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Effect of Drying Temperature on Some Quality Attributes of Mango Slices

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ABSTRACT: The objective of this study was to investigate the effect of three drying temperatures (60, 70 and 80°C) on quality attributes of mango slices. The investigated quality attributes were: color change and rehydration ratio of dried mango slices. Result showed that drying temperatures had great effect on the quality attributes of mango slices. The color was measured from the surface and expressed in the Hunter L*a*b* system. Moreover, the total color change (ΔE), chroma (color saturation), hue angle and browning index (BI) were determined. L* and b* parameters were found to decrease as affected by drying temperature and drying time, whereas a* parameter increases. Results also indicated that drying time has significant effect on color change and rehydration ratio. The lowest total color change and highest rehydration ratio were obtained at drying air temperature of 80°C then 70°C and finally 60°C with drying time of 3,5 and 7 hours, respectively. In contrast to common practice, drying at elevated air temperature (80°C), instead of 60°C for a longer time, was optimal, since significant color changes of mango slices were not observed. Moreover, at increased temperature, drying time was considerably shortened from about 7 h to 3h, resulting in significant extension of drying capacity.

KEYWORDS: Drying temperature; Mango; Quality; Color change; Rehydration ratio.

1 INTRODUCTION

Mango (*Mangifera indica* L.) is one of the tropical and subtropical fruit of great importance for both economical and nutritional point of view. It is considered to be a good source of carbohydrates; vitamin C and very rich source of pro-vitamin A. Since industrial capacities for the processing of highly perishable mangoes into storable products are limited due to seasonal over production of the fruits, drying of excess and partly defected mangoes is a promising preservation technique, meeting the processing requirements of small and medium-size producer [1]. Beside traditional sun drying by direct solar radiation, solar dryers and conventional overflow dryers are presently used by small-scale enterprises to reduce the water activity. According to common practice for preservative-free as well as sulphited mangoes, drying air temperature ranges between 50 and 60 ºC. During sun and solar drying, even lower maximum temperatures are reached. Consequently, drying usually needs at least 20 h, resulting in low drying capacities or high investments, respectively. Observed quality deficiencies of the dried fruits caused by these long–term processes were mainly discoloration, such as browning or bleaching, and cracked or scorched products, while insufficient drying limits the shelf life of the product due to microbial spoilage. Drying air temperature and drying time were shown to be the primary factors influencing product color and water activity [1]. Currently hot air drying is the most widely used method in post-harvest technology of agricultural products. Using this method, a more uniform, hygienic and attractively colored dried product can be produced rapidly [2].

The rehydration capacity and color characteristics are considered as the most important quality parameters for the dehydrated products. The rehydration capacity is used to express ability of the dried material to absorb water. The largest part of the dehydrated products must be rehydrated during their final use. Rehydration is a process performed in order to obtain an adequate restitution of raw material properties when dried material is in contact with water [3]. In some foods, as dry fruits for breakfast, the rehydration velocity is very important in the judgment of its quality [4].

The first quality judgment made by a consumer on a food at the point of sale is its visual appearance. Appearance analyses of foods are used in maintenance of food quality throughout and at the end of processing. Color is one of the most important appearance attribute of food materials, since it influences consumer acceptability. Abnormal colors, especially those associated with deterioration in eating quality or with spoilage, cause the product to be rejected by the consumer [5]. The deterioration of the color attributes with drying conditions has been widely studied in a large number of fruits, mainly in apple [6], kiwifruit [7], cherries [8] and pineapple [4].

The color measurements can be used in an indirect way to estimate color change of foods, since it is simpler and faster than chemical analysis [7]. Hunter color parameters (L,a,b) have previously proved valuable in describing visual color deterioration and providing useful information for quality control in fruits and fruit products such as sultana grapes[9], concentrated fruit pulp[10], diced apple [11], pear puree [12] and banana [13].There are other parameters derived from Hunter L*,a*,b* scale: the total color difference (ΔE), the saturation index or chroma that indicates color saturation and is proportional to its intensity. The Hue angle is another parameter frequently used to characterize color in food products.

