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DEGRADATION KINETICS OF ASCORBIC ACID AND B-CAROTENE IN MANGO SLICES USING DIFFERENT DRYING METHODS

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Abstract
Ascorbic acid and β-carotene are one of the most important vitamins that is essential in human system. Freshly mango was procured from a local farmer in Ogbomoso, Oyo State Nigeria. Mango was sorted, washed to remove extraneous material, peeled, and then cut into slice thicknesses of 3, 6, and 9 mm. The sliced mango samples were dried using three drying methods: oven (40, 45 and 50 °C), solar and sun drying methods. Degradation kinetic of ascorbic and β-carotene was determined and it follow first order kinetics. Half-life and D-value were also determined. For ascorbic acid, the mean value of rate constant at drying temperature of 40 °C was 0.0265 min^{-1}; for 45 °C was 0.0279 min^{-1}; for 50 °C was 0.0344 min^{-1} while that of solar and sun were 0.0541 min^{-1} and 0.0546 min^{-1}, respectively. For β-carotene, the range of values of rate constant for the three drying methods considered were 0.0259 - 0.05342 min^{-1}; 0.0265 - 0.05342 $min^{-1}$and 0.0270 - 0.0561 min^{-1} for slice thicknesses of 3, 6 and 9 mm, respectively. Half- life and β-carotene value decrease with increase in drying temperature for all the drying methods considered. In conclusion, due to reduction in ascorbic acid and β-carotene, it was inferred that heat has effect on the two vitamins considered.

Keywords
Drying, Mongo, Ascorbic Acid, β- carotene, kinetics

1. INTRODUCTION

Mango (*Mangifera indica*) is a tropical fruit that is grown in Nigeria, and is reached in vitamin and minerals [1]. The fruit being one of the fruits that contain low level of fat and contain larger amount of vitamin, mineral and fibre [2]. The fruit is highly perishable due to larger percentage of water present in it. Fruit and vegetable are reach in vitamin, but during process, some of this vitamin degradate due to excessive heat supply. Drying is one of unit operations that is done on highly perishable food such as fruit and vegetable to a level where by microbial growth will be inhibited [3]. Drying causes a change in the physical properties and chemical compositions of food materials, which includes the loss of water-soluble vitamins (mainly ascorbic acid) and changes in colour and rehydration ratios [4]. Ascorbic acid is a heat liable vitamin that degredate with respect to draying time. This vitamin is a very effective scavenger of alkoxy radica [5]. Beta carotene is a vitamin A precursor (retinol) and the most important pro-vitamin A [6]. Series of work have been done on degradation of vitamin [7]; [8]; [9] and [10]. Searching through the literature, there were little information about different drying method and slice thickness of mango slice in relation to ascorbic acid and β-carotene degradation. Hence, this study focusses on degradation kinetics of ascorbic acid and β-carotene in mango during drying.

2. MATERIALS AND METHOD

2.1 Materials

Freshly harvested mango (*Mangifera indicia)* of a variety *julie* mango usually known as Ogbomoso mango was procured from a local farmer at Ogbomoso, Oyo State Nigeria with (latitude and longitude 8.1335˚N and 4.2538˚E), respectively. The fruit was matured and partially ripe (stage three in ripening chart) mango.

2.2 Preparation of the samples

Mango was sorted to select good ones, washed peeled, and then cut into different slice thicknesses of 3, 6, and 9 mm. The sliced mango samples were dried using three drying methods: oven (40, 45 and 50 °C), solar and sun drying methods. Six hundred (600) grams each of slice samples was placed in drying trays (stainless steel) of dimension 50 cm by 27 cm for thin layer drying.

2.3 Drying Procedures of Mango Samples

An oven dryer (Gallenkamp BS oven, UK) was used to dry mango at selected drying temperatures of 40, 45, and 50 °C, with air velocity of 2.5 ms^{-1}. The oven was set at chosen drying temperatures and allowed to run for 1 h (before placing the mango sample in the oven) to allow the oven to equilibrate. After placing the samples in the oven, the samples were weighed at intervals of 30 min throughout the drying process until three consecutive weights were constant [3].

For solar dryer, locally made solar dryer which is located at Owoduni Processing Laboratory, Ladoke Akintola university of Technology Ogbomoso was used for this experimental work. The drying trays with the samples (3, 6, and 9 mm thickness) were placed inside the solar dryer. The samples were weighed every 30 min until three consecutive readings were constant.

