Jurnal Natural
Vol. 23, (3) 2023
DOI 10.24815/jn.v23i3.32158
pISSN 1411-8513
eISSN 2541-4062
ORIGINAL RESEARCH

The effect of ripeness level, storage and heating conditions on vitamin C in Fig (*Ficus carica* L.) fruit juice using bivoltammetry sensor

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Abstract. Vitamin C, as a crucial nutrient, plays a vital role in human health and is known to be sensitive to various factors such as ripeness level, storage and heating conditions. This study aimed to determine the effect of ripeness level, storage and heating conditions on vitamin C in fig (*Ficus carica* L.) fruit juice using bivolmetric sensor. Fig (*Ficus carica* L.) fruit juice samples with different ripeness level were collected and analyzed the vitamin C. Full-ripe fig (*Ficus carica* L.) fruit juice samples subjected at different storage (cold, cool, and room temperature) and heating (30 °C, 60 °C, and 90 °C) conditions. The vitamin C level was monitored using ~~a~~ bivoltammetry sensor. The results showed that the higher ripeness level of fig (*Ficus carica* L.) fruit the lower level of the vitamin C. The results also showed that the higher storage and heating conditions generally accelerate with degradation of vitamin C. Degradation of vitamin C content in fig (*Ficus carica* L.) fruit juice with all different storage temperature had the best kinetic model fit zero order. Meanwhile, heating temperature at 30 °C and 60 °C showed that the best kinetic model fit first order. But, heating temperature at 90 °C showed that the best kinetic model fit second order. The kinetic modeling analysis showed that storage and heating conditions significantly influenced the degradation kinetics of vitamin C in the fig (*Ficus carica* L.) fruit juice.

Keywords: ripeness, storage, heating, bivoltammetry, *Ficus carica* L., vitamin C

INTRODUCTION

Vitamin C, also known as ascorbic acid, is a vital nutrient that plays a crucial role in various physiological processes in the human body. It acts as an antioxidant and enhances immune function. Fruits and vegetables, including fig (*Ficus carica* L.), are excellent natural sources of vitamin C [1]. However, the stability of this essential vitamin can be influenced by various factors, such as storage and heating conditions [2]. The fig (*Ficus carica* L.) is a fruit known for its unique taste and nutritional composition. At the same time, fig (*Ficus carica* L.) are a good source of various nutrients, including dietary fiber, minerals, and vitamins [3]. Vitamin C is one of the nutritional content in fig (*Ficus carica* L.) fruits. However, it's important to note that the vitamin C content can vary depending on ripeness and growing conditions [4].

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Received: May 2023 | Revised: June 2023 | Accepted: July 2023

Fig (*Ficus carica* L.) is a fruit that belongs to the mulberry family (Moraceae). It is native to the Middle East and Mediterranean region but is now cultivated in various parts of the world with suitable climates. The fig (*Ficus carica* L.) fruit is unique and has a distinctive taste and texture [5]. The vitamin C content can gradually decline when fruits are stored, particularly at higher temperature. Higher temperature can accelerate vitamin C degradation, leading to a faster loss of this nutrient [6]. Heated fruits, such as during cooking or processing, can also cause a loss of vitamin C. Vitamin C is heat-sensitive and can degrade when exposed to high temperature. The extent of vitamin C loss depends on factors such as the duration and intensity of heat exposure [7].

The volumetric method with dichlorophenolindophenol for vitamin C titration is commonly used and reliable in analytical chemistry. It is relatively simple to perform compared to instrumentation analysis (chromatographic or spectrophotometric) [8].

Bivoltammetry is a specific type of voltammetry that uses two potential values (oxidation and reduction potential) during the measurement. Bivoltametry is commonly used in pharmaceutical analysis. It offers advantages such as low detection limits, wide dynamic range, ability to differentiate between closely related substances, detecting and quantifying analytes with high sensitivity and selectivity [9].

Kinetic modeling provides a quantitative approach to studying the degradation rate and predicting the stability of vitamin C under different conditions. By investigating the degradation kinetics, valuable insights can be gained into the factors contributing to this vital nutrients' loss in food and drink [10]. Understanding the kinetics of vitamin C degradation is important to maintain its nutritional value and quality [11]. By examining the degradation kinetics, it is possible to identify the rate of vitamin C degradation and establish a mathematical model to describe its behavior over time. This modeling approach enables the prediction of the extent of degradation under various conditions, providing valuable information for the food industry and consumers [12].

This research aimed to utilize the bivoltammetry sensor in volumetric analysis for vitamin C analysis with different ripeness level and expected to provide valuable insights into the degradation kinetics of vitamin C in fig (*Ficus carica* L.) fruit juice, aiding in developing strategies to preserve its nutritional value and enhance product shelf life. By optimizing storage and heating conditions, it may be possible to mitigate the degradation of vitamin C, thus improving the overall quality and consumer satisfaction of fig (*Ficus carica* L.) fruit juice. Ultimately, this study aims to investigate the kinetic behavior and determine the half-life of vitamin C degradation in fig (*Ficus carica* L.) fruit juice under different storage and heating conditions. The study will systematically vary the storage and heating conditions.

METHODOLOGY

This research is a combination of descriptive and experimental studies. A descriptive study to determine the vitamin C content in different ripeness of fig (*Ficus carica* L.) fruit. An experimental study to link the independent variables (storage and heating conditions) to the dependent variable (vitamin C content) in fig (*Ficus carica* L.) fruit. The stages in this research are: determination of plant by Herbarium Medanense, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Padang Bulan, Medan Baru, Medan, Sumatera Utara, Indonesia, 20155; preparation of reagent: metaphosphoric solution, dichlorophenolindophenol solution, and vitamin C solution; determination of equality: vitamin C equality; Descriptive study: determination of the vitamin C content in different ripeness level of fig (*Ficus carica* L.) fruit; and experimental study: determination and kinetic modelling of the vitamin C content in different storage and heating conditions of fig (*Ficus carica* L.) fruit juice.

Tools

Tools used in the study: double Au ring electrode (Metrohm), titrator (Metrohm), analytical balance (Shimadzu), blender (Miyako), glassware (Borosil), thermoreactor (Merck).

Materials

Materials used in the study: fig (*Ficus carica* L.) fruit, metaphosphoric acid (Smart Chemical), dichlorophenolindophenol (Smart Chemical), ascorbic acid (Smart Chemical), acid (Smart Chemical), sodium bicarbonate (Smart Chemical), distilled water (Bratachem).

Determination of Plant

Plant determination was done by taking the plant's roots, stems, leaves, flowers, and fruits. Then an analysis of plant taxonomy was carried out by the Herbarium Medanense, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Padang Bulan, Medan Baru, Medan, Sumatera Utara, Indonesia, 20155. After the determination, the part used in this research is the fruit part of the plant.

