KINETIC MODELLING OF VITAMIN C AND COLOUR LOSS OF KIWIFRUIT PULP AT PASTEURIZATION TEMPERATURE AND STORAGE CONDITION

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Abstract

The effect of pasteurisation treatment on the degradation kinetics of vitamin C and the colour of kiwifruit pulp was evaluated at 60 ºC, 70 ºC and 80 ºC of pasteurization temperature for 10 minute. The processed samples were stored at 25 ºC. The degradation kinetics of vitamin C in kiwi fruit pulp was noticed at 25 ºC. The loss of vitamin C was dependent on time and temperature, which was carried out by the Arrhenius equation and activation energy. For regulating the magnitude of the parameters in agreement with the change in colour of the model, the colour change of kiwi fruit pulp was observed at 25 ºC storage temperature. The Physicochemical properties were assessed by the kiwi fruit pulp pasteurised at various temperatures and stored at 25ºC for 15 days. From the experiment, it was concluded that the rate of vitamin C loss was affected by the high temperature of pasteurisation.

Keywords: Ascorbic acid; Arrhenius plot; Colour change, Browning index; Activation energy.

1. INTRODUCTION

S Kiwifruit (Actinidiadeliciosa) is a temperate fruit which came to be known in 1950, but at present, it is cultivated around the whole world. The high level of vitamin C makes it a highly nutritious fruit which is antioxidant and citrus is a good source of ascorbic acid. The kiwifruit is egg-shaped with the inner part green beaded with black seed and covered with brown skin containing short, stiff hairs. It contains ascorbic acid in high amounts in comparison to oranges, strawberries, lemons and grapefruits.

It is also found that consuming kiwifruit has been serving as a preventive measure for illnesses related to cardiovascular and cancer. Different types of cancer such as stomach, lung and liver, are treated by kiwifruit prescriptions owing to its cytotoxic and antioxidant activities [3]. Esti et al. (1998) investigated that the presence of ascorbic acid in kiwifruit depends on genotype, ripening degree, storage and the method of analysis used [7]. Imeh and Khokhar (2002) suggested the task of pre- and post-harvest factors according to the chemical composition of food obtain from the plant where the maturity stage was noticed to be the significant factor for enhancing the quality of fruits and vegetables related to composition [4]. Various biochemical, physiological and structural modifications occur during maturity stages where alteration investigates the final quality at the time of ripening. The storage condition is responsible for influencing the quality indices and nutritional content of fresh fruit [8,9]. Tavarini et al. (2008) also stated that harvest time and storage could affect the qualitative and nutritional features of kiwifruit [10].

The human eye perceives colour, which is the penetration of wavelength reflecting from a surface object lying on the retina [11]. As the light is focused on the object, it reflects, absorbs and then gets transmitted and the reflected light is responsible for regulating the colour of the object. Hence, there are various factors on which the colour formation of an object depends such as light and its various features namely the amount of source, angle of view, size of object and its background from where the observers are noticing it [12]. Particular instrumentation is present for the colour measurement of food colour correlating with the district evaluation where various colour scales are used to give detailed information on colour in food. The food processing industry faces a challenge such as the stability of colour at the time of processing and storage of food. The loss of nutrients concerning temperature is an essential task in the research field of food technology.

The heat treatment shows degradation in pigments where the storage is responsible for the change in green colour with time and temperature. Non-enzymatic browning is the most significant reason for deterioration while heating as it is deployed through the thermal process. Hence, the period of storage at the respective temperature in the absence of decline is established through kinetic modelling of kiwi fruit pulp by estimating the rate and temperature of the material. Kidmose and Hansen

(1999) suggested the interdependence of change in colour of cooked and stored broccoli and instrumental analysis respectively [13]. Thus, the main objective of the research is to study the kinetic for ascorbic acid degradation along with the kinetic of the colour change of kiwifruit pulp at pasteurisation temperatures of 60°C, 70°C, 80°C and storage temperatures at 25 °C.

