The Effect of Drying Method on the Texture, Color, Vitamin C and β-Carotene Content of Dried Mango Slices (*Cv. Apple and Kent*)

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Abstract. Drying is the oldest method of food preservation. However, the drying method can adversely affect the product quality. This work shows the effect of solar, oven and integrated solar-oven drying methods on the texture, color, vitamin C and β-carotene content of dried mango slices (apple and kent variety). The vitamin C and β-carotene content were measured by UV-Vis spectrophotometer, texture by texture profile analyzer (TPA) and color by spectrophotometer. There is a non-significant effect ($p > 0.05$) on the texture and color apple and kent mango, but significant effect ($p < 0.05$) on the vitamin C and β-carotene content. Apple mango had 72.38 mg/100 g vitamin C and 91.05 μg/100 g β-carotene content and kent mango 66.72 mg/100 g vitamin C and 73.80 μg/100 g β-carotene content. The drying method significantly affect ($p < 0.05$) the texture, color, vitamin C and β-carotene content of dried mango slices. The mango slice structure was become harder in texture and darkens in color. The hardness (5.12 N), color change (48.44), browning index (30.67) and the loss of vitamin C (74.57%) and β-carotene (45.74%) were high in oven dryer as compared to the other drying method. The springiness (1.36) and chewiness (2.13 N) were high in solar dyer. Integrated solar-oven drying method is the best method in terms of keeping the product quality and short processing time.

Keywords: Mango · Drying · Texture · Color · Vitamin C · β-Carotene

1 Introduction

Mango (Mangifera indica L.) is a seasonal flesh stone fruit, widely grown in tropical and subtropical regions. Mango is a healthy and nutritious fruit containing a high amount of nutrients, dietary fiber, bioactive compounds (pro-vitamin A, vitamin C, and phenolic compounds), and minerals (potassium, iron, and calcium) [1–3]. Mango is seasonal and highly perishable fruit due to its high moisture content and respiration rate after harvesting [4, 5] affects its availability in the market and causes wastage of this highly nutritious fruit. Mango can be consumed as a fresh or processed form.

Mango can be preserved by processing it into different forms of products such as concentrate, juice, fruit leather, dried slices, chutney and pure [6]. Drying is the oldest

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and commonly used preservation method used to extend the shelf life of fruits and reduce postharvest loss. For mango drying, numerous suitable drying technologies are available with their advantage and disadvantages [7]. The choice of drying method depends on the availability of the technology and the required sanitary condition. It is easy to access sun and solar drying in the tropical and sub-tropical regions, oven drying the most available technology in the developing countries.

However, the drying method and conditions (temperature and drying time) adversely affect the quality of the dried foods [8–10], especially the flavour, colour, texture, and heat-sensitive bioactive compounds. Vitamin C and carotenoids are the most heat-sensitive compounds when exposed to heat during drying. Mango is reported as the main source vitamin C (100% daily recommended intake) and pro-vitamin A (36% daily recommended intake). Colour is the primary perceived feature of foods that plays a significant role in consumer acceptance [11, 12]. The colour change of dried fruits is mainly associated with carotenoid degradation during exposure to heat, oxygen and light. In addition to the color of the product, the texture and flavour also play an important role in the consumer acceptance of products [11]. Texture is one of the sensory attributes of foods, in which represents the deformation, disintegration and flow of foods under the applied force by molar teeth. The texture change of dried agricultural products is due to the enzymatic and non-enzymatic changes on the cell wall components of the material [13]. The color and texture can be measured either objectively (instrumental) or subjectively (sensory) test [8, 14, 15]. Nevertheless, the sensory evaluation is often an ambiguous. Because many of the consumers are unable to accurately determine the properties of the material and different people perceives differently [16, 17]. Most of the previous studies conducted on fruit drying mainly use freeze drying, oven drying, microwave drying, etc. and there is lack of information on solar drying and integrated solar-oven drying method. The aim of this research work was to measure the effect of solar, oven and integrated solar-oven drying method on the texture, color, vitamin C and β-carotene content of dried mango slices (Apple and Kent cultivars).

