lies in its ability to assess the effect of different heat treatments on residual enzyme activity without performing numerous trial runs (Adams 1991). Carrying out inactivation experiments at several temperatures is considered as a useful tool for testing the validity of mechanisms verified at isothermal conditions (Polakovič and Vrábel 1996).

In experimental studies, thermal inactivation of enzymes has not been often found to follow first-order kinetics (Adams 1997; Soysal and Söylemez 2005). Deviation from the ideal first-order enzyme inactivation model occurs because of the differences in the heat resistivity of the enzyme molecules. For POD, this behavior has been explained in terms of the existence of two isoenzyme populations (heat stable and heat labile), present in the native POD enzyme (Ling and Lund 1978).

The objective of this work was to determine the optimum blanching conditions for carrots in terms of nutrient (vitamin C and β-carotene) retention and to study the kinetics of the inactivation of POD in carrot juice. Various enzyme inactivation models were tested on the basis of statistical and physical parameters to ascertain a suitable model capable of explaining the POD inactivation kinetics.

MATERIALS AND METHODS

Process of Blanching

Fresh carrots (var. Pusa Kesar) were procured from the local market. The carrots were washed properly in tap water for the removal of external impurities and peeled manually using a stainless steel knife. The peeled carrots were cut 1 in. from the top and bottom and sliced (1-cm thickness). These slices were blanched in water, 0.05 N acetic acid solution and 0.2% calcium chloride solution at 80, 85, 90, 95 and 100C, and steamed respectively for 1, 2, 3, 4, 5, 7 and 10 min. Approximately 50 g of carrot slices were taken in 250 mL water or solution prepared with acetic acid or calcium chloride in a beaker. The beakers were placed in a temperature-controlled hot water bath (Macro Scientific Works, New Delhi, India). These blanching treatments were chosen to study the effect of water or blanching solution (acetic acid or calcium chloride solution) on enzyme inactivation, yield of carrot juice and nutrient (vitamin C and β-carotene) concentration of the carrots after the blanching process. All the experiments were done in triplicate immediately after blanching, and average values were used in the analysis.

Chemicals

Hydrogen peroxide (30%) was obtained from Merck (Mumbai, India). Acetic acid and calcium chloride were procured from Qualigens Fine

Chemicals, Mumbai, India. Guaiacol (99.5%), potassium monophosphate, sodium sulfate and dipotassium phosphate (analytical grade) were procured from SD Fine Chemicals, (Mumbai, India). β-Carotene was procured from Sigma Aldrich (Bangalore, India). Deionized distilled water was used for all assays. The buffer system, ionic strength and pH were selected according to Blancas *et al.* (2002). The phosphate buffer (pH 6.5, 0.1 mol/L) was cooled to 4C prior to use.

Catalase and POD Activity

Qualitative Test for POD. The blanched carrot pieces were crushed in a porcelain bowl immediately after blanching. Ten to twenty grams of crushed sample was taken in a test tube and 20 mL distilled water was added. Guaiacol (1%) and hydrogen peroxide (0.3%) solutions were then prepared as prescribed by Ranganna (1991). Guaiacol solution (1 mL) and hydrogen peroxide solution (1.6 mL) were poured into the test tube and the contents were thoroughly mixed. A rapid and intensive brown-reddish tissue coloring within 5 min indicated a high POD activity. The gradual appearance of a weak pink color indicated an incomplete POD inactivation or low POD activity. If there was no color development after 5 min, the reaction was negative and the enzymes were considered inactivated.

Qualitative Test for Catalase. Blanched carrots (approximately 2 g) were crushed immediately after blanching and mixed with 20 mL distilled water in a test tube. After 15 min, 0.5 mL of 1% hydrogen peroxide solution was added. A strong gas (oxygen) generation for about 2–3 min indicated the presence of catalase, and no release of gas showed the complete inactivation of catalase.

Ascorbic Acid Content (Vitamin C)

The ascorbic acid content of carrot slices was determined based on 2,6-dichlorophenolindophenol dye reduction by ascorbic acid at low pH (AOAC 1990).