For sun drying, samples were spread on the drying trays and placed directly under the sun. The weights of the samples were measured every 30 min and the drying continued until three consecutive readings were constant. After each day drying, the samples were placed inside a desiccator until the next day to prevent rehydration. Sample were taking bfor each drying methods at an interval of one hour into the laboratory to determine Ascorbic acid and β-Carotene value.

2.4 Determination of Ascorbic acid and

Standard method of AOAC [11] was used to determine the ascorbic acid and β-carotene.

2.5 Determination of Kinetic model for ascorbic acid and β-carotene degradation

A kinetic model for ascorbic acid and β-carotene degradation during the oven, solar and sun dryer was obtained using a dynamic test approach [12]. An empirical first-order kinetic model was used as shown in Equation 1.

$$-\frac{dc}{dt} = kc \tag{1}$$

where, c is the concentration either of ascorbic acid or beta-carotene (normalize with respect to initial concentration). The first-order rate constant (k) was Arrhenius temperature dependence [12] as shown in Equation 2.

$$k = k_0 \exp\left(-\frac{E_a}{RT}\right) \tag{2}$$

where, k_o and E_a have moisture functionality.

2.6 Determination of Half-life and D-value

Half-life for each drying methods was determined by using rate constant (k) according to the method of [13] as presented in Equation 3

$$\text{Half-life} = {}^{0.693}/_{k} \tag{3}$$

The time required to reduce ascorbic acid and β-carotene concentration by 90% (D-values) was determined according to the methods of [9] as shown in Equation 4

$$D = \frac{K_T}{2.303} \tag{4}$$

3. RESULTS AND DISCUSSION

3.1 Effect of Drying Temperature on Vitamin Contents

Drying temperature has a significant impact on vitamin content as higher temperatures lead to greater losses, particularly in heat sensitive vitamin such as vitamin C due to thermal degradation. The effects of temperature on ascorbic acid and β-carotene are as presented in Figures 1 and 2, respectively which are discussed as follow;

3.2 Ascorbic acid content

The effect of drying on ascorbic acid content of dried mango slice was presented in Figure 1. The initial value of ascorbic acid fresh mango samples used in this research were, 190.01 mg/100 g. Effect of ascorbic acid in human system resulted into scurvy, a disease characterized by weakness and loosing of teeth [14]. At a drying temperature of 40 °C, the values of ascorbic acid measure during drying ranged from 78.810 to

190.011; 68.634 to 190.011 and 60.659 to 190.011 mg/100 g for slice thicknesses of 3, 6 and 9 mm, respectively. There was a significant difference in the ascorbic acid content ($p \leq 0.05$) for all the slice thicknesses. Samples that were oven dried at a temperature of 45 °C had the ascorbic values ranging from 48.536 to 190.011; 39.842 to 190.011 and 30.760 to 190.011 mg/100 g for slice thicknesses of 3, 6 and 9 mm, respectively. There was a significant difference in the ascorbic acid content ($p \leq 0.05$) for all the slice thicknesses. Also, at a temperature of 50 °C the values of ascorbic acid of mango slices during drying ranged from 42.584 to 190.11; 36.595 to 190.011 and 30.027 to 190.011 mg/ 100 g respectively, for slice thickness of 3, 6 and 9 mm. There was a significant difference in the ascorbic.