2 Material and Method

2.1 Raw Material Collection and Experimental Site

Two fully ripe mango varieties (Kent and Apple mango) were collected from *Deq Deset* (Deq Peninsula), *Amhara region*, Ethiopia and further processed at Bahir Dar institute of Technology. All the experiments were carried out in the Food Engineering Department laboratories, at the Faculty of Chemical and Food Engineering, Bahir Dar Institute of Technology, Bahir Dar University.

2.2 Raw Material Preparation

The mango samples were washed with tap water to remove foreign matter such as dirt and other contaminates, followed by blanching at 50 °C for 10 min and further cooling. The washed fruits were peeled and sliced manually using a domestic peeler and a knife.

2.3 Drying of Mango Slices

The drying process of mango slices was performed in three different methods (solar drying, integrated solar-oven drying and oven drying method), until the final moisture content of the dried products reached 10 ± 5%. For the solar-oven integrated drying method, solar drying was performed until the intermediate moisture content reached 35 ± 5%, and then placed in oven dryer at 70 °C. The solar dryer prepared in-house by the faculty of Chemical and Food Engineering, Bahir Dar Institute of Technology was used for this purpose. The temperature and the relative humidity (RH) of the solar dryer during the drying time were recorded using Temperature and RH Data logger. Temperature and RH data logger is a device which can measure both the temperature and RH of the solar dryer.

2.4 Experimental Analysis

2.4.1 Moisture Content

The initial, intermediate and final moisture content of the mango slices was determined by the method used by [18] official method of analysis. The moisture content was expressed on a wet basis using the following equation:

$$MC = \frac{Ww}{Ww + Wd} \tag{1}$$

Where:

MC – moisture content, g of water/g of dry matter, in wet basis.
Ww – weight of water, g
Wd – weight of dry matter, g

2.4.2 Vitamin C Content Determination

The extraction and determination of vitamin C was based on the method used by [19, 20]. Ten gram (10g) mango sample was measured in 100 ml test tube containing 50ml of 5% metaphosphoric acid and 10% glacial acetic acid solution. The sample was homogenized and diluted up to the 100 ml with 5% metaphosphoric acid and 10% glacial acetic acid solution. The obtained solution was centrifuged at 4000 rpm for 15 min and filtered through Whatman filter paper no. 42, to obtain clear solution for UV spectrophotometric determination of vitamin C in the sample. About 30 ml of 3% bromine water was added into the clear sample solution to oxidize the ascorbic acid into dehydroascorbic acid, and a few drops of 10% thiourea solution were added to remove the excess bromine. Standard solutions of ascorbic acid (2, 4, 8, 12, 16 and 20 ppm) were prepared from a stock solution of ascorbic acid by proper dilution. Then 1 ml of 2, 4-DNPH solution was added to form osazone. For the completion of the reaction, all the standards, samples, and blank the solution were kept at 37 °c for 3 h in a thermostatic water bath. After this, all of those were cooled in an ice bath for 30min and treated with 5 ml of 85% H_2SO_4 with constant stirring. The absorbance was taken at 521 nm using UV spectrometer (Cary 60 UV – Vis, Malaysia).

2.4.3 β-carotene Content Determination

The extraction and determination procedure of beta-carotene was based on the method used by [21]. A representative sample of 1g was accurately weighed in a glass test tube containing 5 mL chilled acetone, and held it for 15 min with occasional shaking, and finally centrifuged at 1500 rpm for 10 min. The supernatant was collected into another test tube, and the residue was re-extracted with 5 mL acetone followed by centrifugation once again as above. Both of the supernatants were mixed together and filtered thought Whatman filter paper no. 42. Standard solutions of β-carotene (0.125, 0.25, 0.5, 1, 2 and 4 ppm) were prepared from a stock solution of β-carotene by proper dilution. The absorbance of the extract was determined at 449 nm wavelength in UV-spectrometer (Cary 60 UV – Vis, Malaysia).