Preparation of Reagent

Preparation of reagent used in this study refers and modified to research from Nerdy, 2018. Metaphosphoric solution prepared from 30 g of metaphosphoric acid dissolved and added distilled water until 1000 mL. Dichlorophenolindophenol solution prepared from 250 mg of dichlorophenolindophenol and 2100 mg sodium bicarbonate dissolved and added distilled water until 1000 mL. Vitamin C solution prepared from 25 mg of dissolved in 25 mL metaphosphoric solution and vitamin C and added distilled water until 100 mL [13].

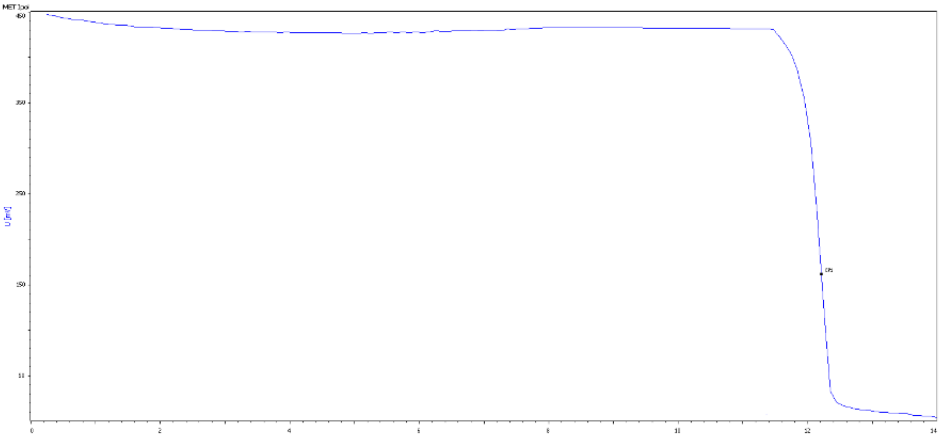


Figure 1. Titration curve of vitamin C by dichlorophenolindophenol

Table 1. Data on vitamin C equality determination

Number	Dichlorophenolindophenol Volume (mL)	Vitamin C Equality (mg / mL)
1	12.2610	0.1021
2	12.3164	0.1016
3	12.2994	0.1017
4	12.2883	0.1018
5	12.2780	0.1019
6	12.2676	0.1020
Total	73.7107	0.6112
Average	12.2851	0.1019
Standard Deviation	0.0206	0.0002
Relative Standard Deviation	0.1681%	0.1682%

*Dichlorophenolindophenol Volume (mL) for Blank Titration was 0.0138

Research Design

Research design used in this study refers and modified to research from Sinchaipanit et al., 2015 and Hardinasinta et al., 2019. The descriptive study had four groups of samples for fig (*Ficus carica* L.) fruit: un-ripe, half-ripe, full-ripe, and over-ripe. Every group was replicated six times. The experimental study used a full-ripe ripeness level and had six groups of samples for fig (*Ficus carica* L.) fruit juice. Three groups of storage conditions consist of group A stored at a cold temperature of 2 °C to 8 °C, group B stored at a cool temperature of 8 °C to 15 °C, and group C stored at a room temperature15 °C to 25 °C. Three group of heating conditions consist of group X heated at a temperature 30 °C, group Y heated at a temperature 60 °C, and group Z heated at a temperature 90 °C. All groups were stored and heated in tightly capped amber glass bottles to minimize the effect of air oxidation and light oxidation; stored and heated for 2 hours with analysis interval times (0, 15, 30, 45, 60, 90, and 120 minutes). Every analysis point was replicated six times [14,15].

Determination of Vitamin C Equality and Vitamin C Content

Ascorbic acid solution was taken 5 mL, inserted into a 150 mL beaker glass, added 10 mL of metaphosphoric solution, added 85 mL distilled water to 100 mL, titrated with dichlorophenolindophenol solution, recorded the end point of standard titration, calculated the vitamin C equality to the titrant.

Fig (*Ficus carica* L.) used as the research sample was mashed with a blender, weighed 5 g, inserted into a 150 mL beaker glass, added 10 mL of the metaphosphoric acid solution, added 85 mL of distilled water, titrated with dichlorophenolindophenol solution, recorded the endpoint of the titration, recorded the volume of the titration, and calculated the vitamin C content in the sample.

Kinetic Modelling of Vitamin C Degradation

The kinetic modeling used in this study refers and modified to research from Dewati et al., 2022. Degradation of vitamin C from fig (*Ficus carica* L.) fruit juice at various storage and heating conditions are modeled kinetically as a function of various storage and heating conditions that relate the vitamin C content to the time of various storage and heating temperature. The various kinetic models for vitamin C degradation from fig (*Ficus carica* L.) fruit juice at various storage and heating conditions were carried out in this study are zero order (equation 1), first order (equation 2), and second order (equation 3).

$$C_t = C_0 - k_0 \times t \quad \text{............... (1)}$$

Figure 2. Ripeness level of fig (*Ficus carica* L.) fruit; 1. un-ripe; 2. half-ripe; 3. full-ripe; 4. over-ripe

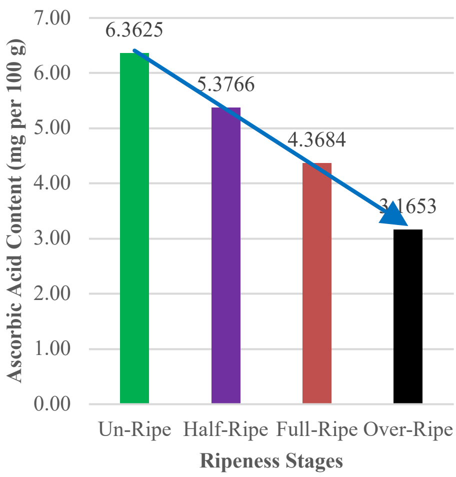


Figure 3. Vitamin C content of fig (*Ficus carica* L.) fruit with different ripeness level

$$\ln C_t = \ln C_0 - k_1 \times t \quad \text{............... (2)}$$

$$\frac{1}{C_t} = \frac{1}{C_0} + k_2 \times t \quad \text{............... (3)}$$

C_0 is the initial vitamin C content (mg / 100 g), C_t is the vitamin C content (mg / 100 g) after being stored and heated for certain time, t is the stored and heated time (minutes), and k_0, k_1, and k_2 are the reaction rate constants (minutes^{-1}) respectively for zero order, first order, and second order [16].