2. MATERIALS AND METHODS

2.1 Materials

Since kiwifruit is imported in India, mature fruit was purchased from the local market of Nagpur and stored at 4 ± 0.5 ºC before the initial analysis. Initial total suspended solids (TSS), acidity, ascorbic acid colour and pH were evaluated of the kiwifruit. All the chemicals and reagents of analytical grade.

2.2 Preparation of Kiwifruit Pulp

Approximately 8 pieces of fruit were blanched for 5 to 6 minutes to make it soft and also for delaying enzymatic reactions leading to an undesired change in colour during the time of storage. It was then submerged in cold water for getting rid of excess heat loss of ascorbic acid and colour. Further, the pulp was made with the help of a masher, and around 15 gm of it was packed in food laminates. Generally, 45 sachets were prepared for experimentation. Here, the laminates as used as it absorbs moisture and acts as a gas barrier as well.

2.3 Pasteurisation treatments

The stability of ascorbic acid at various temperature ranges was firmly established. Here all the sachets of kiwifruit pulp were inserted in the screw-capped test tube which was heated in a thermostatically controlled water bath set at an accuracy of ± 2 ºC at 60 ºC, 70 ºC and 80ºC for 10 minutes. Later on, it was stored at 25 ºC temperature in an incubator. The samples were taken for analysis to carry out a study of the effect of temperature on colour and ascorbic acid degradation for a continuous 15 days.

2.4 Ascorbic acid determination

The ascorbic acid determination was carried out through 2 -6- Dicholoro-phenol Indophenol dye reagent as per the method illustrated by Ruck [14]. The standard of dye was maintained by taking one gram of ascorbic acid, revealing one ml of the dye. Approximately 20 ml of metaphosphoricacetic-acid was blended with 5 ml of sample for 2 minutes and later on filtered with the help of a filter cloth. 50 ml of filtrate was prepared with 0.4% metaphosphoric acetic-acid solution. Ascorbic acid was titrated in 10 ml filtrate against the standard 2-6-Dichlorophenol Indophenol. The results of the experiment are shown in Table 1.

2.5 Kinetic modelling for Ascorbic acid degradation

Ascorbic acid degradation is explained through the reaction rate and the influence of temperature on the reaction rate. The two kinetic parameters were used to describe the ascorbic acid loss such as the reaction rate constant (k) and the Arrhenius activation energy (Ea) which were analysed as suggested by Boekel [15]. To attain the reaction rate constant, the first-order degradation was supposed as the following:

$$\frac{-dC}{dT} = KC \qquad (1)$$

Where C is the instantaneous concentration of ascorbic acid, t is time and k is the reaction rate constant (time-1). On separating variables, the integration of Eq.(1) is as followed:

$$C = C_0 \exp(-Kt) \qquad (2)$$

Taking log on both sides, the linear equation is formed as given below:

$$\ln \frac{C}{C_0} = -Kt \qquad (3)$$

A plot of "ln C/C0" versus process time "t" is a straight line, as shown in Fig. 1 & 2 for the first-order reaction. The slope represents the rate constant with their respective correlation coefficients (R2) listed in Table 1. Arrhenius activation energy equation was employed for determining the ascorbic acid degradation on influencing the temperature

$$K = K_0 \exp(E_a / RT) \qquad (4)$$

where K0 is frequency factor or pre-exponential constant; Ea (kJ/mol) is the activation energy of the reaction; T is the absolute temperature of the medium, and R is the universal gas constant (8.314kJ/mol.K). Taking log on both sides, the linear equation is formed which is given below:

$$\ln K = \ln K_0 - E_a / RT \qquad (5)$$

The ascorbic acid and pre-exponential constant are referred to base onEa. and K0 in eq. 4 & 5, so they are an essential parameter for the reactions and the values were calculated from the plots of lnK versus 1/T.

2.6 Modeling for Colour Degradation

The Colour of the sample was evaluated as different parameters such as L (whiteness/darkness), a (redness/greenness) and b (yellowness/blueness). Estimated values were employed for figuring out the different parameters such as total colour change (ΔE), Chroma, hue angle and Browning Index. The three various values L, aand b were used for explaining the placement of Colour inside a 3D visible Colour space. The L value is represented a slight–dark spectrum ranging from 0 (black) to 100 (white), as the green–a red spectrum ranging from -60 (green) to +60 (red) and b as the blue-yellow spectrum ranging from -60 (blue) to +60 (yellow) dimensions.