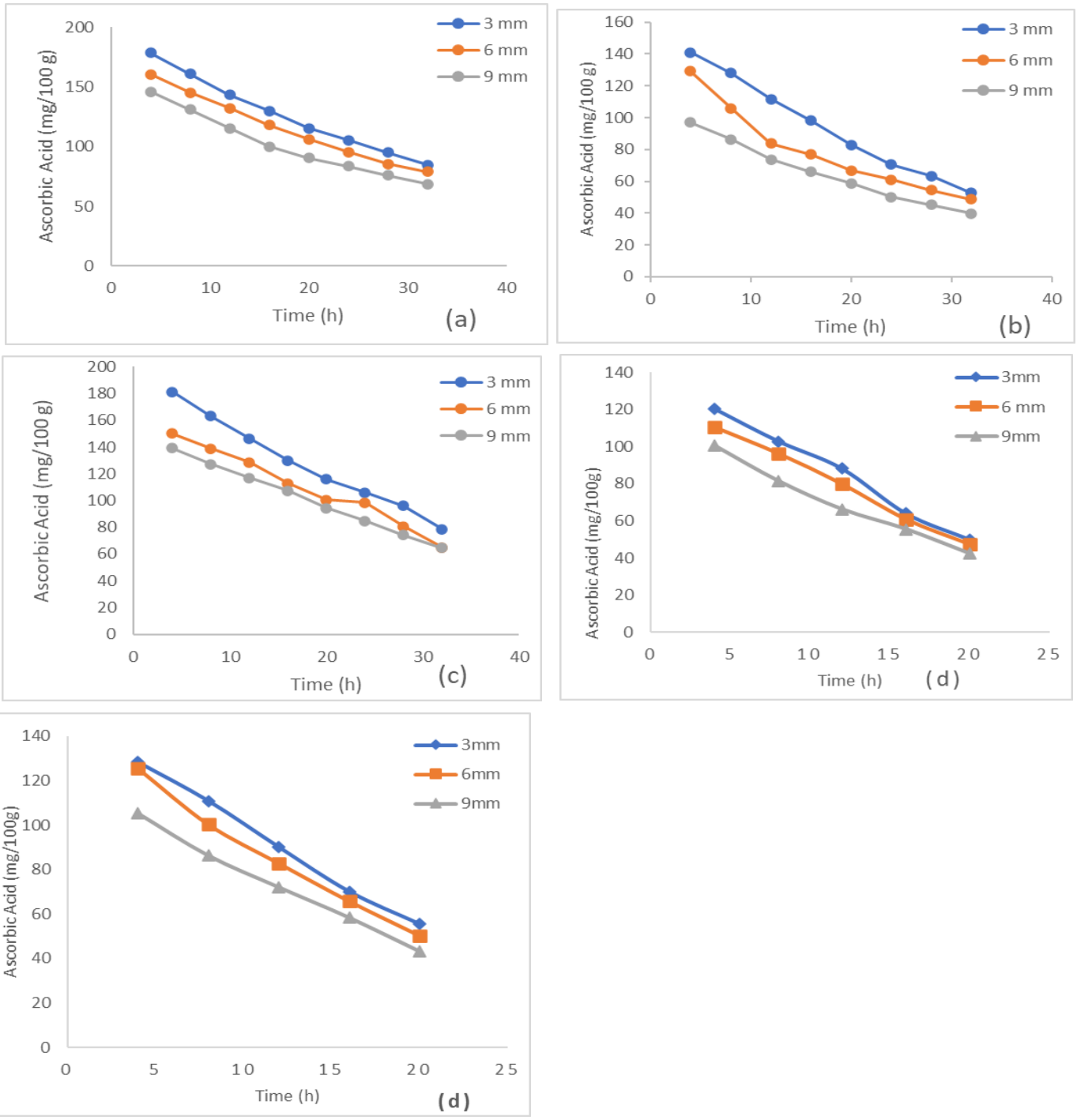

Figure 1: Graph of ascorbic acid content against time using (a) oven 40 °C, (b) oven 45 °C, (c) oven at 50 °C, (d) solar drying and (e) sun drying

acid content ($p \leq 0.05$) for all the slice thicknesses. The values of ascorbic acid for solar dried samples ranged from 50.021 to 190.011; 47.406 to 190.011 and 42.308 to 190.011 mg/ 100g, at slice thicknesses of 3, 6 and 9 mm, respectively, while that of sun dried samples were 55.431 to 190.011; 50.406 to 190.011 and 43.308 to 190.011 mg/ 100 g at the same slice thicknesses. There was a significant difference in the ascorbic acid content ($p \leq 0.05$) for solar and sun dried sample and for all the slice thicknesses. It was observed that as temperature increased, the values of ascorbic decreased with increase in temperature. Furthermore, it was observed that as thickness increased the ascorbic acid content decreased for all oven drying temperatures (40, 45 and 50 °C). This is because as slice thickness increased, it took a longer time for it to dry, which indicates that samples with larger slice thickness was exposed to more heat which degraded the ascorbic acid content of the samples. The result was in line with that of [15] and [16], who reported that higher temperature reduced ascorbic acid of okro slice; and the longer the heat process and the higher the temperature, the more the adverse effect on ascorbic acid content because it is a heat labile vitamin.

Furthermore, it was noted that an increase in slice thickness led to a decrease in ascorbic acid content across the oven drying temperatures (40, 45 and 50 °C). This is because as slice thickness increased, it took a longer time for it to dry, which indicates that samples with larger slice thickness was exposed to more heat which degraded the ascorbic acid content of the samples. The result was in line with that of [15] and [16], who reported that higher temperature reduced ascorbic acid of okro slice; and the longer the heat process and the higher the temperature, the more the adverse effect on ascorbic acid content because it is a heat labile vitamin.