The reaction order and the relevant coefficients were determined by comparing the determination coefficient (R^2). The model with higher value for R^2 shows a better fit with the results. The half-life ($t_{½}$) is the time required by the oxidation reaction for the vitamin C content to decrease by 50 % from its initial content (C_t = 50 % × C_0). Determination of the half-life of the oxidation reaction of vitamin C in fig (*Ficus carica* L.) fruit juice stored and heated are carried out by equation that corresponds to the order of the reaction, zero order (equation 4), first order (equation 5), and second order (equation 6).

$$t_{½} = \frac{C_0}{2 \times k_0} \quad \text{............... (4)}$$

$$t_{½} = \frac{0.693}{k_1} \quad \text{............... (5)}$$

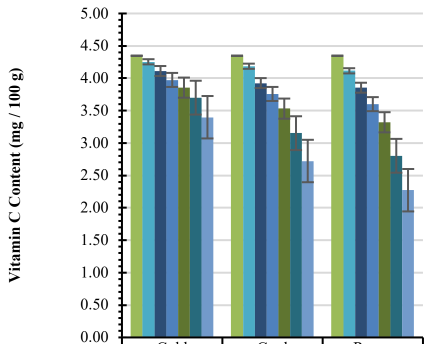
$$t_{½} = \frac{1}{C_0 \times k_2} \quad \text{............... (6)}$$

$t_{½}$ is the half-life of vitamin C (minutes), C_0 is the initial vitamin C content (mg / 100 g), and k_0, k_1, and k_2 are the reaction rate constants (minutes^{-1}) respectively for zero order, first order, and second order [14].

RESULTS AND DISCUSSION

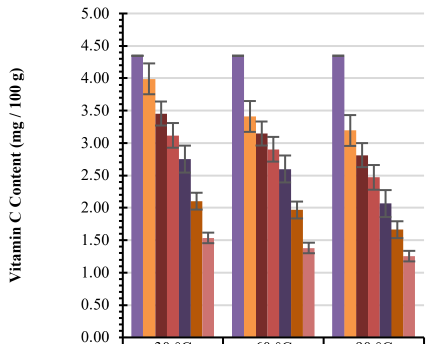
The results of the plant determination show that the plants used in the study are fig with *Ficus carica* species from Moraceae family. Fig (*Ficus carica*) is a deciduous fruit-bearing, native to the Middle East and Mediterranean region. Fig (*Ficus carica*) trees are now cultivated in many parts of the world with suitable climates [17]. Fig (*Ficus carica*) fruit is unique in appearance and has a pear or teardrop shape. Fig (*Ficus carica*) fruit can vary, ranging from small to medium-sized. Fig (*Ficus carica*) have thin, delicate skin that can be green, purple, brown, or black, depending on the level of ripeness and the specific cultivar [18].

The flesh of the fig (*Ficus carica* L.) is soft and sweet, often with a honey-like flavor. The interior of the fig (*Ficus carica* L.) contains numerous small, edible seeds [19]. Fig (*Ficus carica* L.) fruit is typically harvested when fully ripe, as fig (*Ficus carica* L.) do not continue to ripen once picked. Harvesting figs at the peak of ripeness ensures the best flavor and texture [20]. So it is very important to know the nutritional content in fig (*Ficus carica* L.) fruit according to its ripeness level to get information about the best nutritional content at the right ripeness level. Research on vitamin C content



	Cold	Cool	Room
0 Minute	4.3475	4.3475	4.3475
15 Minutes	4.2543	4.1857	4.1152
30 Minutes	4.1121	3.9257	3.8543
45 Minutes	3.9744	3.7580	3.6008
60 Minutes	3.8554	3.5314	3.3208
90 Minutes	3.7008	3.1526	2.8034
120 Minutes	3.3988	2.7230	2.2724

(A)



	30 °C	60 °C	90 °C
0 Minute	4.3475	4.3475	4.3475
15 Minutes	3.9914	3.4107	3.1938
30 Minutes	3.4559	3.1472	2.8140
45 Minutes	3.1186	2.9044	2.4706
60 Minutes	2.7525	2.6002	2.0662
90 Minutes	2.1031	1.9669	1.6631
120 Minutes	1.5362	1.3810	1.2549

(B)

Figure 4. Vitamin C content in fig (*Ficus carica* L.) fruit juice with (A) different storage and (B) heating conditions

was continued with the determination of vitamin C equality (equality of vitamin C to dichlorophenolindophenol). Figure 1 shows the titration curve of vitamin C by dichlorophenolindophenol. Table 1 shows the data on vitamin C equality determination.

A good titration curve typically exhibits a steep slope at the equivalence point and should be reproducible [21]. The region around the equivalence point, where the analyte and titrant are present in stoichiometric amounts, should have a steep slope on the titration curve. This allows for accurate determination of the equivalence point and enhances the precision of the titration [22]. The titration curve should be reproducible, that repeating the titration under the same conditions should yield similar results. This is essential for obtaining reliable and consistent data with relative standard deviation not more than 2% [23].

The results of the research showed that the titration curve of vitamin C by dichlorophenolindophenol in volumetric analysis using a bivoltammetry sensor has a good curve with steep slope (figure 1) and has a good reproducibility with relative standard deviation 0.1682%. The equality of vitamin C obtained was 0.1019 mg of vitamin C per 1 mL of dichlorophenolindophenol. The study continued with the determination of vitamin C of fig (*Ficus carica* L.) fruit with different ripeness level. Figure 2 shows the physical appearance of fig (*Ficus carica* L.) fruit with different ripeness level. Figure 3 shows the vitamin C content of fig (*Ficus carica* L.) fruit with different ripeness level.

The results showed that the riper fig (*Ficus carica* L.) fruit, the lower the vitamin C content. It is a prevalent phenomenon that as fruits ripen, their vitamin C content decreases. This is because vitamin C is a water-soluble vitamin sensitive to various factors, including light, heat, and oxygen exposure. As fruits ripen, their vitamin C undergoes natural degradation [24]. The enzymatic activity and respiration process may affect the vitamin C content in fruits may decrease as they ripen [25]. During the ripening process, enzymes become more active, leading to the breakdown of vitamin C. These enzymes, such as ascorbate oxidase, can oxidize and degrade vitamin C, reducing its content [26]. Ripening of fruits undergo respiration, a metabolic process involving carbohydrates breakdown to produce energy. This process can contribute to the depletion of vitamin C as it is utilized for various metabolic reactions [27].