Therefore, the objectives of this study were :(1) to investigate the effect of drying temperatures on color and rehydration ratio of mango slices and (2) to determine the optimum drying temperature for mango slices.

2 MATERIALS AND METHODS

2.1 RAW MATERIAL

Fresh mangoes, var. *Kent*, from Mali, were purchased at the wholesale market in Goettingen, Germany. The mangoes were left for 5days for post-harvest ripening at 25±2ºC and 50% relative humidity [1]. The fruits were then washed, manually peeled using a stainless steel knife, and sliced using an electric food-slicer (Krups variotronic, Germany) to a thickness of 3 mm.

2.2 DRYING EXPERIMENTS

Drying experiments were performed using a convective cross flow cabinet dryer (Heraeus, UT6120, Germany) at temperature of 60, 70 and 80°C. The dryer is consisted of heating unit, temperature control unit, drying chamber and centrifugal fan that has a fixed air velocity of 0.5 m/s. The average initial moisture content of the mango fruit was 82.5±0.4 %(w.b.), as determined using a precision air-oven method, at a temperature of 135°C for 2 hours until constant weight was reached, according to the standard method of AOAC [14] and moisture content on wet basis (w.b.) was calculated by the following equation:

$$MC_{wb} = \frac{W_w}{(W_w + W_d)} \text{ x}100\% \qquad (1)$$

Where:

MC_{wb} = moisture content, percent, wet basis

W_w = weight of water, g

W_d = weight of dry matter, g

Prior to starting the experiments, the dryer was adjusted to the selected temperature for about half an hour to reach thermal stabilization. Then the samples were uniformly spread in a single layer of 3mm thick on a tray. A representative sample of sliced mango for moisture loss assessment was placed in a circular wire mesh of 10cm diameter and placed onto the center of the tray. For the determination of the drying curve and estimation of total drying time, the sample on the circular wire mesh was taken out of the drying chamber and weighed on a digital balance and placed back into the drying chamber every 30 min during the drying process. The digital top pan balance (Sartorius, Goettingen, Germany) of ±0.01g accuracy, was kept near to the drying unit and weight measurement process took less than 10 seconds time. The drying process was stopped when the moisture content decreased to about 9.5±0.2 % (w.b). At the end of the drying process, some of the dried samples were taken for color measurement and the rest were placed in plastic bags and wrapped by aluminum foil and stored at -18C for subsequent quality parameter measurements (rehydration ratio). All the experiments were replicated two times at each air temperature and the average values were used.

2.3 COLOR MEASUREMENT

Color parameters were measured using a Minolta CR-310 Chroma-meter (Minolta, Japan). The chroma meter consisted of a respective measuring head and the data processor. The measuring head of the chroma meter CR-310 uses wide-area illumination and a 0° viewing angle and has 50mm-diameter measuring area to average the reading. Hunter scale (L*, a*, b*) system was used. The instrument was calibrated with a standard white plate at D_{65} illumination before taking measurements (Y=94.3, x= 0.3156 and y= 0.3324) equivalent to HL system: HL = 97.10, a = -0.17 and b= 1.80. Calibration was made at each experiment. The parameter L* represents the brightness of the color, a* the hue range of the colors red (+) and green (-) and b*hue range of colors yellow (+) and blue (-). Three measurements were made on the surface of sliced mango fresh and after drying and average values were made for calculation and each experiment was duplicated. From the color values, total color change (ΔE), chroma (C), hue angle (h) and browning index (BI) were calculated using equations described by Maskan [7] as follows:

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2} \tag{2}$$

$$Chroma = \sqrt{a^2 + b^2} \tag{3}$$

$$\text{Hue angle} = \tan^{-1}(\frac{b}{a}) \tag{4}$$

Where; subscript “0” refers to the color reading of fresh mango slices. Fresh mango was used as a reference and a larger ΔE denotes greater color change from the reference material [7].

$$BI = \frac{[100(x - 0.31)]}{0.17} \tag{5}$$

Where:

$$x = \frac{(a + 1.75L)}{(5.645L + a - 3.01b)}$$

2.4 REHYDRATION RATIO

Rehydration characteristics of the dried products were used as a quality index and they indicated the physical and chemical changes that occurred during the drying and were influenced by processing conditions, sample compositions, sample preparation and extent of structural and chemical disruptions induced by drying [15].