β-Carotene Content

The β-carotene content was determined using the spectrophotometric method as described by Ranganna (1991). The sample (2 g) was extracted in a separating funnel using petroleum ether diluted with acetone (3:1, v/v) containing a few crystals of sodium sulfate (Na_2SO_4), until it became colorless. Ether layer containing β-carotene was separated. After the dilution with petroleum ether, the β-carotene content (milligram per 100 g) was measured by

measuring the absorbance of the extract at 452 nm using a UV visible spectrophotometer (UV 2401 PC, Shimadzu Co., Singapore). The standard curve (absorbance against concentration) was drawn using the β-carotene solution at different concentrations. The β-carotene content in the sample was calculated from the standard curve.

Yield

The blanched carrot slices were taken for juice extraction immediately after blanching and for the removal of external moisture on the surface by tissue paper. The yield was measured by the amount of juice extracted from a 300-g blanched carrot sample using a laboratory food processor (Singer, New Delhi, India). After the extraction of the juice in the food processor, the carrot juice was passed through a muslin cloth and weighed.

Preparation of the Enzyme Extracts

Preliminary experiments were performed to determine the guaiacol concentration to be used in the substrate solution for optimal reproducibility. The ratio of the mass of the carrot extract and the extracting buffer volume (gram sample : milliliter buffer) was also standardized to achieve linearity between the enzyme concentration and observed activity. The carrot slices (40 g) were homogenized with 100 mL buffer in a laboratory blender at 4C for 30 s at 18,000 rpm. The suspensions were filtered using two layers of linen cloth to remove solid particles. To eliminate the remaining turbidity, the extract was then centrifuged in a cooling centrifuge (model C-24, Remi, Mumbai, India) at 4C, 13,000 rpm for 20 min using polypropylene tubes. The supernatants were then filtered and kept on ice until analyzed.

Thermal Inactivation of POD

Heat inactivation experiments of the enzyme extract were conducted following the capillary tube method as described by Haas *et al.* (1996). Capillary tubes of 2.5-mm internal diameter and 7-cm length were filled with the fresh carrot enzyme extract and immersed in a water bath (Macro Scientific Works), maintained at the desired temperature ($\pm$0.5C). Heat inactivation was studied at temperatures ranging from 80 to 100C, while the treatment times varied between 5 s and 4 min. The time of heat treatment for enzyme inactivation was determined from the qualitative test of POD inactivation. After the preset time, the samples were removed from the water bath and kept in ice to stop the thermal inactivation instantaneously. The experiments on the thermal processing of the carrot enzyme extract were done in duplicate.

Determination of POD Activity

POD was analyzed according to the method of Blancas *et al.* (2002). The POD substrate solution was prepared daily by mixing 0.1 mL guaiacol, 0.1 mL hydrogen peroxide (30%) and 99.8 mL potassium phosphate buffer (0.1 mol/L, pH 6.5). The substrate was mixed well by shaking vigorously for a few minutes. The POD assays were conducted by pipetting 0.12 mL of enzyme extract and 3.48 mL of substrate solution in the quartz cuvette, and mixing these with a capillary glass rod. The POD activity was measured from the increase in absorbance at 470 nm using the time course mode of a spectrophotometer (UVPC 2401, Shimadzu Co.). The reaction was monitored for 20 min. An average of two replicates was considered for the final analysis.

Enzyme activity was determined from a change in absorbance per minute under the assay conditions at 25C. To calculate the change in absorbance with time (ΔAbs./min) using linear regression, only the linear part of the absorption curve was taken into account

$$Enzyme\ activity\ (\%) = \frac{s}{s_o} \times 100 \tag{1}$$

where s and s_o are ΔAbs./min after heat treatment for time (t) and native enzyme, respectively. Data on the residual POD activity in carrot enzyme extract with respect to thermal processing time at different temperatures were fitted to selected models using nonlinear regression by Statistica software (Statsoft, Inc., ver. 5, 1995, Tulsa, OK).

Kinetics Analysis for Enzyme Inactivation

First-order kinetics has been reported to describe the thermal inactivation of enzymes in general (Seyderhelm *et al.* 1996; Ludikhuyze *et al.* 1997)

$$\ln \frac{A}{A_o} = -k \times t \tag{2}$$

where A represents the enzyme activity at time (t) in minutes, A_o is the initial enzyme activity at zero time and k is the reaction rate constant at a given temperature (1/min), respectively.