Fig (*Ficus carica* L.) are highly versatile fruits with various culinary applications. They can be enjoyed fresh, either on their own or as a delicious addition to salads, cheese platters, or desserts. Fig (*Ficus carica* L.) are also commonly dried, intensifying their sweetness and creating a chewy texture. Dried figs are used in baking and cooking and consumed as a snack. Fig (*Ficus carica* L.) preserves, jams, and syrups are popular as well [28]. Fig (*Ficus carica* L.) trees are relatively hardy and adaptable. They prefer warm, dry climates and

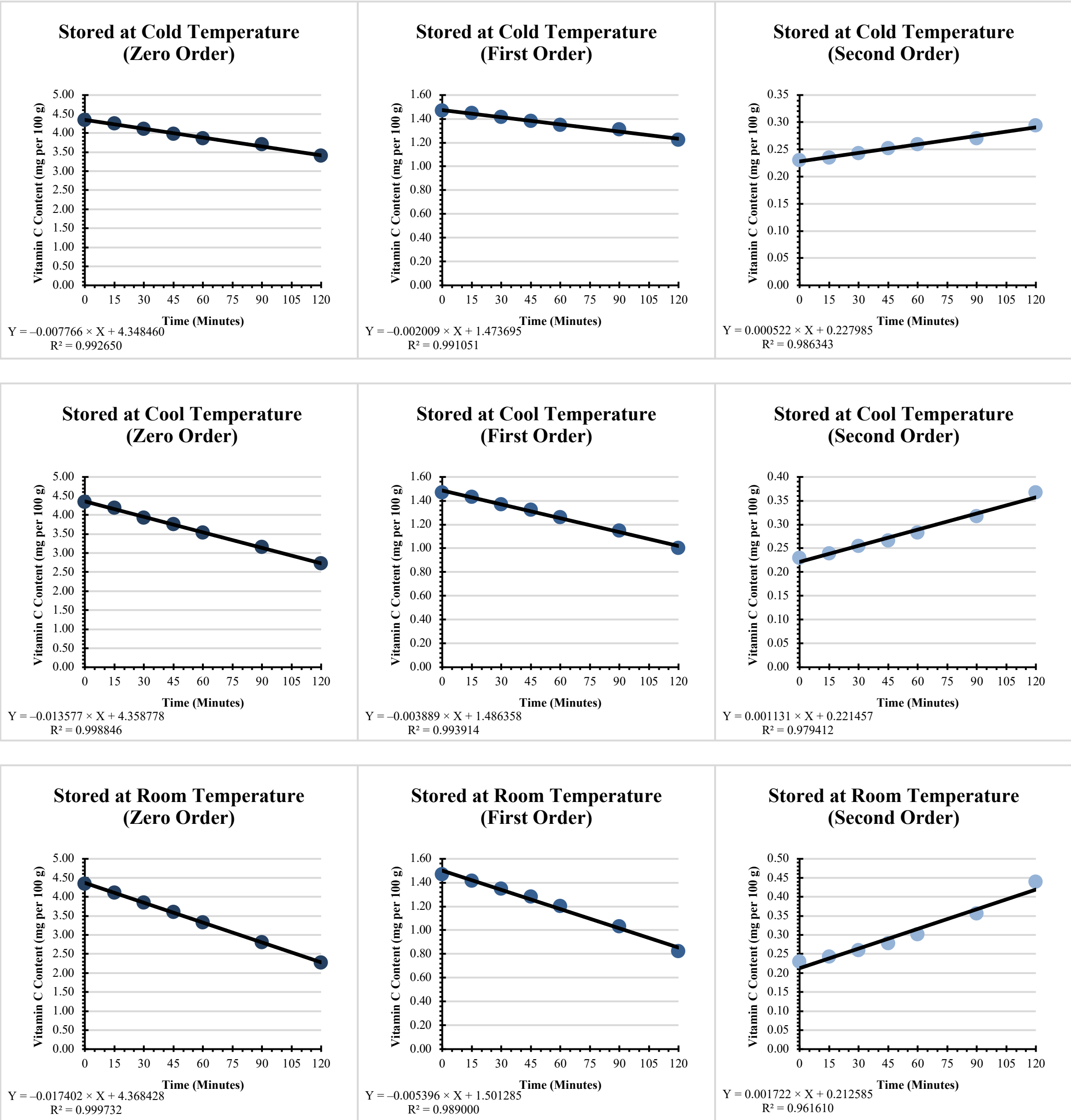


Figure 5. Kinetic modeling graph of vitamin C in fig (*Ficus carica* L.) fruit juice with different storage conditions

are commonly grown in Mediterranean, subtropical, and warm temperate regions. Fig (*Ficus carica* L.) trees are known for tolerating drought and thriving in well-drained soil. They are often propagated through cuttings or grafting. Fig (*Ficus carica* L.) can be grown as ornamental trees in gardens or cultivated on a larger scale for their fruits [29].

Because the available fig (*Ficus carica* L.) fruits are quite limited, they must be properly utilized with proper storage and heating conditions to slow down the degradation rate of vitamin C content. The results showed that different ripeness level provide different vitamin C content; this reinforces that vitamin C from fig (*Ficus carica* L.) fruit needs to be maintained, and its degradation rate slowed down. Slowing the degradation rate of vitamin C can be done with proper treatment (storage and heating conditions). The research continued by determining the vitamin C content in fig (*Ficus carica* L.) fruit juice with different storage and heating conditions. Figure 4 shows the vitamin C content in fig (*Ficus carica* L.) fruit juice with different storage and heating conditions.

The results showed that higher temperature of storage and higher temperature of heating generally accelerate the degradation of vitamin C. This finding is consistent with previous