2.4.4 Texture Profile Analysis

Stable Micro System Texture Analyser (TA.XT Plus, Surrey, UK) was used to measure the texture profile of fresh and dried mango slices. The texture analyser was calibrated by adding 2kg of calibration weight on the top of the texture analyser. According to the method used by [22], the samples were compressed twice to 5mm depth (60% of the original height) by 2 mm cylindrical probe with a trigger force of 5 g at 3 mm/s pre-test, 2 mm/s test and 10 mm/s post-test speed. During the double compression of the mango slices it draws a force vs time graph. From the force vs time curves the maximum force of first cycle (F1), maximum force of second cycle (F2), area under first curve (A1), area under second curve (A2), time elapsed from area 1 above positive y axis (T1) and time elapsed from area 2 above positive y axis (T2) were used for the expression of the texture profile. The texture attributes of the dried mango slices were calculated by the following equation [13]. The fresh mango reading was used for comparison.

$$Hardness, H = F1 \tag{2}$$

$$Springness, S = \frac{T2}{T1} \tag{3}$$

$$Cohessiveness, C = \frac{A2}{A1} \tag{4}$$

$$Chewiness, CW = H * S * C \tag{5}$$

2.4.5 Colour Evaluation

The method used by [13] was used to determine the color of fresh and dried mango slices based on the color scale of Commission International de I'Ecairage (CIE) using Spectrophotometer (CM-600d Spectrophotometer, Konica Minolta Inc., Japan). CIE used L*, a*, b* to express the color of samples and measured against white standard. L* represents lightness (0 for black and 100 for white), a* expresses red (+) or green (−) and b* expresses yellow (+) or blue (−). The experiment was made in six replication and the average value was used to calculate the color change (ΔE), Chroma (ΔC), hue angle (h) and browning index (BI) by the following equation described by [13, 23]. The fresh mango reading was used as a reference and indicated by the subscript 'o'.

$$\text{Change in color } (\Delta E) = \sqrt{\left(L_0^* - L^*\right)^2 + \left(a_0^* - a^*\right)^2 + \left(b_0^* - b^*\right)^2} \tag{6}$$

$$\text{Change in Chroma } (\Delta C) = \sqrt{a^{*2} + b^{*2}} \tag{7}$$

$$\text{Hue Angle(h)} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \tag{8}$$

$$\text{Browing index (BI)} = \frac{100(x - 0.31)}{0.17} \tag{9}$$

$$x = \frac{a^* + 1.75L^*}{5.64L^* + a^* - 0.01b^*} \tag{10}$$

2.5 Data Analysis

The data were measured in triplicates and SAS software (9.1.3 version) was used to analyze the result. Significance was accepted at 0.05 level of probability ($p < 0.05$). Mean separation was performed by Duncan multiple range test for multiple comparisons of means. Microsoft Excel 2013 was used to plot the graph.

3 Result and Discussion

3.1 Temperature, RH and Moisture Content

The solar drying was performed for three different days from May 27–29/ 2019 and the average value was presented in Fig. 1 below. The average maximum solar dryer temperature was measured as 39.51 °C with 33.64%RH, and the lowest average minimum solar dryer temperature was 30.57 °C with 48.91%RH (Fig. 1). The [24] report shows the average actual temperature during the experiment day was 25.65 °C, respectively at the experiment site in Bahir Dar, Ethiopia. During the day of the experiment, there is a significant difference in the daily temperature and RH value. April, May, and June are the sunniest month in Ethiopia. The sliced mango initial, intermediate and final moisture content was 0.84 g/g water, 0.34 g/g water and 0.13 g/g water for apple mango and 0.83 g/g water, 0.35 g/g water and 0.14 g/g water for kent mango as shown in (Fig. 2) in wet basis.