Weemaes *et al.* (1998) suggested that the enzyme activity loss could be described by the summation of two exponential decays, one for the hypothesized heat-labile enzyme and the other for the hypothesized heat-stable enzyme (Eq. 3):

$$\frac{A}{A_o} = A_L \exp(-k_L t) + A_R \exp(-k_R t) \tag{3}$$

This model is referred to as the distinct isozymes model in literature (Ling and Lund 1978). A_L and A_R are residual enzyme activity for heat-labile and stable fractions, respectively. Coefficients k_L and k_R are the first-order reaction rate constants for heat-labile and heat-resistant fractions, respectively.

The series-type model (Henley and Sadana 1985) is based on a succession of two irreversible first-order steps, that is, an irreversible conversion of the native enzyme (E) to an intermediate (E_I) with lower specific activity and the subsequent irreversible conversion of the intermediate to an inactive enzyme form (E_D):

$$E \xrightarrow{k_1} \overset{\alpha_1}{E_I} \xrightarrow{k_2} \overset{\alpha_2}{E_D} \tag{4}$$

The activity decay is therefore described by Eq. (5)

$$\frac{A}{A_o} = \alpha_2 + \left[1 + \frac{\alpha_1 k_1}{k_2 - k_1} - \frac{\alpha_2 k_2}{k_2 - k_1}\right] \exp(-k_1 \times t) - \left[\frac{\alpha_1 k_1}{k_2 - k_1} - \frac{\alpha_2 k_1}{k_2 - k_1}\right] \exp(-k_2 \times t) \tag{5}$$

where k_1 and k_2 are the first-order inactivation rate coefficients; E, E_1 and E_2 are the specific activities; and α_1 and α_2 are the ratio of specific activities E_1/E and E_2/E, respectively.

Some researchers have applied the nth-order decay (Eq. 6) and the fractional conversion model (Eq. 7) to describe the thermal inactivation of the enzymes (Lourencüo *et al.* 1990; Robert *et al.* 1995; Weemaes *et al.* 1998). Fractional conversion refers to a first-order inactivation process and takes into account the nonzero enzyme activity upon prolonged heating because of the presence of an extremely heat-resistant enzyme fraction:

$$\frac{A}{A_o} = \left\{A_o^{1-n} + (n-1)kt\right\}^{1/(1-n)} \tag{6}$$

$$\frac{A}{A_o} = A_r + (A_o - A_r)\exp(-kt) \tag{7}$$

A_r is the enzyme activity for the resistant fraction and n is the order of the reaction.

The mathematical characteristics of enzyme populations during heat inactivation can be adequately described by continuous functions. It was

therefore decided to test the Weibull distribution pattern (Weibull 1951) for its applicability to the experimental data as suggested by Peleg (2003) and Corradini and Peleg (2004). Equation (8) represents the cumulative form of the Weibull distribution.

$$s = s_o \exp\left(-bt^n\right) \tag{8}$$

Weibull distribution is characterized by two parameters: b and n. The value of n determines the shape of the distribution curve, while b determines its scaling. Consequently, b and n are called the scale and shape factors, respectively.

Statistical and physical criteria were considered to discriminate among the enzyme inactivation models tested (Ladero *et al.* 2006). Statistical criteria include the coefficient of determination (R^2), SE and residual plots. In general, low R^2, high SE values and clear patterns of the residual plots infer that the model is not able to explain the variation in the experimental data. The physical criterion for the selection of a model includes that the parameters estimated at a given temperature should not be negative.

RESULTS AND DISCUSSION

Optimization of the Blanching Process

Effect of Different Blanching Treatments on the Inactivation of Catalase and POD. Steam blanching resulted in nonuniformity of the enzyme inactivation, and the inactivation time of catalase and POD during steam blanching were consistently higher than that of hot water, acetic acid or calcium chloride solution blanching. Therefore, steam blanching of carrots was not investigated further and the quality loss parameters (β-carotene, vitamin C loss) during steam blanching were not measured. The inactivation time of catalase and POD in hot water, 0.05 N acetic acid and 0.2% calcium chloride solution at selected temperatures are shown in Figs. 1–3. It was observed that the inactivation time for POD was, in general, higher than catalase irrespective of the type of blanching treatment used. Therefore, POD was considered as an index of blanching for carrots. The inactivation time of POD in water blanching was 7 min at 80–90C, 5 min at 95C and 4 min at 100C, respectively. Kidmose and Martens (1999) reported that POD inactivation occurs in 4 min at 90C during hot water blanching treatment. The blanching experiments of carrots were subsequently done according to the time of the inactivation of the POD enzyme in water, acetic acid or calcium chloride.