2.7 Titrable Acidity

Acidity in terms of citric acid was determined using the titrimetric method (Ough, Amerine, & Sparks, 1969). Titratable acidity was measured by titration against 0.1 N sodium hydroxide solution and using a 1% ethanol solution of phenolphthalein as an indicator.

2.8 Statistical Analysis

Each sample was thrice analysed, and the average of it was considered. To get the kinetic parameter of the sample of kiwifruit pulp, linear regression was employed. The kinetic rate constant was estimated where the value of correlation coefficient (R2) was used for selecting reading for calculating the parameter of the model at respective pasteurization temperature.

3. RESULTS AND DISCUSSION

3.1. Change in vitamin C content in thermal processing

Table 1represents the change in Vitamin C content in thermal processing at pasteurization for 15 days from the initial concentration of ascorbic acid 42.71. It is clear from the data that ascorbic acid content decreases with an increase in pasteurization temperature. The initial ascorbic acid content of Kiwifruit was 42.71 mg/100gm during the period of storage. The ascorbic acid content of the fruit ranges between 25 to 155 mg/100gm of fresh-weight of fruit [16]. The non-homogeneity of nutrients was dependent on various factors such as cultivation, climatic conditions and maturity [17]. Tavariniet.al (2008) suggested that there was no change in the content of ascorbic acid of Kiwifruit harvested at 10º brix by the end of a long time storage period as well [18]. Lee and Kader (2000) suggested that ascorbic acid content is increased in the ripening of apricot, peach & papaya whereas it decreases in apples& mango [19].

After complete 15 days of storage, the ascorbic acid content of Kiwifruit pulp was decreased to 3.2 mg/100 gm at 25 ºC temperature. This indicates that ascorbic acid content decreases during thermal processing. At 80 ºC, the loss of ascorbic acid was highest from the initial day to the complete storage day when compared to the loss at 70 ºC. Approximately 90 to 95% of vitamin C loss was found due to thermal processing at 25 ºC storage.

Table 01 Vitamin C Content (mg/100g) (Amount of dye required) 2-6 dichloroendophenol solution for 25 °C storage

	Fresh 0 Day	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	7 Day		8 Day	9 Day	10 Day	11 Day	12 Day	13 Day	14 Day	15 Day
	60°C Pasteurization Temperature																
Vitamin C	42.71±0.04	25±0.01	20 ±0.03	16.9 ±0.03	13.75 ±0.01	10.59 ±0.01	9.46 ±0.01	8.99 ±0.01		7.99 ±0.01	5 ±0.01	4.7 ±0.01	3.72 ±0.01	3.24 ±0.01	3.24 ±0.01	3.24 ±0.01	3.2 ±0.01
	70°C Pasteurization Temperature																
Vitamin C	42.71±0.04	23.84 ±0.01	19.25 ±0.01	15.78 ±0.01	12.23 ±0.01	9.5 ±0.01	7.15 ±0.01	6.43 ±0.01		5.12 ±0.01	4.62 ±0.01	3.96 ±0.01	3.69 ±0.01	3.5 ±0.01	3.39 ±0.01	3.4 ±0.01	3.2 ±0.01
	80°C Pasteurization Temperature																
Vitamin C	42.71 ±0.04	20 ±0.02	16.68 ±0.01	13.78 ±0.01	11.48 ±0.01	9.64 ±0.01	7.51 ±0.05	6.6 ±0.01		5.46 ±0.01	4.25 ±0.01	4.05 ±0.01	3.75 ±0.01	3.99 ±0.01	3.44 ±0.01	3.1 ±0.01	2.25 ±0.05

3.2 Kinetic study of vitamin C loss in Kiwifruit pulp

To evaluate the reaction rate constant a first-ordered degradation of ascorbic acid is taken into account. The value of ascorbic acid on the first day of the experiment was 42.7 ºC with the concentration of ascorbic acid in 10 g in Kiwifruit. The concentration of ascorbic acid was represented through first-order reaction as shown in eq. (3) with help of plot ln (C/C0) versus time 't' in Figure 1.