3.2 Calibration Curve

The absorbance of all standards was used to construct a calibration curve, by plotting the concentration versus the corresponding absorbance as shown in Fig. 3 and 4. The limit of detection (LOD) and the limit of quantification (LOQ) of vitamin C were 2.91 μg/ml and 8.81 μg/ml, respectively. The limit of detection (LOD) and the limit of quantification (LOQ) of β-carotene were 0.72 μg/ml and 2.17 μg/ml, respectively.

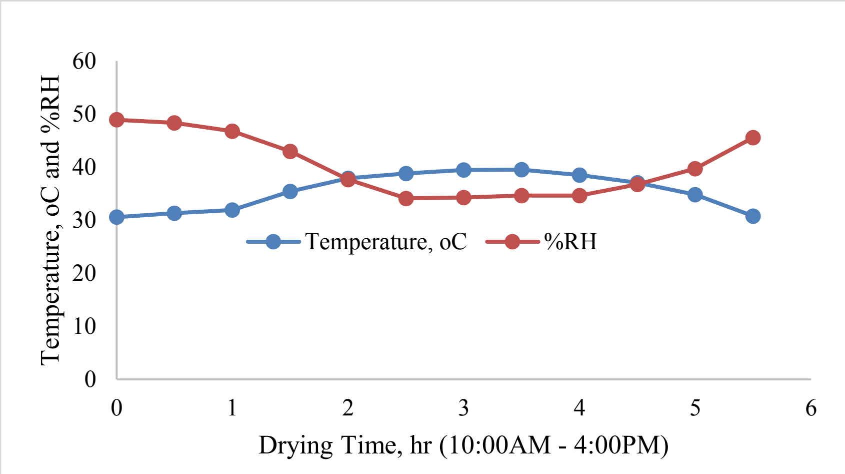

Fig. 1. Temperature and RH of Solar Dryer vs Drying time

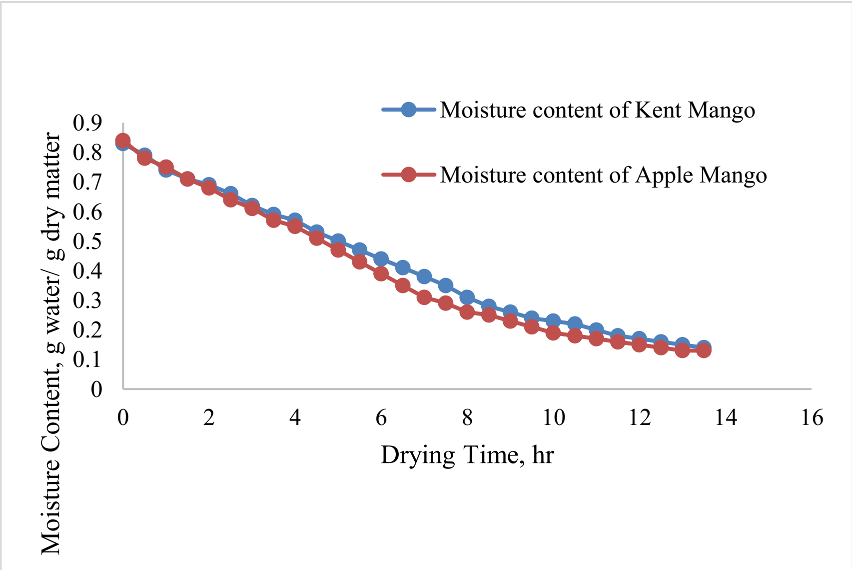

Fig. 2. The Moisture content of Apple and Kent mango variety with Drying Time

3.3 Vitamin C and β-carotene Content

The result in (Table 1) indicates the vitamin C and β-carotene content of fresh apple and kent mango fruit variety, used for comparison of the effect of drying method on the dried sample. Statistically speaking, there is a significant difference ($p < 0.05$) between the fresh apple and kent mango vitamin C and β-carotene content. Apple mango variety has had a high content of vitamin C (72.38 mg/100 g) and β-carotene (91.05 µg/100 g)