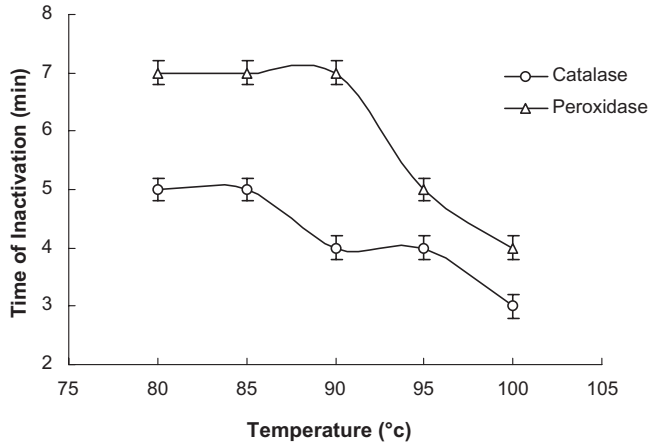

FIG. 1. TIME OF INACTIVATION OF PEROXIDASE AND CATALASE FOR BLANCHING OF CARROTS IN HOT WATER

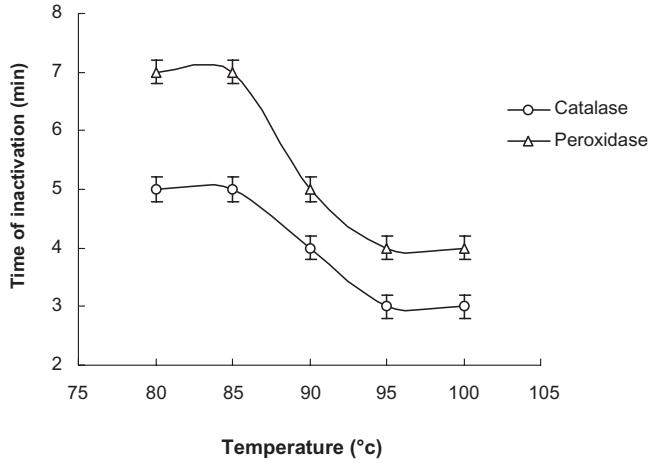

FIG. 2. TIME OF INACTIVATION OF PEROXIDASE AND CATALASE FOR BLANCHING CARROTS IN 0.05 N ACETIC ACID SOLUTION

Effect of Blanching Treatments on β-Carotene Content. Variation in the β-carotene content of carrot slices at different blanching treatments is shown in Fig. 4. It may be inferred that the β-carotene concentration was maximum at 95C during blanching in water and acetic acid. It was also found that β-carotene retention was maximum at 80C during blanching in calcium