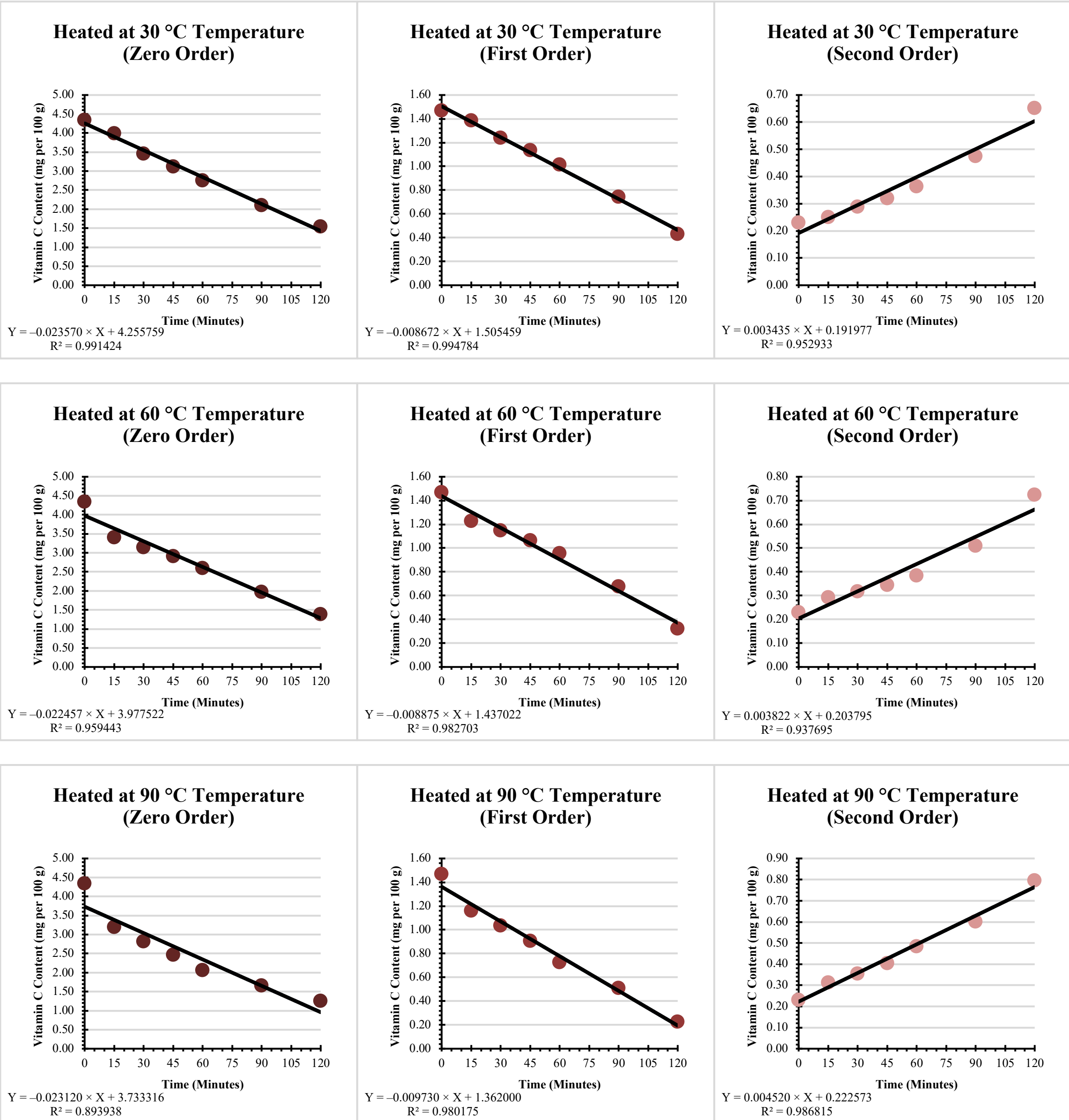


Figure 6. Kinetic modeling graph of vitamin C in fig (*Ficus carica* L.) fruit juice with different heating conditions

research indicating that vitamin C is sensitive to heat. High temperature can promote oxidation reactions, leading to the breakdown of vitamin C molecules. The degradation rate increases with temperature, suggesting that even slight temperature variations can significantly impact vitamin C stability [30]. The results also indicate that longer exposure to specific temperature increases vitamin C degradation. This finding aligns with the general understanding that vitamin C is prone to degradation over time. As the duration of exposure to unfavorable conditions (elevated temperature) increases, more vitamin C molecules undergo degradation reactions, resulting in a decrease in overall concentration [31].

As the temperature and duration of storage and heating of fig (*Ficus carica* L.) fruit juice increase, it is necessary to carry out further analysis of the kinetic model of vitamin C degradation. Kinetic modeling plays a crucial role in understanding and predicting the degradation of vitamin C over time. Figure 5 shows the kinetic modeling graph of vitamin C in fig (*Ficus carica* L.) fruit juice with different storage conditions. Figure 6 shows the kinetic modeling graph of vitamin C in fig (*Ficus carica* L.) fruit juice with different heating conditions. Table 2 shows the kinetic modeling data of vitamin C in fig (*Ficus carica* L.) fruit juice with different storage and heating conditions.

Table 2. Kinetic modeling data of vitamin C in fig (*Ficus carica* L.) fruit juice with different storage and heating conditions

Condition	Order	Slope (A)	Intercept (B)	Regression Equation (Y = A × X + B)	Determination Coefficient (R^2)	Half-Life ($t_{½}$)
Stored at Cold	Zero	–0.007766	4.348460	Y = –0.007766 × X + 4.348460	0.992650	279.967808
	First	–0.002009	1.473695	Y = –0.002009 × X + 1.473695	0.991051	344.947735
	Second	0.000522	0.227985	Y = 0.000522 × X + 0.227985	0.986343	436.752874
Stored at Cool	Zero	–0.013577	4.358778	Y = –0.013577 × X + 4.358778	0.998846	160.520660
	First	–0.003889	1.486358	Y = –0.003889 × X + 1.486358	0.993914	178.194909
	Second	0.001131	0.221457	Y = 0.001131 × X + 0.221457	0.979412	195.806366
Stored at Room	Zero	–0.017402	4.368428	Y = –0.017402 × X + 4.368428	0.999732	125.515113
	First	–0.005396	1.501285	Y = –0.005396 × X + 1.501285	0.989000	128.428466
	Second	0.001722	0.212585	Y = 0.001722 × X + 0.212585	0.961610	123.452381
Heated at 30 °C	Zero	–0.023570	4.255759	Y = –0.023570 × X + 4.255759	0.991424	90.279147
	First	–0.008672	1.505459	Y = –0.008672 × X + 1.505459	0.994784	79.912362
	Second	0.003435	0.191977	Y = 0.003435 × X + 0.191977	0.952933	55.888501
Heated at 60 °C	Zero	–0.022457	3.977522	Y = –0.022457 × X + 3.977522	0.959443	88.558623
	First	–0.008875	1.437022	Y = –0.008875 × X + 1.437022	0.982703	78.084507
	Second	0.003822	0.203795	Y = 0.003822 × X + 0.203795	0.937695	53.321559
Heated at 90 °C	Zero	–0.023120	3.73316	Y = –0.023120 × X + 3.73316	0.893938	80.737803
	First	–0.009730	1.362000	Y = –0.009730 × X + 1.362000	0.980175	71.223022
	Second	0.004520	0.222573	Y = 0.004520 × X + 0.222573	0.986815	49.241418

For zero order : Y is C_t, A is $-k_0$, X is t, and B is C_0
For first order : Y is ln C_t, A is $-k_1$, X is t, and B is ln C_0
For second order : Y is 1 / C_t, A is k_2, X is t, and B is 1 / C_0