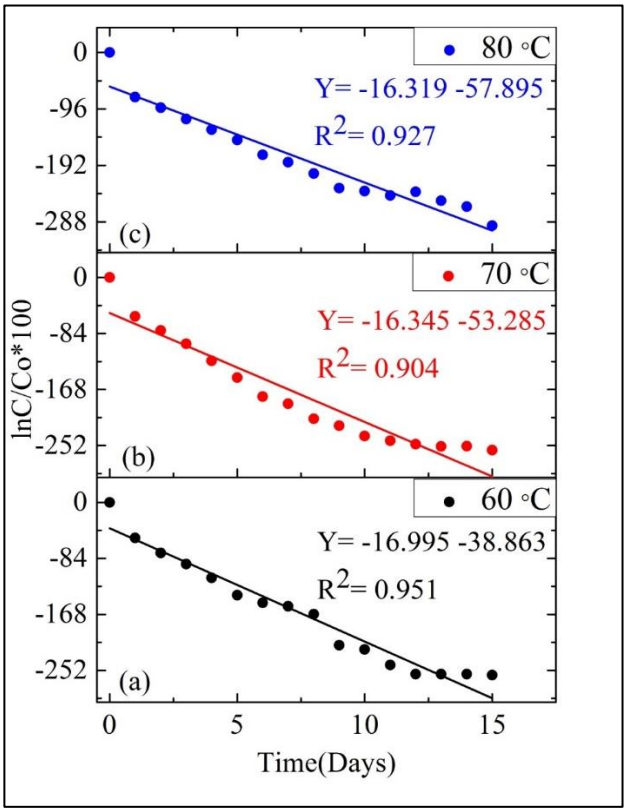

Figure 1: Comparison of experimental and predicted results of Vitamin C loss of Kiwifruit pulp at various temperatures

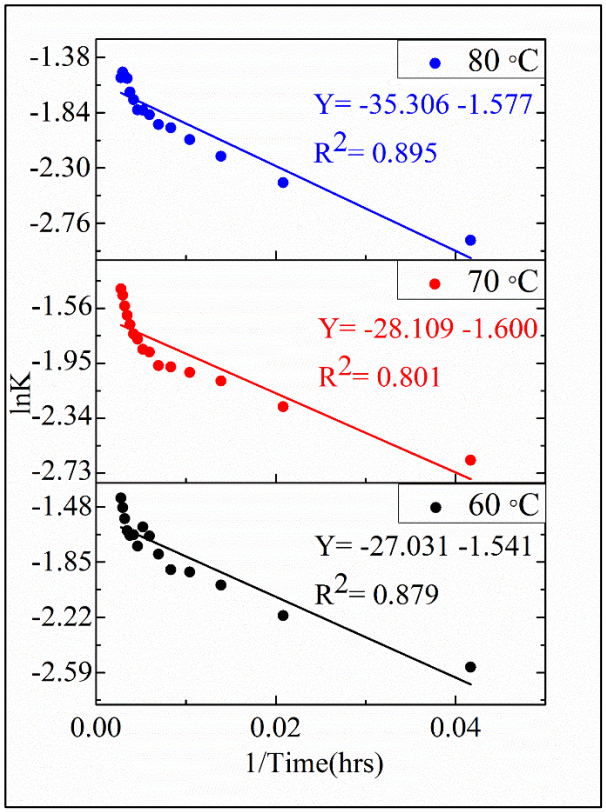

Figure 2: Experimental kinetics and predicted results of vitamin C loss of kiwifruit pulp at various temperatures