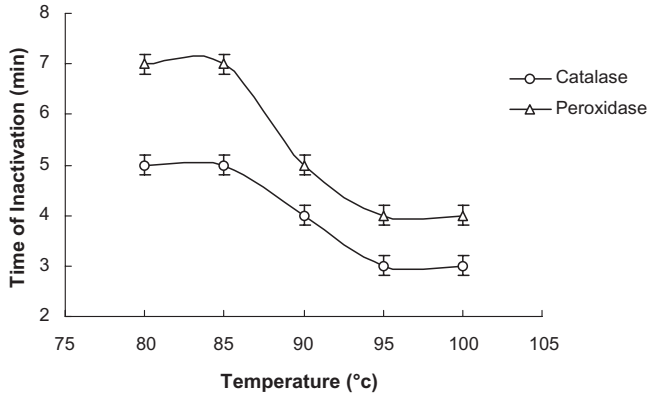

FIG. 3. TIME OF INACTIVATION OF PEROXIDASE AND CATALASE FOR BLANCHING OF CARROTS IN 0.2% CALCIUM CHLORIDE SOLUTION

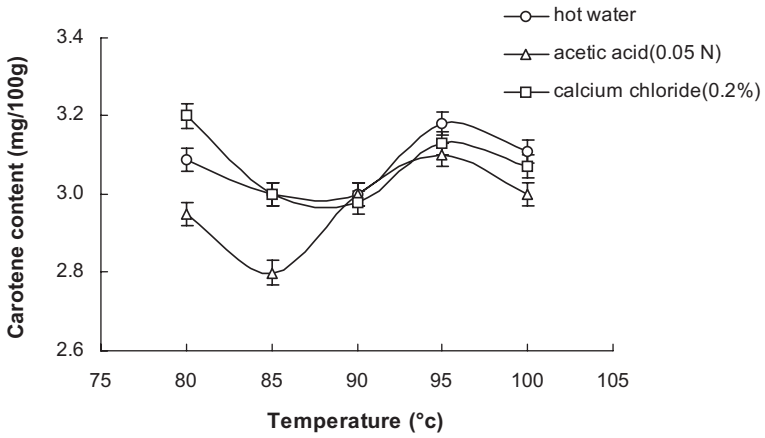

FIG. 4. EFFECT OF BLANCHING ON β-CAROTENE CONTENT OF CARROTS

chloride solution. β-Carotene retention in carrot slices showed a systematic trend with temperature of processing in all three blanching conditions.

Effect of Blanching Treatments on Vitamin C Content. Variation of vitamin C present in the extract after blanching of the carrot at selected temperatures is shown in Fig. 5. Vitamin C content was maximum in 0.05 N acetic acid solution blanching treatment at 90–95C for 5 min followed by water blanching. Though vitamin C retention was found to be maximum in the case of 0.05 N acetic acid solution, the yield of carrot juice and the β-carotene

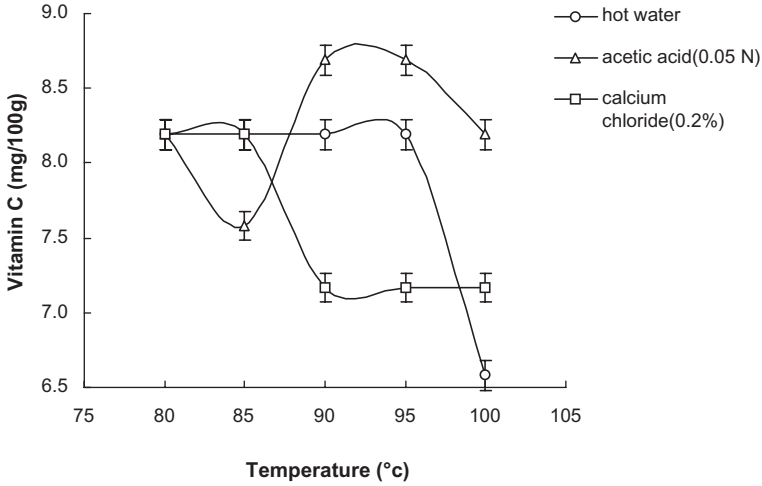

FIG. 5. EFFECT OF BLANCHING ON VITAMIN C CONTENT OF CARROTS

retention were maximum in the case of water blanching at 95C for 5 min. Therefore, among the three different blanching treatments, blanching in water (95C for 5 min) was inferred to be better and selected for enzyme inactivation studies.

Effect of Blanching Treatments on the Yield of Carrot Juice. The yield of unblanched carrot juice was 59%, and it decreased after the blanching treatment because the texture of whole carrots became soft, thus making juice extraction difficult, and because of the leaching loss during the blanching process (Bao and Chang 1994). The yield of carrot juice was found to be maximum, i.e., 55% in water blanching at 95C for 5 min (Fig. 6).