Degradation of vitamin C content in fig (*Ficus carica* L.) fruit juice stored at cold, cool, and room temperature showed that the best kinetic model fit zero order. Degradation of vitamin C content in fig (*Ficus carica* L.) fruit juice heated at temperature 30 °C and 60 °C showed that the best kinetic model fit first order, and at temperature 90 °C showed that the best kinetic model fit second order. The best order fit to the condition is based on the best R^2 value, which is higher and nearest to one. For stored at cold temperature the best R^2 value 0.992650, at cool temperature the best R^2 value 0.998846, and at room temperature the best R^2 value 0.999732. For stored at cold temperature the C_0 value is 4.348460 and k_0 constant is 0.007766 so that a complete zero order kinetic model obtained is $C_t = 4.348460 - 0.007766 \times t$. For stored at cool temperature the C_0 value is 4.358778 and k_0 constant is 0.013577 so that a complete zero order kinetic model obtained is $C_t = 4.358778 - 0.013577 \times t$. For stored at room temperature the C_0 value is 4.368428 and k_0 constant is 0.017402 so that a complete zero order kinetic model obtained is $C_t = 4.368428 - 0.017402 \times$. For heated at 30 °C temperature the best R^2 value 0.994784, at 60 °C temperature the best R^2 value 0.982703, and at 90 °C temperature the best R^2 value 0.986815. For heated at 30 °C temperature the C_0 value is 1.505459 and k_1 constant is 0.008672 so that a complete first order kinetic model obtained is $\ln C_t = \ln 1.505459 - 0.008672 \times t$. For heated at 60 °C temperature the C_0 value is 1.437022 and k_1 constant is 0.008875 so that a complete first order kinetic model obtained is $\ln C_t = \ln 1.437022 - 0.008875 \times t$. For heated at 90 °C temperature the C_0 value is 0.222573 and k_2 constant is 0.004520 so that a complete second order kinetic model obtained is $\frac{1}{C_t} = \frac{1}{0.222573} + 0.004520 \times t$.

The degradation of vitamin C under different storage and heating conditions (temperature and duration) it is possible to observe variations in the kinetic order of degradation. The kinetic order refers to the relationship between the degradation rate of vitamin C and the concentration of the vitamin itself [32]. Different kinetic orders for vitamin C degradation under different temperature and duration conditions suggest that the degradation process is inconsistent or follows a single pattern. This can be attributed to the complex nature of the degradation reactions [33]. The different kinetic orders imply that the rate of vitamin C degradation may be influenced by multiple factors simultaneously, such as temperature and duration [34]

The research showed that all the R^2 value is above 0.9, within the acceptance range. The acceptable R^2 value was higher than 0.9; thus indicating that the independent variable can well predict the dependent variable [35]. The coefficient of determination, also known as R-squared (R^2), is a statistical measure representing the proportion of the variance in the dependent variable that is predictable from the independent variable(s). In the context of regression analysis, a higher R^2 value indicates a better fit of the regression model to the data [36]. In general, a high R^2 value close to 1 suggests that a large proportion of the variance in the dependent variable is explained by the independent variable(s). This indicates a strong relationship between the variables and a good model fit [37].

By employing kinetic modelling, researchers can analyze the rate of vitamin C degradation under various conditions and make predictions about its stability and shelf life. Several functions and benefits of kinetic modeling in studying vitamin C degradation is predicting degradation rates, optimizing storage conditions, assessing the impact of processing techniques, and shelf life prediction [38]. Kinetic models provide a quantitative representation of the degradation kinetics of vitamin C. These models allow researchers to determine the rate at which vitamin C breaks down under specific conditions, such as temperature. By estimating degradation rates, researchers can assess the stability of vitamin C and predict its behavior over time [39].

Kinetic modeling helps determine the optimal storage conditions for maintaining vitamin C content in products. By understanding the factors that affect vitamin C degradation, such as temperature and duration, researchers can develop storage strategies to minimize vitamin C losses and extend the shelf life of vitamin C-containing foods [40]. Kinetic modeling allows for evaluating the effect of various processing techniques on vitamin C degradation. For example, researchers can study the impact of thermal processing, such as pasteurization or cooking, on vitamin C stability. This information can help optimize processing methods to minimize vitamin C losses and maintain the nutritional quality of food products [41].

Kinetic models estimate the shelf life of vitamin C-containing products. By integrating degradation rates of storage and heating conditions, researchers can simulate the degradation process over time and determine when the vitamin C content reaches a specified threshold. This information is valuable for setting appropriate expiration dates, quality control, and product formulation decisions [42]. The half-life value of vitamin C degradation refers to the time it takes for the concentration of vitamin C to decrease by half. The specific half-life value for vitamin C degradation can vary depending on various factors, such as temperature and duration [43]. The research on vitamin C degradation with different temperature gave different half-life results. It is important to consider that the half-life value of vitamin C degradation can change under other conditions [44]. For example, exposure to higher temperature, such as during cooking or food processing, can accelerate the degradation process and result in a shorter half-life. Conversely, refrigeration or other preservation techniques can slow down degradation and extend the half-life [45].

CONCLUSION

The research has been successfully highlighting the complex nature of vitamin C degradation in fig (*Ficus carica* L.) fruit juice with different ripeness level, also the importance of storage and heating conditions. Different storage and heating conditions of fig (*Ficus carica* L.) fruit juice have different kinetic orders. The obtained kinetic models provide valuable insights into the degradation behavior of vitamin C in fig (*Ficus carica* L.) fruit juice, enabling a better understanding of the underlying mechanisms. This knowledge can be utilized to optimize stored and processing parameters to minimize vitamin C degradation and preserve its nutritional value. Using the bivoltammetry sensor in volumetric analysis proved to be an effective and sensitive method for monitoring vitamin C degradation in the fig (*Ficus carica* L.) fruit juice samples. The combination of this sensor with kinetic modeling techniques offers a comprehensive approach to studying the degradation kinetics of vitamin C in complex matrices. Future research is expected to conduct research on other fruits to provide broader information on understanding vitamin C degradation.

ACKNOWLEDGMENT

The authors thank to Industri Farmasi Mutiara Mukti Farma for instrumentation support and Universitas Tjut Nyak Dhien for fund support.

REFERENCE

[1]. Michalak, M. 2022. Plant-Derived Antioxidants: Significance in Skin Health and the Ageing Process. *Int. J. Mol. Sci.* **23** (2) 585.

[2]. Yang, H.; Xu, L.; Hou, L.; Xu, T.C.; and Ye, S.H. 2022. Stability of Vitamin A, E, C and Thiamine During Storage of Different Powdered Enteral Formulas. *Heliyon* **8** (11) e11460.

[3]. Rasool, I.F.u.; Aziz, A.; Khalid, W.; Koraqi, H.; Siddiqui, S.A.; AL-Farga, A.; Lai, W.-F.; and Ali, A. 2023. Industrial Application and Health Prospective of Fig (*Ficus carica* L.) by-Products. *Molecules* **28** (3) 960.