Rehydration ratio was determined according to the official method of AOAC[16], 5g of dried sample was soaked for 60 min in 50 ml distilled water, filtered through filter paper and then the filtrates were weighed (two measurements for each sample). The rehydration ratio (R/R) was used to express ability of the dried material to absorb water. It was determined by the following equation:

$$\text{Rehydration ratio (R/R)} = \frac{W_2}{W_1} \tag{6}$$

Where: W_2 = weight of drained material, g

W_1 = weight of dried material, g

2.5 STSTISTICAL ANALYSIS

Statistical analysis was conducted using Minitab version 16. Significant differences ($p<0.05$) between means were evaluated by one-way ANOVA and Tukey’s test. Results were presented as mean± standard deviation (SD).

3 RESULTS AND DISCUSSION

3.1 EFFECT OF DRYING TEMPERATURE ON DRYING TIME AND MOISTURE CONTENT

The effect of drying temperature on the time required to reach the final moisture content of 9.5±0.2 (w.b.) is shown in Fig. 1. As expected, the moisture content decreased considerably with increasing drying temperature. The time required to reduce the moisture content to any given level was dependent on the drying temperature, being highest at 60°C and lowest at 80°C. The time required to reduce the moisture content of mango slices from 82.5±0.4 % (w.b.) to the final 9.5±0.2 % (w.b.) was 3, 5 and 7 h at 80°C,70°C and 60°C, respectively. It was observed that the main factor influencing drying time was the drying air temperature, as noted in other studies [17],[18]. Thus, a higher drying air temperature produced a higher drying rate and consequently the moisture content decreased faster. This is due to increase of air heat supply rate to the product and the acceleration of water migration inside the mango slices.

3.2 EFFECT OF DRYING TEMPERATURE ON COLOR PARAMETERS

3.2.1 COLOR PARAMETERS L*, a*, b* AND TOTAL COLOR CHANGE (ΔE)

The results of color measurements on fresh and dried mango slices at different drying temperatures are shown in Table 1 and Fig.2. The lightness (L*) and yellowness/ blueness (b*) values of all of the samples decreased from 70.39 to 65.16 and 36.49 to 34.41, respectively. However, the redness/ greenness (a*) value increased from -3.44 to -0.25. All of the color values of fresh mango did not differ significantly from the values of the dried mango slices ($p<0.05$). Among all of the drying temperatures used for mango slices, the closets value to the color of fresh mango slices was obtained at 80°C. While the raw material was characterized by an average greenish shade of the yellow slice surface as represented by a chromaticity coordinate of a*=-3.44±0.14, this values was increased towards positive direction regardless of drying temperature indicating that the sample color shifting to redness. However, all applied air temperatures did not cause browning (a*<1.0). These results are in agreement with findings of Pott et al.[1] (2005). On the other hand, it was observed that the lightness, L*, for mango slices decreased with drying temperature and drying time. Since it is a measure of the color in the light-dark axis, this falling value indicates that the samples were turning darker. It has been stated that the variation in the brightness of dried samples can be taken as a measurement of browning [5], [12]. These findings indicated that the lightness (L*) was inversely correlated with the drying time and drying temperature. These results are in well agreement with those reported by Arsland and Özcan [19] for oven drying of pepper slices, Karabulut et al. [20] for apricot drying and Maskan [7] for kiwifruit drying. The decrease in the L* value can be attributed to the formation of brown pigment during drying [19]. It is clear that browning increases with an increase in drying temperature and time [21], [22]. Avila and Silva [5] examined the color degradation of peach puree as affected by heat treatment. Peach puree became darker, corresponding to a decrease in L* value and an increase in a* value, with increasing temperature. Moreover, the loss of yellowness was also expressed by a decrease in the b* value. They concluded that the major causes of color change were due to carotenoid degradation and non-enzymatic browning (Maillard).