3.3 Beta-carotene content

The effect of drying on β-carotene content of the dried mango samples is as presented in Figures 2a-e. The initial value of β-carotene for fresh mango slice was 5.773 mg/100 g. β-carotene is an essential vitamin which is responsible for good eye sight, prevent night blindness and essential for regeneration of rhodopsin [17]. The values of β-carotene ranged from 2.743 to 4.653; 2.000 to 4.358 and 1.915 to 4.20 mg/ 100 g for slice thicknesses of 3, 6 and 9 a significant difference ($p \leq 0.05$) in β-carotene values at different slice thickness. It was observed that as slice thickness increased, the values for β-carotene reduced because it took longer time for samples of larger slice thicknesses to dry. From the result obtained, the sample dried at 40 °C had the highest β-carotene (2.743) and the smallest values was obtained from samples dried at 50 ºC (2.362 mg/100 g) which shows that heat has an adverse effect on β-carotene. This result is in harmony with that of [18], who suggested that exposure of vegetable to high temperatures or sunlight destroys β-carotene and that better retention can be obtained from drying with low temperature or under shade.

The values of β-carotene for solar drying ranged from 3.100 to 4.621; 3.000 to 4.321 and 2.601 to 3.992 mg/100 g for 3, 6 and 9 mm slice thicknesses, respectively. There was a significant difference in β-carotene values for all slice thicknesses considered in solar drying. The β-carotene values of sun-dried samples ranged from 3.353 to 4.763; 3.173 to 4.54 and 2.905 to 4.029 mg/100 g for slice thicknesses of 3, 6 and 9 mm, respectively. There was no significant ($p > 0.05$) difference among β-carotene values for all slice thicknesses throughout the drying time for sun-drying. For oven dried mango samples, the β-carotene values for oven drying at temperature of 40 ºC was higher (in all slice thicknesses), follow by sample dried at 45 ºC while sample dried at 50 ºC had the least values of β-carotene. It was observed that reduction in the values of β-carotene occurred because of its sensitivity to heat. Sun dried samples had higher values of β-carotene compared with solar dried samples, because the solar drying temperature was higher than the sun drying temperature.

3.4 Degradation Kinetics of Ascorbic Acid and β-carotene

The result of degradation kinetics of ascorbic acid and β-carotene during the drying of mango is as discussed below.

3.4.1 Ascorbic acid

Figure 3a-e shows the linear regression equations that were used to calculate the degradation rate constants for each mango slice and at different drying methods (temperature of 40, 45 and 50 °C solar and sun). It was observed that there is a decrease in ascorbic acid content of mango slices in all the drying methods used. Also, straight line graphs were obtained in all the graphs plotted and the values of correlation coefficients greater than 0.9 which indicates that the plot follow a first order kinetics ([19], [9] and [15]). From the plot (Figure 3), the slope of the graph yielded degradation rate constants which was obtained from regression lines and was presented in Table 1. The values of degradation rate constants are useful in optimization of process control which is applicable in blanching and drying in the food industry.