Enzyme Inactivation Kinetics in Carrot Extract

The first-order inactivation kinetics model was tested for its applicability to thermal inactivation data for carrot extract. Linear regression of Eq. (2) was carried out using the least squares technique and the coefficients were determined (Tables 1 and 2). Though it yielded good R^2 (>0.88) and low SE values at all temperatures, the residual plot showed a patterned behavior (Eq. 2, Table 1). Consequently, the distinct isozyme model (Weemaes *et al.* 1998), based on the presence of two isoenzyme populations inactivated by the first-order mechanism, was tested. Although this model showed a high R^2, low SE

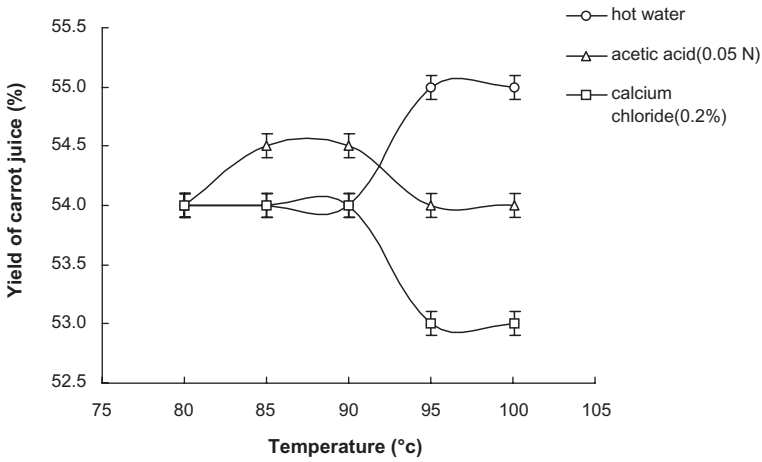

FIG. 6. YIELD OF CARROT JUICE AT DIFFERENT PROCESSING TEMPERATURES AND BLANCHING CONDITIONS (HOT WATER, ACETIC ACID AND CALCIUM CHLORIDE BLANCHING SOLUTION)

TABLE 1.
SUMMARY OF THE PERFORMANCE OF THE SELECTED MODELS TO DESCRIBE THE INACTIVATION OF PEROXIDASE

Equation no.	Model	R^2	SE	Residuals	Remarks
2	First order	0.886–0.994	0.062–0.717	Patterned	Rejected
3	Distinct isozymes	0.916–0.990	0.008–0.057	Random	Equal parameter estimates $A_L = A_S$; $k_L = k_R$; rejected
5	Series	0.981–0.995	0.004–0.018	Random	Negative parameter estimates; rejected
6	nth order	0.373–0.999	0.010–1.827	Patterned	Poor fit; rejected
7	Fractional conversion	0.917–0.985	0.012–0.056	Patterned	Negative parameter estimates; rejected
8	Weibull distribution	0.976–0.992	0.006–0.018	Random	Accepted

R^2, coefficient of determination.

values and random residual pattern at all the temperatures, the model gave equal values for parameters k_1 and k_2 (Eq. 3, Table 3), which nullifies the presence of isoenzymes. Therefore, both first-order and distinct isozyme models were rejected for fitting of the enzyme activity with the time of thermal processing.

TABLE 2.
COMPUTED VALUES OF KINETIC PARAMETERS FOR THE FIRST-ORDER MODEL (EQ. 2) OF PEROXIDASE INACTIVATION

Temperature (C)	k	R^2	SE
80	0.683	0.994	0.062
85	0.857	0.919	0.256
90	3.133	0.886	0.717
95	1.881	0.981	0.165
100	2.547	0.957	0.285

k, reaction rate constant at a given temperature; R^2, coefficient of determination.

TABLE 3.
COMPUTED VALUES OF KINETIC PARAMETERS FOR THE DISTINCT MODEL (EQ. 3) OF PEROXIDASE INACTIVATION

Temperature (C)	A_L	k_L	A_R	k_R	R^2	SE
80	0.478	0.684	0.478	0.684	0.990	0.008
85	0.515	0.684	0.515	0.684	0.975	0.015
90	0.433	2.268	0.433	2.268	0.916	0.015
95	0.515	1.719	0.515	1.719	0.982	0.016
100	0.480	3.202	0.480	3.202	0.982	0.015

A_L, residual enzyme activity for the heat-labile fraction; k_L, first-order reaction rate constant for the heat-labile fraction; A_R, residual enzyme activity for the stable fraction; k_R, first-order reaction rate constant for the heat-resistant fraction; R^2, coefficient of determination.