The total color change (ΔE), which is a combination of parameters L*, a* and b* values, is a colorimetric parameter extensively used to characterize the variation of colors in foods during processing. It was calculated from Eq. (2). The color change parameter had lowest value of 7.24 at 80°C (3 h) and highest value of 26.39 at 60°C (7h). Thus, drying temperature and drying time had a great effect on total color change of dried mango slices. An increase in ΔE was observed with drying time and drying temperature (Table 1.). The lowest total color change (Δ E) was recorded at 80°C as shown in Fig. 3. From this result it could be concluded that 80ºC is the optimum drying temperature for mango slices.

3.2.2. CHROMA, HUE ANGLE AND BROWNING INDEX (BI)

The values of the chroma, the hue angle and the browning index were calculated using Eqs. (3) - (5) and are shown in Table.2. The chroma values decreased during drying process and closely followed the b* values (Fig. 3.), and were found to be 36.65, 34.41, 34.49 and 35.44 for fresh, 60°C, 70°C and 80°C, respectively. The chroma value indicates the degree of saturation of color and is proportional to strength of the color. Little change in values of chroma was found between fresh and dried fruit and they were not significant ($P<0.05$) among the drying temperatures considered in this study. This indicates stability of yellow color in mango fruit. On the other hand, the hue angle values were also decreased from about 95.39 to 90.41 during drying process. It suggested reduction from a more green (when Hue>90°) to an orange-red (when Hue <90º) color of dried mango slices. Similar findings were reported by Maskan [7] for color change of kiwifruits, Ramallo and Mascheroni [4]for color change of pineapple and Izli and Isik [23]for dent corn drying. The changes in hue angle values were not significant ($P<0.05$) compared to drying temperatures. Another color parameter is the browning index (BI) which represents the purity of brown color and is reported as important parameters in processes where enzymatic and non-enzymatic browning taking place [24]. In this study, the browning index (BI) values were found to be 65.66, 71.24, 68.52and 67.37 for fresh, 60°C, 70°C, 80°C, respectively. Statistically, the change among the three temperatures, was not significant (P<0.05). However, these results suggested that drying time strongly affected the color quality of mango fruit.

3.3 Rehydration Ratio Of Dried Mango Slices

The capability for fast and complete rehydration is considered to be one of the most important characteristics of dried mango slices. The rehydration ratio of mango was measured at ambient temperature of 20°C. Fig.4. shows rehydration ratio versus drying temperature. It is clear that drying temperature 80°C scored the highest rehydration ratio, then 70°C and finally 60°C. There is decreasing rehydration ratio with increasing drying time. This may be due to changes in the structure/ texture of the samples during long time drying. From these results it could be concluded that 80°C is the optimum drying temperature for mango slices.

4 Conclusions

The results revealed that drying temperature had great effect on color change of mango slices. Increasing the temperature caused a significant decrease in the drying time. Statistical analysis of data revealed no significant difference (P>0.05) among color at the different drying temperatures. However, these results suggested that drying time strongly affected the color quality of mango fruit. Mango slices dried at 80°C had better rehydration ability and less color change than those obtained by 60°C and 70C. Hence, 80°C drying temperature was the best condition for mango quality preservation.

Table 1. Effect of drying temperature on color parameters of mango slices

Treatment	L*	a*	b*	Total color change (ΔE)	Drying time (h)
Fresh	70.39±1.12	-3.44±0.18	36.49±0.5	-	-
60ºC	65.16±1.3	-0.21±0.9	34.41±0.3	26.39±0.77	7
70°C	66.11±1.24	-1.59±0.25	34.55±0.4	22.54±0.14	5
80°C	67.92±1.1	-2.31±0.31	35.36±0.5	7.24±0.13	3

Values are: means ± standard deviation (SD).