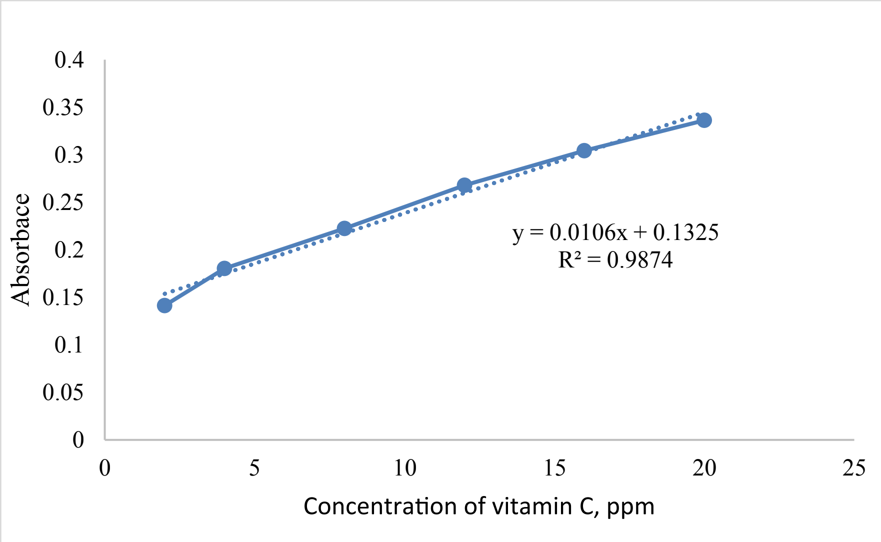

Fig. 3. The calibration curve of Vitamin C

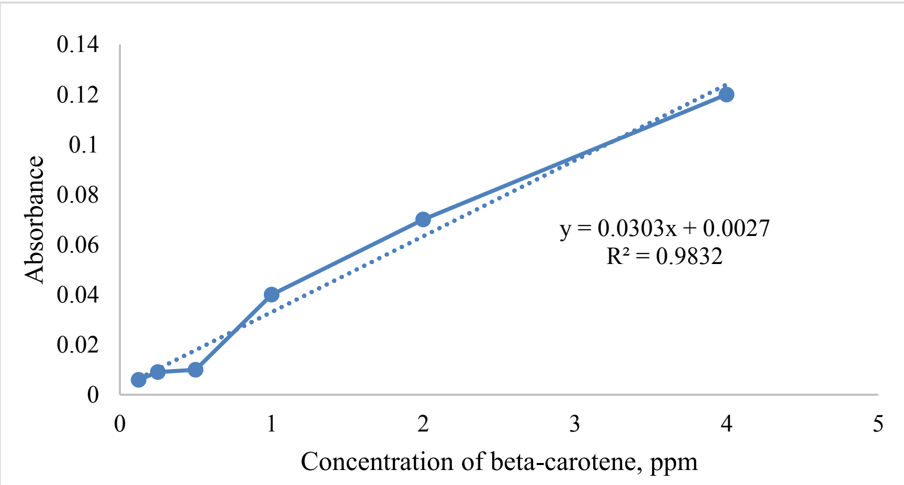

Fig. 4. The Calibration Curve of beta-carotene

content than the kent mango variety (66.72 mg/100 g and 73.80 µg/100 g), respectively. This would be due to that; the nutritional composition would be varied with cultivars [25–28]. The result in (Table 2) indicates the effect of the drying method on vitamin C and β-carotene content of dried mango slices. The vitamin C and β-carotene content of the mango were significantly decreased ($p < 0.05$) with the drying method. The solar dryer was observed higher retention of the vitamin C (83.98%) and β-carotene (71.09%), and lower retention was observed in oven drying method (25.43%) vitamin