TABLE 4.
COMPUTED VALUES OF THE KINETIC PARAMETERS OF THE SERIES MODEL (EQ. 5) OF PEROXIDASE INACTIVATION

Temperature (C)	α_1	α_2	k_1	k_2	R^2	SE
80	–1.687	–0.032	0.576	10.442	0.995	0.004
85	0.230	0.289	0.815	–0.773	0.984	0.015
90	–6.944	–0.066	1.085	19.629	0.987	0.008
95	–27.967	–0.870	0.057	1.770	0.981	0.018
100	–1.221	–0.006	2.114	9.199	0.993	0.006

α_1, ratio of specific activity (E_1/E); α_2, ratio of specific activity (E_2/E); k_1 and k_2, first-order inactivation rate coefficients; R^2, coefficient of determination.

The series model (Eq. 5, Table 4) and the fractional conversion model (Eq. 7, Table 5) were not found to satisfy the physical criteria because of the negative parameter estimates. The general nth order (Eq. 6) was consequently considered. A poor fit of the data with the model equation and the highly

TABLE 5.
COMPUTED VALUES OF THE KINETIC PARAMETERS FOR THE FRACTIONAL CONVERSION MODEL (EQ. 7) OF PEROXIDASE INACTIVATION

Temperature (C)	A_r	k	R^2	SE
80	0.053	0.836	0.984	0.012
85	–0.273	0.441	0.981	0.017
90	0.134	4.056	0.917	0.056
95	–0.020	1.585	0.980	0.018
100	0.046	3.754	0.985	0.013

A_r, enzyme activity for the resistant fraction; k, reaction rate constant at a given temperature; R^2, coefficient of determination.

TABLE 6.
COMPUTED VALUES OF THE KINETIC PARAMETERS FOR THE nTH-ORDER MODEL (EQ. 6) OF PEROXIDASE INACTIVATION

Temperature (C)	n	k	R^2	SE
80	1.290	0.856	0.999	0.010
85	0.631	0.546	0.979	0.019
90	–0.114	0.449	–	1.442
95	–0.049	0.477	0.373	0.576
100	–0.111	0.450	–	1.828

n, order of the reaction; k, reaction rate constant at a given temperature R^2, coefficient of determination.

patterned behavior of the residual plots led to the rejection of this model (Table 6). It may therefore be inferred that none of the models based on the preconceived mechanism could adequately explain the thermal inactivation pattern.

The Weibull function (Eq. 8) was then considered for the estimation of POD inactivation parameters. Statistical (low SE, high R^2), physical (nonnegative parameter estimates) and random residual pattern indicated that the Weibull distribution model is the best model to describe the kinetics of POD inactivation of carrot extract (Table 7). The values of the scale factor (b) ranged from 0.641 to 2.669, while the shape factor (n) varied from 0.568 to 1.117 for the entire temperature range. The POD activity curves fitted with the Weibull distribution function at the temperature range of 80–100C are shown in Fig. 7. A representative residual pattern of POD activity at 80C as depicted by the Weibull distribution function is shown in Fig. 8. The parity between the experimental data and the activity predicted by the Weibull distribution is shown in Fig. 9. The broken lines in Fig. 9 represent the ±5% confidence

TABLE 7.
COMPUTED COEFFICIENTS OF THE WEIBULL DISTRIBUTION FUNCTION (EQ. 8) FOR PEROXIDASE INACTIVATION

Temperature (C)	*b*	*n*	R^2	SE
80	0.739	0.855	0.992	0.006
85	0.641	1.117	0.976	0.022
90	1.802	0.568	0.981	0.013
95	1.695	1.043	0.981	0.178
100	2.669	0.804	0.991	0.007

b, scale factor; *n*, shape factor; R^2, coefficient of determination.