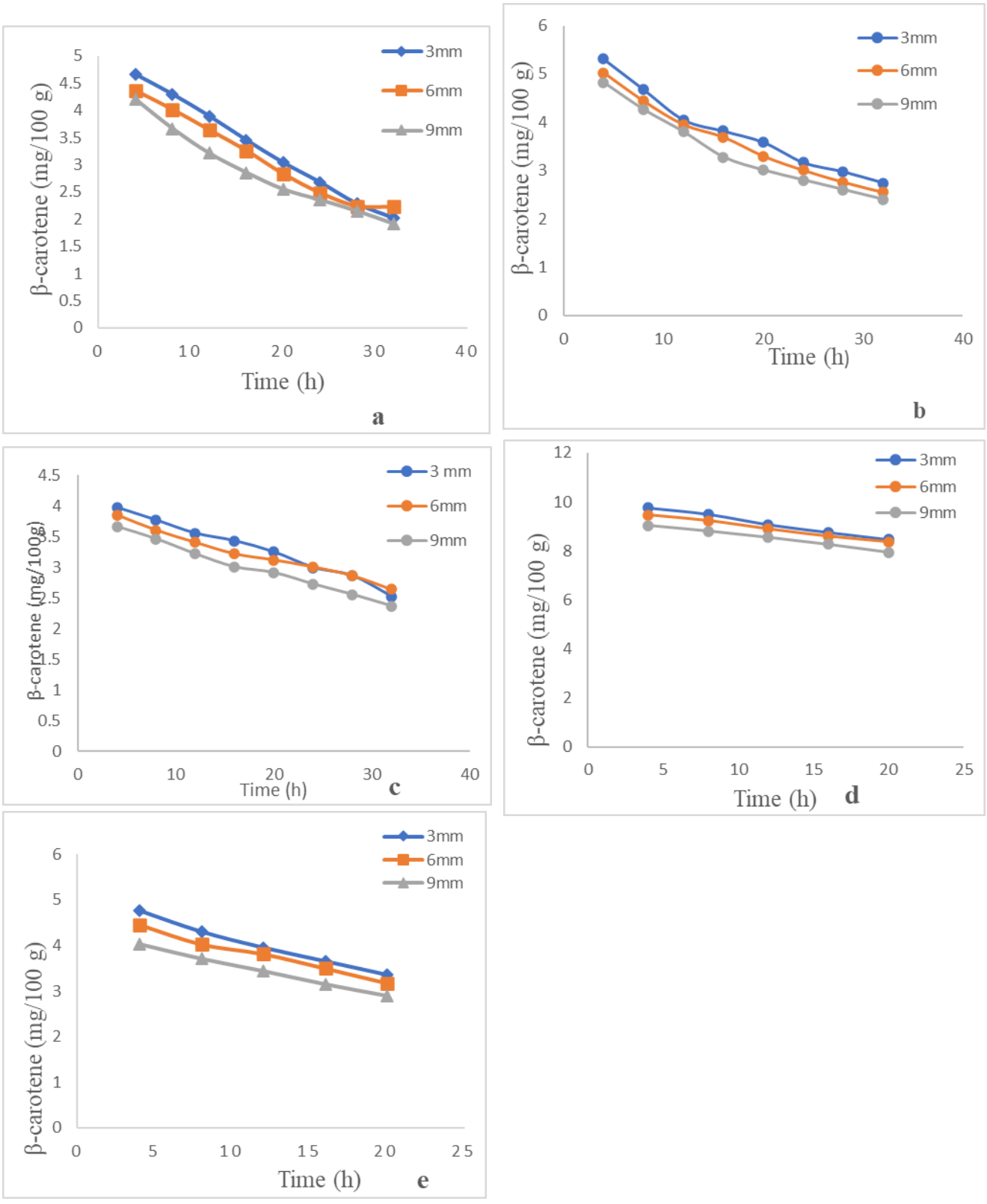

Figure 2: Graph of β-carotene content against time for all the drying methods using (a) oven 40 °C, (b) oven 45 °C (c), oven at 50 °C, (d) solar drying and (e) sun drying