C and (28.76%) β-carotene. The retention capacity of the integrated solar-oven drying method was an intermediate value between the solar and oven drying method (60.47% Vitamin C and 54.26% β-carotene). The high drying temperature of the oven dryer also diminishes the vitamin C and β-carotene content of the mango slices greatly. The solar dryer had a minimal effect on the vitamin C and β-carotene content of the mango slices as compared to the oven and integrated solar-oven drying method, but the long drying time (more than 3 days of drying) it takes, contamination with dust and other foreign material, and variability of the solar intensity makes it unsuitable method. The loss of vitamin C and β-carotene of integrated solar-over drying method were 23.51% and 16.83%, respectively, as compared to the solar dryer. This would be due to that; most vitamins are susceptible to heat [29]. The study of [30] indicates the drying of fruit at a higher temperature (100 °C) reduces the vitamin C content significantly. This study indicates that the use of integrated solar-oven drying method can be used as an alternative method to the solar drying method. The result table (Table 3) also indicates the interaction effect of variety and drying method on the vitamin C content and β-carotene content. The result shows drying significantly affects the vitamin C and β-carotene content of the two cultivars dried mango slices as compared to the fresh mango. The average loss of the three drying method (48.68%) was high in kent mango than apple mango variety (38.48%). The highest loss was observed in oven drying method (83.95%) for kent and (65.90%) for apple variety. However, the average loss of β-carotene was higher in apple mango (51.97%) than kent mango variety (44.49%), whereas kent mango variety oven drying method was registered as the highest loss (74.84%) of β-carotene.

Table 1. Effect of variety on the vitamin C and β-carotene content of mango

Variety	Vitamin C, mg/100 g	β-carotene, μg/100 g
Apple	72.38 ± 0.43 a	91.05 ± 0.50 a
Kent	66.72 ± 0.33 b	73.80 ± 0.40 b

Mean ± Standard Deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

Table 2. Effect of drying method on the vitamin C and β-carotene content of mango

Drying method	Vitamin C, mg/100 g	β-carotene, μg/100 g
Solar drying	58.41 ± 4.45 a	58.60 ± 1.11 a
Oven drying	17.69 ± 7.66 c	23.71 ± 5.63 c
Solar-oven integrated	42.06 ± 4.83 b	44.73 ± 2.19 b

Mean ± Standard Deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

Table 3. Interaction effect of variety and drying method on the vitamin C and β-carotene content

Variety	Drying method	Vitamin C, mg/100 g	β-carotene, μg/100 g
Apple	Solar drying	62.46 ± 0.21 a	59.58 ± 0.37 a
	Oven drying	24.68 ± 0.26 e	28.85 ± 0.20 e
	Solar-oven integrated	46.46 ± 0.32 c	42.76 ± 0.53 c
Kent	Solar drying	54.36 ± 0.46 b	57.63 ± 0.33 b
	Oven drying	10.71 ± 0.51 f	18.57 ± 0.14 f
	Solar-oven integrated	37.65 ± 0.28 d	46.70 ± 0.23 d