[4]. Moura, E.A.; Mendonça, V.; Figueirêdo, V.B.; Oliveira, L.M.; Melo, M.F.; Irineu, T.H.S.; Andrade, A.D.M.; Chagas, E.A.; Chagas, P.C.; Ferreira, E.S.; Mendonça, L.F.M.; Figueiredo, F.R.A. 2023. Irrigation Depth and Potassium Doses

Affect Fruit Yield and Quality of Figs (*Ficus carica* L.). *Agriculture* **13** (3) 640.
[5]. Moisescu, E.; and Antoce, A.O. 2022. Figs *(Ficus carica* L.) Used as Raw Material for Obtaining Alcoholic Fermented Beverages. *Beverages* **8**(4) 60.
[6]. Yin, X.; Chen, K.; Cheng, H.; Chen, X.; Feng, S.; Song, Y.; and Liang, L. 2022. Chemical Stability of Ascorbic Acid Integrated into Commercial Products: A Review on Bioactivity and Delivery Technology. *Antioxidants* **11** (1) 153.
[7]. Piepiórka-Stepuk, J.; Wojtasik-Kalinowska, I.; Sterczyńska, M.; Mierzejewska, S.; Stachnik, M.; and Jakubowski, M. 2023. The Effect of Heat Treatment on Bioactive Compounds and Color of Selected Pumpkin Cultivars. *LWT Food Sci. Tech.* **175** 114469.
[8]. Abe-Matsumoto, L.T.; Sampaio, G.R.; and Bastos, D.H.M. 2020. Is Titration as Accurate as HPLC for Determination of Vitamin C in Supplements? - Titration versus HPLC for Vitamin C Analysis. *Am. J. Anal. Chem.* **11** (7) 269-279.
[9]. Mahmudiono, T.; Bokov, D.O.; Jasim, S.A.; Abdelbasset, W.K.; and Khashirbaeva, D.M. 2022. State-of-the-Art of Convenient and Low-Cost Electrochemical Sensor for Food Contamination Detection - Technical and Analytical Overview. *Microchem. J.* **179** 107460.
[10]. Nakilcioğlu-Taş, E.; and Ötleş, S. 2020. Kinetic Modelling of Vitamin C Losses in Fresh Citrus Juices under Different Storage Conditions. *An. Acad. Bras. Cienc.* **92** (2): e20190328.
[11]. Miller, F.A.; Brandão, T.R.S.; and Silva, C.L.M. 2023. New Approaches for Improving the Quality of Processed Fruits and Vegetables and Their By-Products. *Foods* **12** (7) 1353.
[12]. Giannakourou, M.C.; and Taoukis, P.S. 2021. Effect of Alternative Preservation Steps and Storage on Vitamin C Stability in Fruit and Vegetable Products: Critical Review and Kinetic Modelling Approaches. *Foods* **10** (11) 2630.
[13]. Nerdy, N. 2018. Determination of Vitamin C in Various Colours of Bell Pepper (Capsicum annuum L.) by Titration Method. Alchemy *J. Pen. Kim.* **14** (1) 164-177.
[14]. Sinchaipanit, P.; Ahmad, M.; and Twichatwitayakul, R. 2015. Kinetics of Ascorbic Acid Degradation and Quality Changes in Guava Juice during Refrigerated Storage. *J. Food Nutr. Res.* **3** (8) 550-557.
[15]. Hardinasinta, G.; Salengke, S.; Juaedi, M.; and Mursalim, M. 2019. Ohmic heating characteristics and degradation kinetics of anthocyanin in mulberry juice. *IOP Conf. Ser.: Earth Environ. Sci.* **355** 012094.
[16]. Dewati, P.R.; Rochmadi, R.; Rohman, A.; and Budiman, A. 2022. Degradation rate of astaxanthin from Haematococcus pluvialis. *Food Res.* **6** (4) 254-258.
[17]. Mellal, M.K.; Khelifa, R.; Chelli, A.; Djouadi, N.; and Madani, K. 2023. Combined Effects of Climate and Pests on Fig (*Ficus carica* L.) Yield in a Mediterranean Region: Implications for Sustainable Agricultural Strategies. *Sustainability* **15** (7) 5820.
[18]. Wang, Z.; Cui, Y.; Vainstein, A.; Chen, S.; and Ma, H. 2017. Regulation of Fig (*Ficus carica* L.) Fruit Color: Metabolomic and Transcriptomic Analyses of the Flavonoid Biosynthetic Pathway. *Front. Plant Sci.* **8** 1990.
[19]. Ayuso, M.; Carpena, M.; Taofiq, O.; Albuquerque, T.G.; Simal-Gandara, J.; Oliveira, M.B.P.P.; Prieto, M.A.; Ferreira, I.C.F.R.; and Barros, L. 2022. Fig "*Ficus carica* L." and its by-products: A decade evidence of their health-promoting benefits towards the development of novel food formulations. *Trends Food Sci. Technol.* **127** 1-13.
[20]. Ferrara, G.; Magarelli, A.; Mazzeo, A.; Coletta, A.; Crupi, P.; Loperfido, F.; Maggi, G.; and Venerito, P. 2023. Underutilized Fig (*Ficus carica* L.) Cultivars from Puglia Region, Southeastern Italy, for an Innovative Product: Dried Fig Disks. *Processes* **11** (5) 1485.
[21]. Allkja, J.; van Charante, F.; Aizawa, J.; Reigada, I.; Guarch-Pérez, C.; Vazquez-Rodriguez, J.A.; Cos, P.; Coenye, T.; Fallarero, A.; Zaat, S.A.J.; Felici, A.; Ferrari, L.; Azevedo, N.F.; Parker, A.E.; and Goeres. D.M. 2021. Interlaboratory Study for the Evaluation of three Microtiter Plate-Based Biofilm Quantification Methods. *Sci. Rep.* **11** 13779.
[22]. Fernandez-Maestre, R. 2020. The Importance of Teaching Titration Curves in Analytical Chemistry. *Per. Tchê Quím.* **17** (34) 213-219.
[23]. Nadporozhskaya, M.; Kovsh, N.; Paolesse, R.; and Lvova, L. 2022. Recent Advances in Chemical Sensors for Soil Analysis: A Review. *Chemosensors* **10** (1) 35.
[24]. Doseděl, M.; Jirkovský, E.; Macáková, K.; Krčmová, L.K.; Javorská, L.; Pourová, J.;

Mercolini, L.; Remião, F.; Nováková, L.; and Mladěnka, P. 2021. Vitamin C-Sources, Physiological Role, Kinetics, Deficiency, Use, Toxicity, and Determination. *Nutrients* **13** (2) 615.