At all the temperature range, after the process of thermal treatment processing and subsequent storage, the Kiwifruit pulp show first-order kinetics for loss of vitamin C as shown in Figure 2. The graph all present a high value of correlation coefficient (R2= 0.879, R2=0.801, R2=0.895) at a different range of temperature as the regression analysis indicatesfirst-order reaction kinetics for Kiwifruit pulp. The results are in corresponding with other studies as well, where the dependency of loss of vitamin C with respect to temperature is expressed by the Arrhenius plot and activation energy (Ea) with a 90% confidence range as R2= 0.895 at 80 ºC. Eq. (4) was employed for determining the ascorbic acid degradation under the influence of

temperature. At varying pasteurization temperatures, under the storage condition, the rate constant (K) increases from -2.902 (ln K) to -1.5496(lnK) min -1 at 80 ºC.The value of rate constant "K" increase from 2.6386(lnK) to -1.4221(lnK)min-1 at 70 ℃ and for 60℃ from -2.5536(lnK) to -1.422(lnK) min -1for ascorbic acid degradation processing temperature. The above factors indicate the thermal degradation of Vitamin C at thermal processes namely blanching, pasteurization, sterilization and storage temperature.

At the harvesting stage, titrable acidity (TA) content was decreased due to a delay in harvest from the standard maturity stage (6.5-7 °Brix). The lowest value of fruit harvest was noticed at 8 °Brix and TA rapidly decreased when the storage was done. In the present study, the lower value of TA after storage was mainly accompanied by a decrease in acidity. The TA was said to be associated with a high TSS, but it was not as significant as TSS.

The TSS/TA of kiwifruits were influenced by the harvesting stages and the interaction between two variables. Dependent on harvesting stages, the storage for a long durationincreases the TSS/TA of kiwifruits. The values of TSS/T A vary in the early and later stages, as in the later stage the value was observed as 9 and 10 °Brix after a few days of storage. The hydrolytic change in starch and conversion of starch to pure sugar led to an increase in TSS content which was capable of ripening the fruits. The increase in the ratio of TSS/TA of fruit at the storage period corresponded to the rise in TSS and decrease in TA. Glycolytic enzymes lead to starch degradation and also converted starch to sucrose as well. Hence, with an increase in the activity of the glycolytic enzyme, the result obtained was the same throughout the study. But it was observed that TSS/TA was less during early harvest time in comparison to late harvest time.

3.3 Effect of pasteurisation temperature on colour kinetics of Kiwifruit at storage condition

The variation of pasteurisation temperature on colour change kinetics of Kiwifruit was pasteurized at 60 °C, 70 °C and 80 °C temperature for 10 min, then after stored at 25 °C storage temperature. The various parameters of L, a, b and total colour change (ΔE) were obtained from the experimental data and model data.

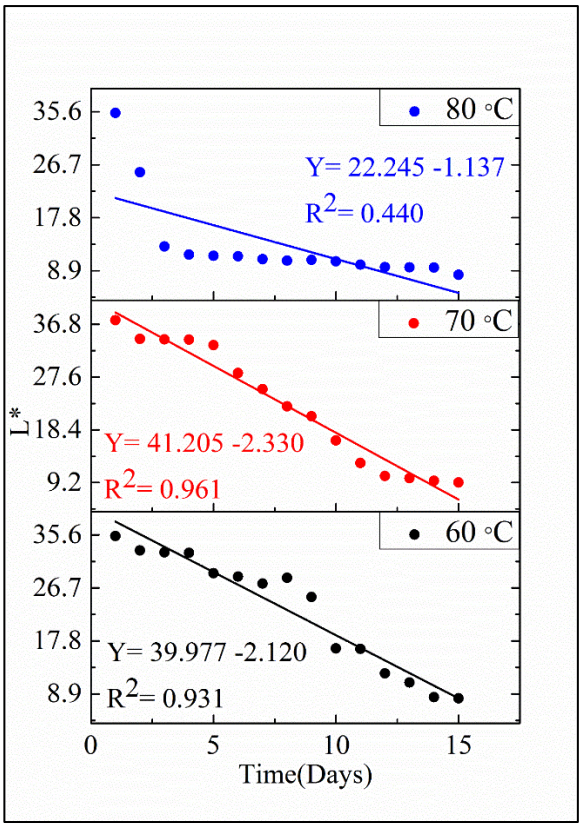

Figure 3: Experimental kinetics and predicted results of colour changes in l values of Kiwifruit pulp during storage at various temperatures