Mean ± Standard Deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

3.3.1 Texture Profile Analysis

The result in (Table 4) indicates variety had no significant effect ($p > 0.05$) on the texture attributes, however, the hardness, cohesiveness, springiness, and chewiness of apple mango had a higher value than the kent mango. The result in (Table 5) indicates that there is a significant effect ($p < 0.05$) of the drying method on the texture attributes of fresh and dried mango slices. The hardness, cohesiveness, springiness, and chewiness were significantly affected by the drying method. The hardness of dried mango slices was significantly increased ($p < 0.05$) with the drying method (1.47 N, 4.93 N and 5.12 N) for solar, integrated solar-oven and oven drying method, respectively as compared to the fresh mango (0.81N). This could be since heating would disrupt the cell wall structure of the mango slices and increases the strength of the mango slices. This was in agreement with the study of [13]. The hardness was higher in oven and integrated solar-oven drying method, due to the higher drying temperature (70 °C). The study of [16] shows that increasing the drying temperature by 10 °C increases the hardness. Similarly, the chewiness also increased with respect to the hardness. The cohesiveness (1.08) and springiness (1.36) of solar-dried increased significantly ($p < 0.05$), as compared to that of the fresh mango slices (0.83 and 1.06), respectively. However, the cohesiveness (0.47) and springiness (0.56) of integrated solar-oven dried and that of oven-dried (0.39 and 0.48), respectively, decreased significantly as compared to that of the fresh mango slices (0.83 and 1.06). This could be due to drying at a lower temperature (solar drier 36.37 °C, average), which is not enough to break the cellular structure of mango slices. This would increase the elasticity and the mastication energy under a given force. In the integrated solar-oven and oven drying methods, the drying process was fast relatively at a higher temperature, which was enough to break the structure of the mango slices. The study of [13] was in agreement with this result but does not show a significant effect ($p > 0.05$) for springiness. The study of [11] indicates the hardness and chewiness were decreased while the cohesiveness and springiness were increased.

Table 4. Effect of Variety on the Texture attributes of two mango varieties

Variety	Hardness, N	Cohesiveness	Springiness	Chewiness, N
Apple	3.09 ± 2.05 a	0.73 ± 0.37 a	0.89 ± 0.39 a	1.38 ± 0.79 a
Kent	3.08 ± 2.00 a	0.65 ± 0.29 a	0.84 ± 0.36 a	1.18 ± 0.57 a

Mean ± Standard Deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

Table 5. Effect of drying method on the texture profile of dried mango slices

Drying method	Hardness, N	Cohesiveness	Springiness	Chewiness, N
Fresh	0.81 ± 0.11 c	0.83 ± 0.22 b	1.06 ± 0.06 b	0.71 ± 0.21 c
Solar drying	1.47 ± 0.29 b	1.08 ± 0.26 a	1.36 ± 0.14 a	2.13 ± 0.65 a
Oven drying	5.12 ± 0.35 a	0.39 ± 0.10 c	0.48 ± 0.08 d	0.94 ± 0.29 c
Solar-oven integrated	4.93 ± 0.42 a	0.47 ± 0.12 c	0.56 ± 0.08 c	1.32 ± 0.45 b

Mean ± standard deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

3.4 Color Analysis

The result in (Table 6) shows the effect of mango variety on the color parameters. It was observed that mango variety has no significant effect ($p > 0.05$) on the color parameters. However, the result in (Table 7) indicates there is a significant effect ($p < 0.05$) of the drying method on the color parameter of mango slices. The lightness (L*) of fresh mango (65.28) significantly decreased ($p < 0.05$) to 57.33 for solar, 47.68 for integrated solar-oven and 36.77 for oven drying. This indicates that the mango slices go through darker as drying proceeds.

Table 6. Effect of variety on the CIE colour scale and colour parameter of dried mango slices

Variety	L*	a*	b*	Colour change	Chroma change	Hue angle	Browning index
Apple	51.01 ± 11.71 a	19.77 ± 4.33 a	40.31 ± 15.93 a	34.58 ± 14.63 a	28.23 ± 11.44 a	89.35 ± 0.15 a	29.66 ± 4.23 a
Kent	52.47 ± 11.85 a	17.55 ± 2.16 a	43.30 ± 16.87 a	31.03 ± 16.43 a	26.11 ± 13.29 a	89.46 ± 0.21 a	25.72 ± 6.83 a