[25]. Zheng, X.; Gong, M.; Zhang, Q.; Tan, H.; Li, L.; Tang, Y.; Li, Z.; Peng, M.; and Deng, W. 2022. Metabolism and Regulation of Ascorbic Acid in Fruits. *Plants* **11** (12) 1602.

[26]. Fenech, M.; Amaya, I.; Valpuesta, V.; and Botella, M.A. 2019. Vitamin C Content in Fruits: Biosynthesis and Regulation. *Front. Plant Sci.* **9** 2006.

[27]. Chaturvedi, S.; Khan, S.; Bhunia, R.K.; Kaur, K.; and Tiwari, S. 2022. Metabolic Engineering in Food Crops to Enhance Ascorbic Acid Production - Crop Biofortification Perspectives for Human Health. *Physiol. Mol. Biol. Plants* **28** (4) 871-884.

[28]. Çavdaroğlu, E.; and Yemenicioğlu, A. 2022. Utilization of Stalk Waste Separated During Processing of Sun-Dried Figs (*Ficus carica*) as a Source of Pectin - Extraction and Determination of Molecular and Functional Properties. *LWT Food Sci. Tech.* **154** 112624.

[29]. Mellal, M.K.; Khelifa, R.; Chelli, A.; Djouadi, N.; and Madani, K. 2023. Combined Effects of Climate and Pests on Fig (*Ficus carica* L.) Yield in a Mediterranean Region: Implications for Sustainable Agricultural Strategies. *Sustainability* **15** (7) 5820.

[30]. Fata, N.A.; Georgé, S.; Dlalah, N.; and Renard, C.M.G.C. 2018. Influence of Partial Pressure of Oxygen on Ascorbic Acid Degradation at Canning Temperature. *Innov. Food Sci. Emerg. Technol.* **49** 215-221.

[31]. Carr, A.C.; and Maggini, S. 2017. Vitamin C and Immune Function. *Nutrients* **9** (11) 1211.

[32]. Scrob, T.; Varodi, S.M.; Vintilă, G.A.; Casoni, D.; and Cimpoiu, C. 2022. Estimation of Degradation Kinetics of Bioactive Compounds in Several Lingonberry Jams as Affected by Different Sweeteners and Storage Conditions. *Food Chem X* **16** 100471.

[33]. Tajnšek, T.K.; Grape, E.S.; Willhammar, T.; Jelić, T.A.; Javornik, U.; Dražić, G.; Logar, N.Z.; and Mazaj, M. 2022. Design and Degradation of Permanently Porous Vitamin C and Zinc-Based Metal-Organic Framework. *Commun. Chem.* **5** 24.

[34]. Bhangare, D.; Rajput, N.; Jadav, T.; Sahu, A.K.; Tekade, R.K.; and Sengupta, P. 2022. Systematic Strategies for Degradation Kinetic Study of Pharmaceuticals - an Issue of Utmost Importance Concerning Current Stability Analysis Practices. *J. Anal. Sci. Technol.* **13** 7.

[35]. Matsui, Y.; Imamura, K.; Chujo, S.; Mase, Y.; Matsubara, H.; Sugimoto, M.; Kawanaka, H.; Kondo, M. 2022. Which Explanatory Variables Contribute to the Classification of Good Visual Acuity over Time in Patients with Branch Retinal Vein Occlusion with Macular Edema Using Machine Learning? *J. Clin. Med.* **11** (13) 3903.

[36]. Chicco, D.; Warrens, M.J.; and Jurman, G. 2021. The Coefficient of Determination R-Squared is More Informative than SMAPE, MAE, MAPE, MSE and RMSE in Regression Analysis Evaluation. *PeerJ Comput, Sci.* **7** e623.

[37]. Schober, P.; Boer, C.; and Schwarte, L. 2018. Correlation Coefficients: Appropriate Use and Interpretation. *Anesth. Analg.* **126** (5) 1763-1768.

[38]. Awagu, E.F.; Ekanem, E.O.; Kolo, A.M.; and Adamu, M.M. 2017. Kinetic Modeling of Vitamin C (Ascorbic Acid) Degradation in Blanched Commonly Consumed Salad Vegetables Using Computer Simulation Analysis. *IOSR J. Appl. Chem.* **10** (4) 59-66.

[39]. Peleg, M.; Normand, M.D.; Dixon, W.R.; and Goulette, T.R. 2018. Modeling the Degradation Kinetics of Ascorbic Acid. *Crit. Rev. Food Sci. Nutr.* **58** (9) 1478-1494.

[40]. Farah, H.S.; Alhmoud, J.F.; Al-Othman, A.; Alqaisi, K.M.; Atoom, A.M.; Shadid, K.; Shakya, A.; and AlQaisi, T. 2020. Effect of pH, Temperature and Metal Salts in Different Storage Conditions on the Stability of Vitamin C Content of Yellow Bell Pepper Extracted in Aqueous Media. *Sys. Rev. Pharm.* **11** (9) 661-667

[41]. Amit, S.K.; Uddin, M.M.; Rahman, R.; Islam, S.M.R.; and Khan, M.S. 2017. A Review on Mechanisms and Commercial Aspects of Food Preservation and Processing. *Agric. Food Secur.* **6** 51.

[42]. de Oliveira, L.d.L.; Sanchez, B.A.O.; Celestino, I.C.; Celestino, S.M.C.; de Alencar, E.R.; and Costa, A.M. 2022. Shelf Life and Retention of Bioactive Compounds in Storage of Pasteurized *Passiflora setacea* Pulp, an Exotic Fruit from Brazilian Savannah. *LWT Food Sci. Tech.* **159** 113202

[43]. Nkwocha, A.C.; Ekeke, I.C.; Kamalu, C.I.O.; Oghome, P.I.; Osoka, E.C.; and Nkuzinna, O.C. 2018. Kinetic Modelling

of Vitamin C Degradation in Selected Fruits under Market Storage Conditions. Int. J. Environ. *Agric. Biotechnol.* **3** (5) 1618-1627.

[44]. Essodolom, P.; Chantal, B.E.; Mamatchi, M.; and Kousanta, A. 2020. Effect of Temperature on the Degradation of Ascorbic Acid (Vitamin C) Contained in Infant Supplement Flours During the Preparation of Porridges. *Int. J. Adv. Res.* **8** (3), 116-121.

[45]. Lee, S.; Choi, Y.; Jeong, H.S.; Lee, J.; and Sung, J. 2018. Effect of Different Cooking Methods on the Content of Vitamins and True Retention in Selected Vegetables. *Food Sci. Biotechnol.* **27** (2): 333-342.