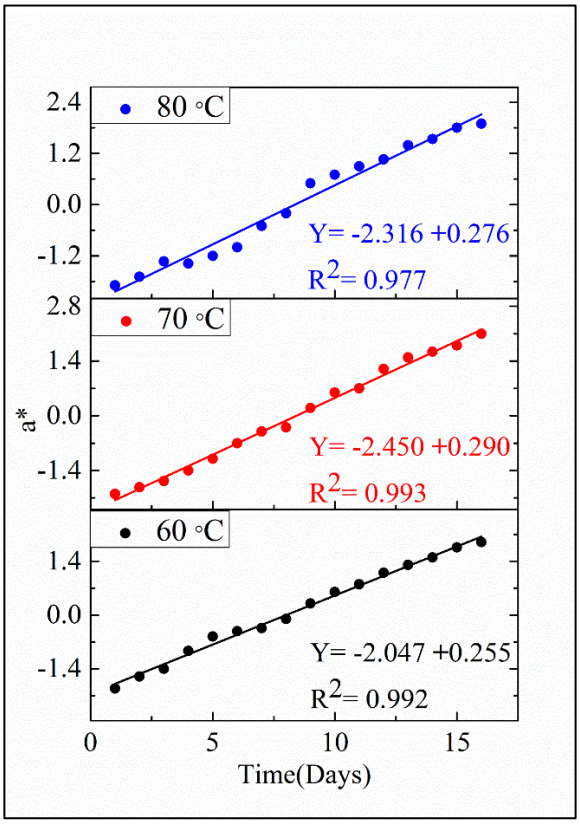

Figure 4: Experimental kinetics and predicted results of colour changes a* values of Kiwifruit pulp at various temperatures

On the redness/greenness scale, the initial negative value reflects greenness for the value of a*. Fig.4 shows the different values of a* noted for 15 days of storage scale due to the degradation of green pigment with thermal processing and storage parameters. Similarly, on the yellowness/blueness scale, there is a decrease in brightness and an increase in blueness with an increase in the value of b* which is mainly because of the decomposition of chlorophyll and carotenoid pigments [21], non-enzymatic Maillard browning and also by the formation of brown pigments [22].

It was noticed that the L* value of the colour change of Kiwifruit fitted well with the first-order kinetic model. Figure 3 and Figure 4 show the kinetic parameters of L,a,b and total colour change (ΔE) and coefficients of determination. The kinetics of rate constant for L* decreases from 35.6 to 8.3 min-1, a* valuefrom -1.85 to 2.21 min-1, b value from 8.12 to 15.22 min-1, and total colour change (ΔE) from 4.58to 0.71min-1 for 60 °C, Similarly L* values decreases from 36.8 to 9.22 min-1, a* valuefrom -1.85 to 2.21 min1 , b value from -3.09 to 0.91 min-1, and total colour change (ΔE) from 6.11 to 0.50 min-1 for 70 °C and for 80 °C, L* values decreases from 35.59 to 8.89 min-1, a* valuefrom -1.01 to 1.40 min-1, b value from 6.91 to 13.84 min-1, and total colour change (ΔE) from 12.50 to 0.40 min-1. This shows that with an increment in pasteurisation temperature, the degradation rate of colour turns out to be quicker as an after-effect pasteurisation of high vitality inside the sustenance material for a steady period. The outcomes acquired were in concurrence with the reviews distributed in writing and expressed by a few writers that the first-order kinetics was better for L*, a*, b* value, the value of double concentrated tomato paste [23], pineapple [24], and peach puree [25]. Eq. 6 and 7 were employed to estimate the value of Chroma, Hue angle and Browning Index. It was observed that non-enzymatic browning reaction with the increase in temperature and storage time.