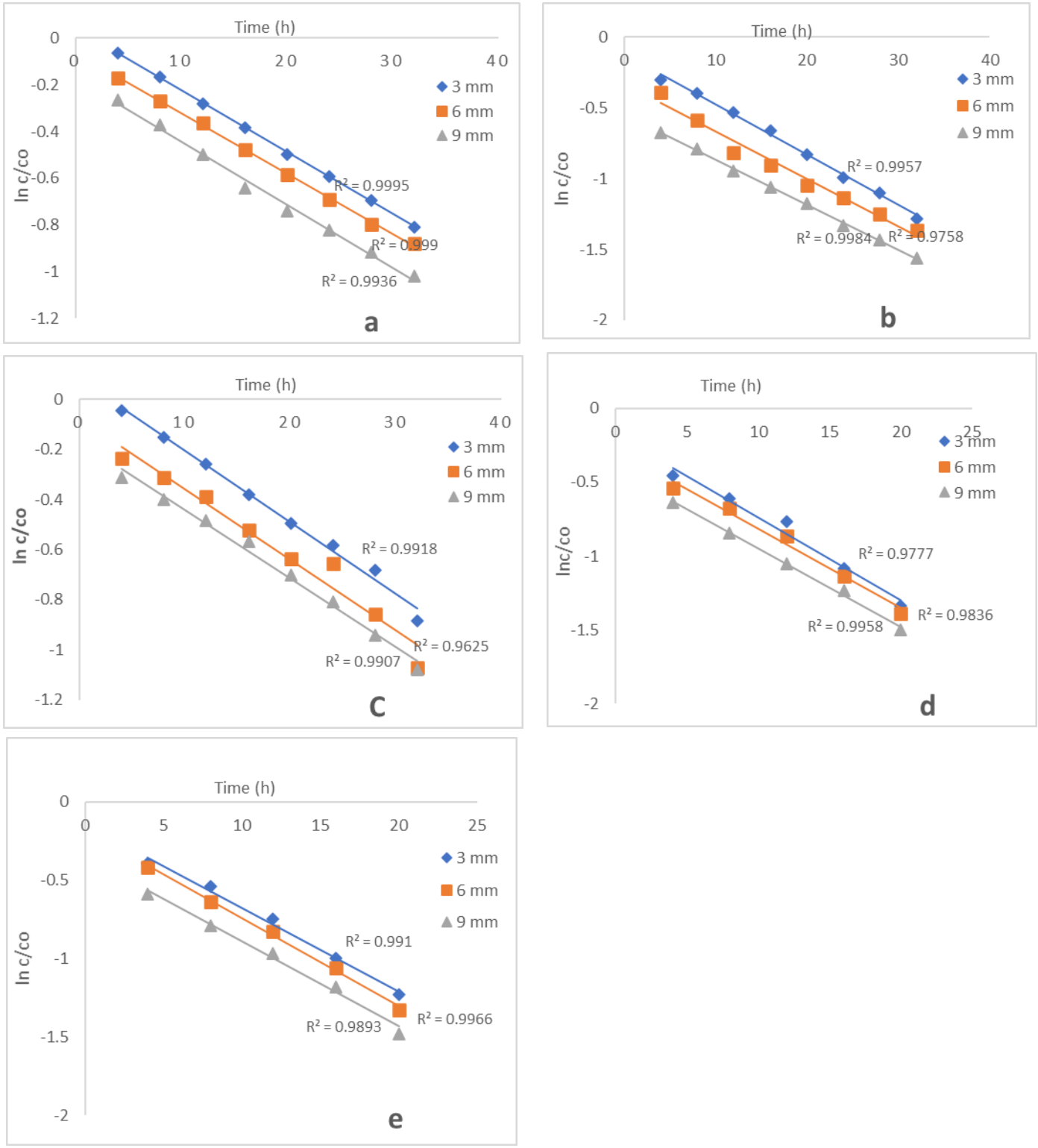

Figure 3: Graph of ascorbic acid degradation of mango slices for all the three drying methods using (a) oven 40, (b) oven 45 (c), oven at 50 °C, (d) solar and (e) sun drying

Table 1: Regression equations for degradation, R^2 and D values of ascorbic acid for dried mango slices

Drying Methods	Slice Thickness (mm)	Regression equation for degradation	R^2	$t_{1/2}$	D x 10^{-2}
40 °C	3	y = -0.0259x - 0.0615	0.999	1605	92.75
	6	y = -0.0265 + 0.0419	0.999	1569	92.75
	9	y = -0.0270 - 0.1729	0.9936	1540	83.37
45 °C	3	y = -0.0270 - 0.1706	0.9907	1540	74.25
	6	y = -0.0283 - 0.0769	0.9625	1469	73.73
	9	y = -0.0285x - 0.0789	0.9918	1459	70.34
50 °C	3	y = -0.0320x - 0.5489	0.9984	1299	70.34
	6	y = -0.0356x - 0.1201	0.9957	1168	69.04
	9	y = -0.0356x - 0.1201	0.9957	1168	67.48
Solar	3	y = -0.0529x - 0.4195	0.9958	786	146.16
	6	y = -0.0538x - 0.2771	0.9836	773	145.12
	9	y = -0.0557x - 0.1833	0.9777	747	141.16
Sun	3	y = -0.0534x - 0.1400	0.991	779	140.17
	6	y = -0.0543x - 0.3481	0.9893	766	139.17
	9	y = -0.0561x - 0.18	0.9966	741	137.82

It was observed that degradation rates increased with increase in drying temperature as presented in Table 1. The mean value of rate constant at drying temperature of 40 °C was 0.0265 min^{-1}; for 45 °C was 0.0279 min^{-1}; for 50 °C was 0.0344 min^{-1} while that of solar and sun were 0.0541 min^{-1} and 0.0546 min^{-1}, respectively. The range of values of rate constant for the three drying methods/temperatures considered are 0.0259 - 0.05342 min^{-1}; 0.0265 - 0.05342 $min^{-1}$and 0.0270 - 0.0561 min^{-1} for slice thicknesses of 3, 6 and 9 mm, respectively. Samples that were oven dried had the lowest values while samples that were dried using solar had the highest values for all the drying methods considered. The result obtained was in line with that of [9] during the thermal degradation kinetic of pawpaw and potato and [15] during degradation kinetic of okro slices. Half- life of mango samples reduced as drying temperature increased for each slice thickness, this means that the time required for mango degrading to 50% of its original value of ascorbic acid reduced as drying temperature increased. The value of D values ranges from 83.37 - 92.75 $x10^{-2}$; 70.34 - 74.25 $x10^{-2}$; 67.48 - 70.34 $x10^{-2}$; 141.16 - 146.16 $x10^{-2}$ and 137.82 - 140.17 $x10^{-2}$ for sample dried at 40, 45, 50 °C, solar and sun, respectively. It was observed that D-value decreased as temperature increased. The values obtained were lower compared to the value obtained by [20], during degradation kinetics of ascorbic acid and β-carotene in mango juice.