Mean ± standard deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

The oven-dried samples were going through the darkness ($L^* < 50$). Drying of high moisture content foods (~85%) at a higher temperature (70 °C) causes the darkness of the foods due to non-enzymatic reactions [13]. The mango slices were slightly light-colored in integrated solar-oven drying ($L^* \sim 50$) and in the solar drying method ($L^* >$

Table 7. Effect of drying method on the CIE colour scale and colour parameter of dried mango slices

Drying method	L*	a*	b*	Colour change	Chroma change	Hue angle	Browning index
Fresh	65.28 ± 2.39 a	18.36 ± 1.80 a	61.71 ± 3.00 a	–	–	–	–
Solar	57.33 ± 6.79 b	19.44 ± 4.55 a	48.86 ± 10.48 b	16.92 ± 9.10 c	14.31 ± 7.61 c	89.58 ± 0.14 a	23.81 ± 6.71 b
Oven	36.77 ± 3.28 d	16.94 ± 3.28 a	22.73 ± 5.51 d	48.44 ± 6.71 a	39.12 ± 5.42 a	89.24 ± 0.11 c	30.67 ± 4.15 a
Integrated Solar-Oven	47.68 ± 4.86 c	19.89 ± 3.73 a	33.90 ± 5.86 c	33.06 ± 9.41 b	28.11 ± 7.40 b	89.39 ± 0.12 b	28.58 ± 4.81 a

Mean ± standard deviation
Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

50), as the majority of the moisture was removed at a lower temperature. Similarly, this can affect the redness (a*) and yellowness (b*) value of the dried mango slices. The a* value of fresh mango (18.36) was increased in solar drying (19.44) and integrated solar-oven drying (19.89) and decreasing in the oven drying method (16.94). Similarly, the b* value of fresh mango (61.71) decreased in solar drying (48.86), integrated solar-oven (33.90) and oven drying (22.73). The result in (Table 7), also indicates that the drying method has a significant effect ($p < 0.05$) on the change in color, chroma, hue angle, and browning index. The color, chroma and browning index of dried mango slices were significantly increased ($p < 0.05$) in the solar drying (16.92, 14.31 and 23.51), integrated solar-oven drying (33.06, 28.11 and 28.58) and oven drying (48.44, 39.12 and 30.67) methods, due to none-enzymatic browning reaction. However, the hue angle significantly decreased ($p < 0.05$) from solar drying (89.58) to integrated solar-oven (89.39) and to oven drying (89.24). The study of [11, 13, 31] shows the L* and b* values were decreased significantly, and the value of a* increased significantly with increasing the convective air-drying temperature. The study also shows the color and chroma changes were increased, while the hue angle was decreased which is in agreement with this study. The study of [32] indicates the dried fruit tends darker (redder) as the drying proceeds, due to the increasing of a* values without change of L* values.

4 Conclusion

It was found that mango variety have a significant difference ($p < 0.05$) on the vitamin C and β-carotene content while no significant effect ($p > 0.05$) on the texture attribute and color value. However, the drying method significantly affects ($p < 0.05$) the vitamin C and β-carotene content, texture, and also color. Different drying methods have different retention capacity of vitamin C and β-carotene. The solar dying has a very good retention capacity of vitamin C and β-carotene, while the long drying time makes it unacceptable but oven drying was observed lowest retention capacity. The integrated solar-oven drying method plays a very important role in reducing the long-time taken by the solar dryer and loss of vitamin C and β-carotene in oven drying. The hardness and chewiness were increased significantly ($p < 0.05$) with the drying method (solar, solar-oven integrated and oven) respectively while the cohesiveness and springiness decreased significantly ($p < 0.05$). Similarly, the color scale result shows a significant decrease in the L* and b* value, with an increase in a* value in solar, solar-oven integrated and oven drying method as compared to the fresh mango sample. The change in color and chroma and the browning index was high in the oven drying method and low in the solar drying method, whereas the hue angle was high in solar drying and low in the oven drying method.

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