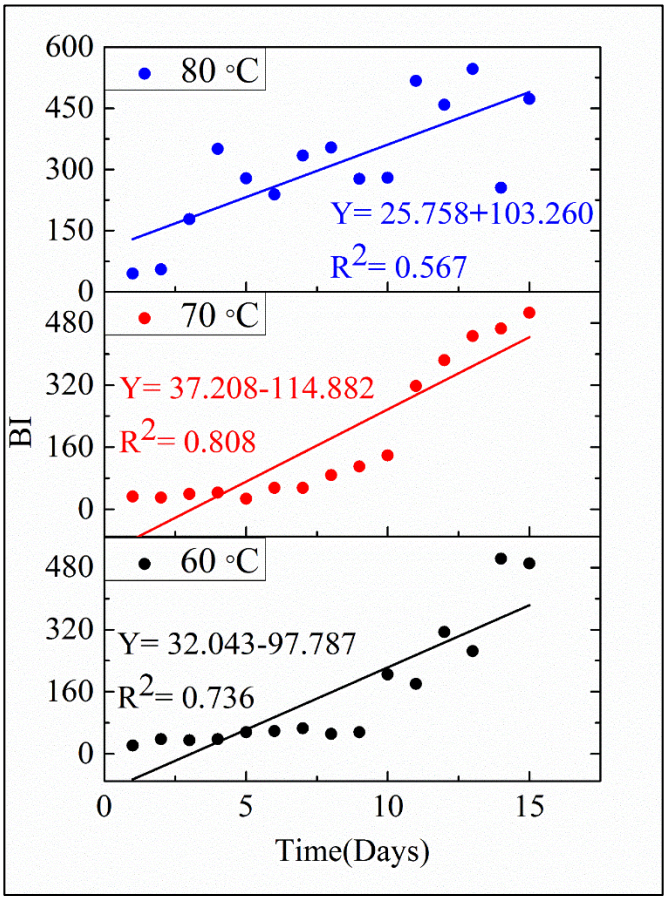

Figure 5: Comparison of experimental and predicted results of Browning of Kiwifruit pulp

The change in colour from green to red is due to the rise of BI value and decrease in the value of lightness as shown in Figure 5. The plot of lightness versus storage period exhibit first-order kinetic for 60°Cand 70 °C pasteurisation temperature with value of R2 as 0.736 and 0.808, but there was no particular kinetic model for non-enzymatic browning at 80 ºC.

The value of Chroma and hue angle decreases with temperature. The value of the hue angle corresponds to the red, orange, yellow, green, blue or violet region. The initial hue angle of Kiwifruit was 104.19º at 60 °C representing a colour dimension of green, and yellow region. On heating and storage, the hue angle decreases showing a shift towards a slightly reddish yellow region (83.723º, 60 °C). The process of heating shows influences on the colour profile of fruit with an increase in temperature. The Hue angle at 70 °C shifted from102.94º to 88.086º and at 80 °C, it shifted from 96.677 to 82.367º within the storage period. The kinetic study states that Chroma and Hue's angle does not follow first-order kinetics.

4. CONCLUSION

In the current study, the effect of different pasteurisation conditions at 25ºC (room temperature) storage temperature of kiwifruit pulp, the ascorbic acid degradation and colour changes are evaluated. The loss of ascorbic acid in kiwifruit pulp at storage temperatures and pasteurisation temperature states the dependence on the first-order kinetic model. Ascorbic acid decomposes quickly at the high temperature of pasteurisation that is at 80 ºC than that 60 °C and 70 °C. The highest ascorbic acid was noticed at 80 ºC for the Kiwifruit pulp. The parameters such as L, a, b and Chroma, hue angle for the colour change of Kiwifruit put was used to describe the real behaviour of pulp at various Pasteurization temperatures i.e. 60 ºC, 70 ºC and 80 ºC. At storage temperature, the value of L, a, b, □E, Chroma, and hue angle are enhanced. The BI value leads to more browning of a compound. This outcome was bolstered by the expansion in value. The first-order kinetic models were utilised to clarify the colour change kinetics and it was observed that L, a, Chroma and browning index were fitted to a first-order kinetic model. On the other hand, total colour change (ΔE) and hue angle values do not follow the first-order kinetic model.

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