3.4.2 β-carotene

Figures 4a-e shows the linear regression equations and were used to calculate the degradation rate constant for each mango slice and at different drying methods (temperature of 40, 45 and 50 °C, solar and sun). It was observed that there was a decrease in β-carotene content of mango slices. Also, straight line graphs were obtained in all the graph plotted and the values of correlation coefficient were greater than 0.9 which indicate that the plot follow a first order kinetics [20] and [15]. From the plot of Figure 4, the slope of the graph yielded degradation rate constants which were obtained from regression lines and presented in Table 2. The values of degradation rate constant is useful in optimization of process control which is applicable in blanching and drying operations in food industry. It was observed that degradation rates increased with increase in drying temperature as presented in Table 2. Rate constant for the 40, 45 and 50 °C were 0.0142 min^{-1}, 0.0239 min^{-1} and 0.0282 min^{-1} while that of solar and sun

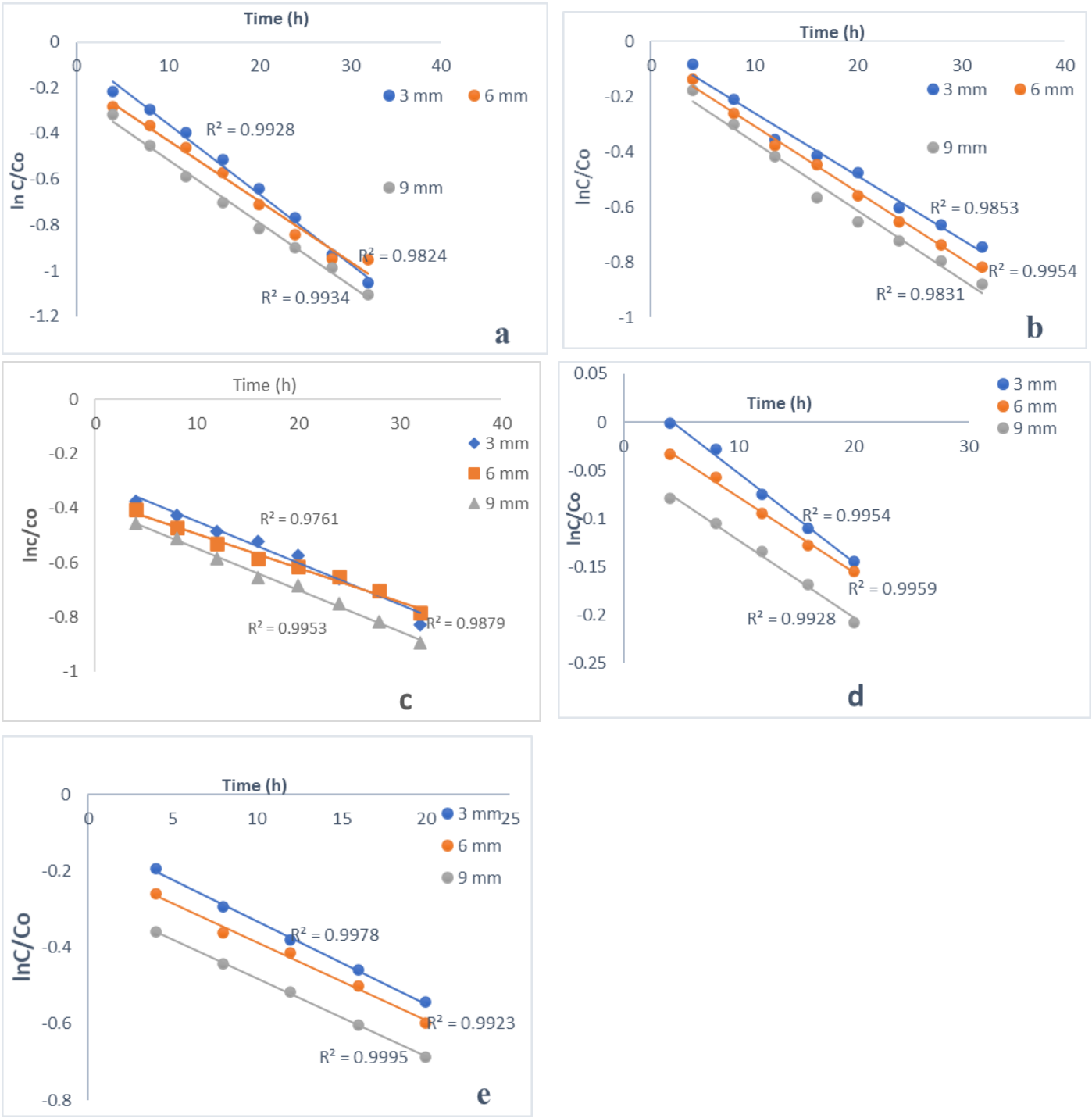

Figure 4: Graph of β-carotene degradation of mango slices for all the three drying methods using (a) oven 40 °C, (b) oven 45 °C (c), oven at 50 °C, (d) solar and (e) sun drying

Table 2: Regression equations for degradation, R^2 and D values of β- carotene for dried mango slices

Drying Methods	Slice Thickness (mm)	Regression Equation for Degradation	R^2	$t_{1/2}$	$Dx10^{-2}$
40 ºC	3	Y= -0.0125x – 0.3688	0.9879	3326	79.70
	6	Y= -0.0147x – 0.3378	0.9961	2829	71.40
	9	Y= -0.0153x – 0.9953	0.9953	2718	69.00
45 ºC	3	Y= -0.0229x – 0.0304	0.9853	1816	64.90
	6	Y= -0.0239x – 0.0682	0.9954	1740	62.30
	9	Y= -0.0249x – 0.1166	0.9831	1670	59.70
50 ºC	3	Y= -0.0265x – 0.1649	0.9824	1569	39.90
	6	Y= -0.0274x – 0.2403	0.9934	1518	38.30
	9	Y= -0.0306x – 0.0519	0.9928	1359	32.60
Solar	3	Y= -0.0078x + 0.0040	0.9959	5331	56.30
	6	Y= -0.0080x – 0.0426	0.9928	5198	53.40
	9	Y= -0.0093x + 0.0372	0.9954	4471	53.10
Sun	3	Y= -0.0204x – 0.2770	0.9950	2038	24.20
	6	Y= -0.0205x – 0.1812	0.9923	2028	20.80
	9	Y= -0.0216x – 0.1137	0.9978	1925	20.30