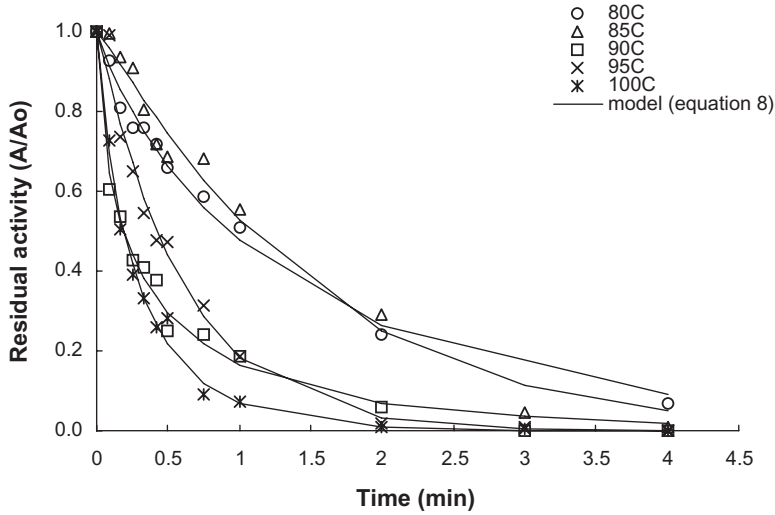

FIG. 7. THE ACTIVITY CURVE OF PEROXIDASE IN CARROT EXTRACT FITTED WITH THE WEIBULL DISTRIBUTION AT 80–100C
A, enzyme activity at time (*t*) min; A_o, initial enzyme activity at zero time.

interval of the experimental and predicted values. It can be seen that all the data lie within the 5% confidence interval.

CONCLUSION

Blanching is extremely important for further processing of carrots and to improve the product quality and shelf life. In this study, various blanching

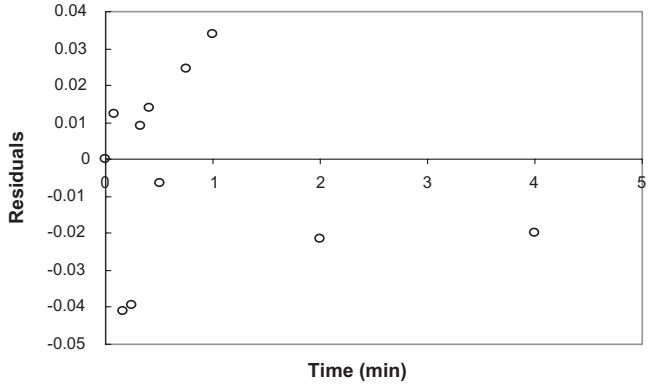

FIG. 8. RESIDUAL DISTRIBUTION PLOT OF PEROXIDASE ACTIVITY AT 80C BASED ON THE WEIBULL DISTRIBUTION FUNCTION

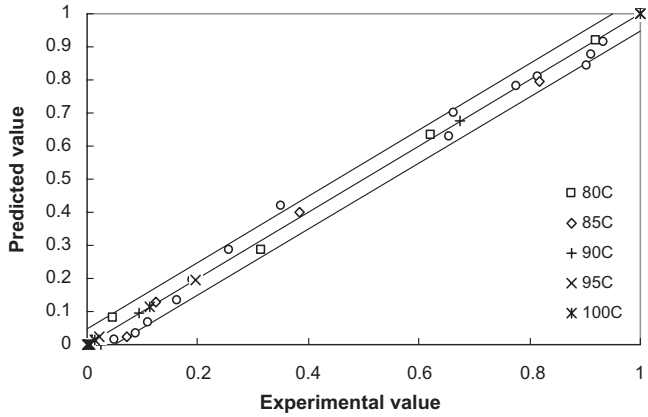

FIG. 9. PARITY BETWEEN EXPERIMENTAL DATA AND PREDICTED (USING EQ. 8) VALUES

treatments were considered based on the inactivation time of POD and catalase and the process was optimized on the basis of the maximum yield of carrot juice and minimum loss of vitamin C and β-carotene. The best blanching treatment for carrots based on these process parameters was 95C for 5 min in water. At this time–temperature combination, both POD and catalase enzyme were inactivated and 8.192 mg/100 g vitamin C, 55% yield of carrot juice and 3.18 mg/100 g β-carotene content were observed. The Weibull distribution model provided a good description of the kinetics of inactivation of POD in

carrot extract in the experimental range of temperatures and, therefore, was inferred to be appropriate for predictive modeling purposes. The Weibull function can therefore be recommended to describe the heat inactivation kinetics of POD, provided it satisfies the statistical and physical criteria.

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