were 0.0082 and 0.0208 min^{-1}, respectively. The range of values of rate constant for the three drying methods/temperatures considered are 0.0078 - 0.0204 min^{-1}; 0.0080 - 0.0274 min^{-1}; 0.0093 - 0.0306 min^{-1} for slice thicknesses of 3, 6 and 9 mm, respectively. Samples that were dried using solar had the lowest values while samples that were dried using oven at 50 °C had the highest values for all the drying methods considered. The result obtained was in line with that of [19] during Kinetics of degradation of ODAP in *Lathyrus sativus*; [15] during degradation kinetics of okro slices. Half- life of mango samples reduced as drying temperature increased for each slice thickness, this means that the time required for mango degrading to 50% of its original value of ascorbic acid reduced as drying temperature increased. The result obtained was in agreement with that of [15], during degradation kinetics of okro slices. The D values ranges from 69.00 to 79.70 $\chi 10^{-2}$, 59.70 to 64.90 $\chi 10^{-2}$, 32.60 to 39.9 $\chi 10^{-2}$ 53.10 to 56.30 $\chi 10^{-2}$ and 20.30 to 24.20 $\chi 10^{-2}$ for samples dried at 40, 45, 50 ºC solar and sun, respectively. It was observed that D-value decrease as drying temperature increase for all the drying methods considered.

4. CONCLUSION

Sliced mango of different thicknesses (3, 6 and 9 mm) were dried using different drying methods, oven temperature (40, 45, 50 °C), solar dried and sun dried. There was a significant difference in the residual ascorbic acid content of mango for all slices at difference dying temperatures and drying methods. Furthermore, β-carotene values reduced with increase in drying temperature for all slices and different modes of drying. Half-life of ascorbic acid and β-carotene of mango reduced as temperature increased for each slice. D-value decreased as temperature increased for both ascorbic acid and β-carotene in all the drying methods considered. It is recommended that drying at lower temperature (40 ºC), sun drying and at slice thickness (3 mm) should be employed because it retain more ascorbic and B-carotene values of mango slices. From this study, it was concluded that ascorbic acid was observed to degrade with increase in temperature, because it is heat-labile.

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