Table 2. Effect of drying temperature on Chroma, Hue angle and Browning index of mango slices

Treatment	Chroma	Hue angle (degree)	Browning index (BI)
Fresh	36.65±0.53	95.39	65.66
60°C	34.41±0.95	90.41	71.24
70°C	34.59±0.47	92.64	68.52
80°C	35.44±0.59	93.73	67.32

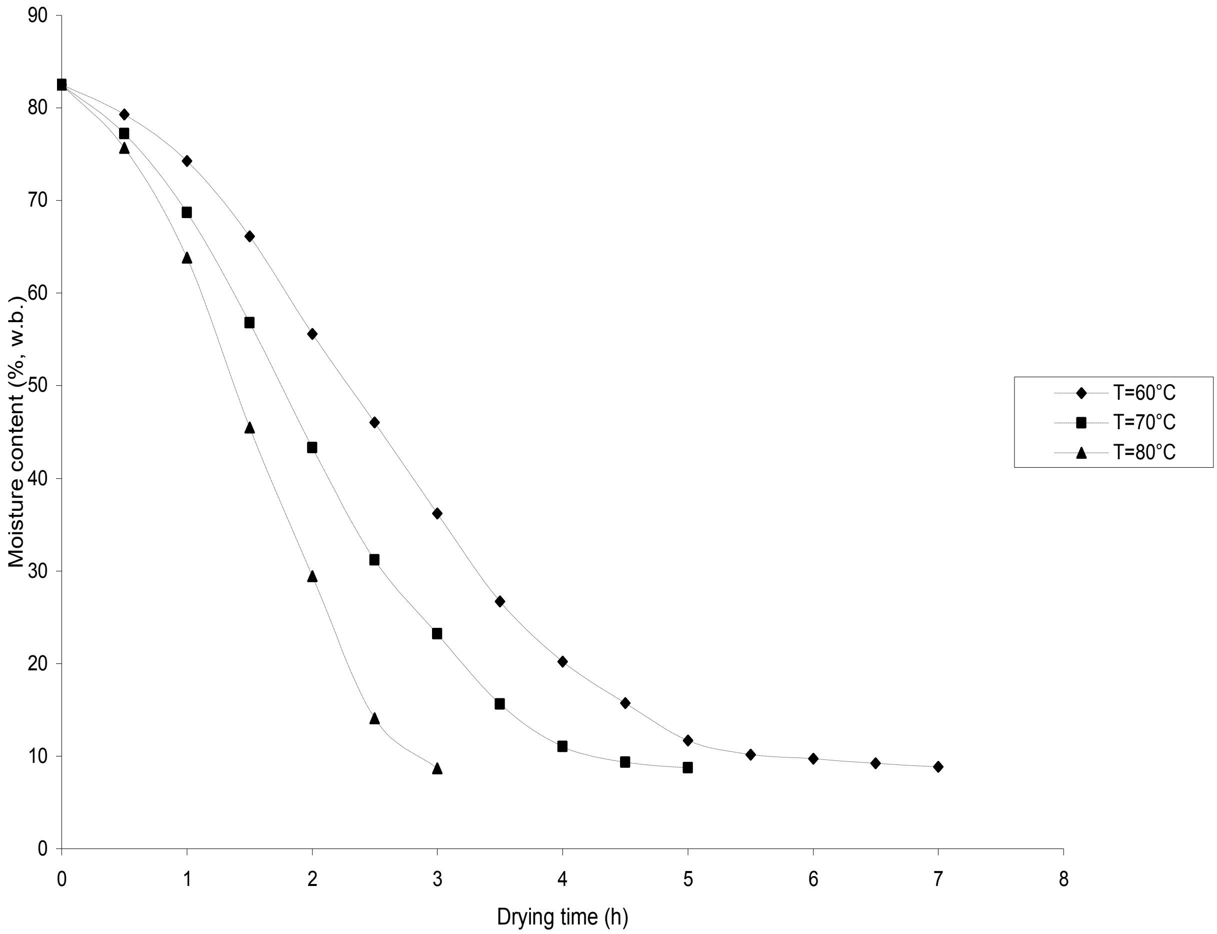

Fig. 1. Effect of drying temperature on the drying time and moisture content of mango slices.

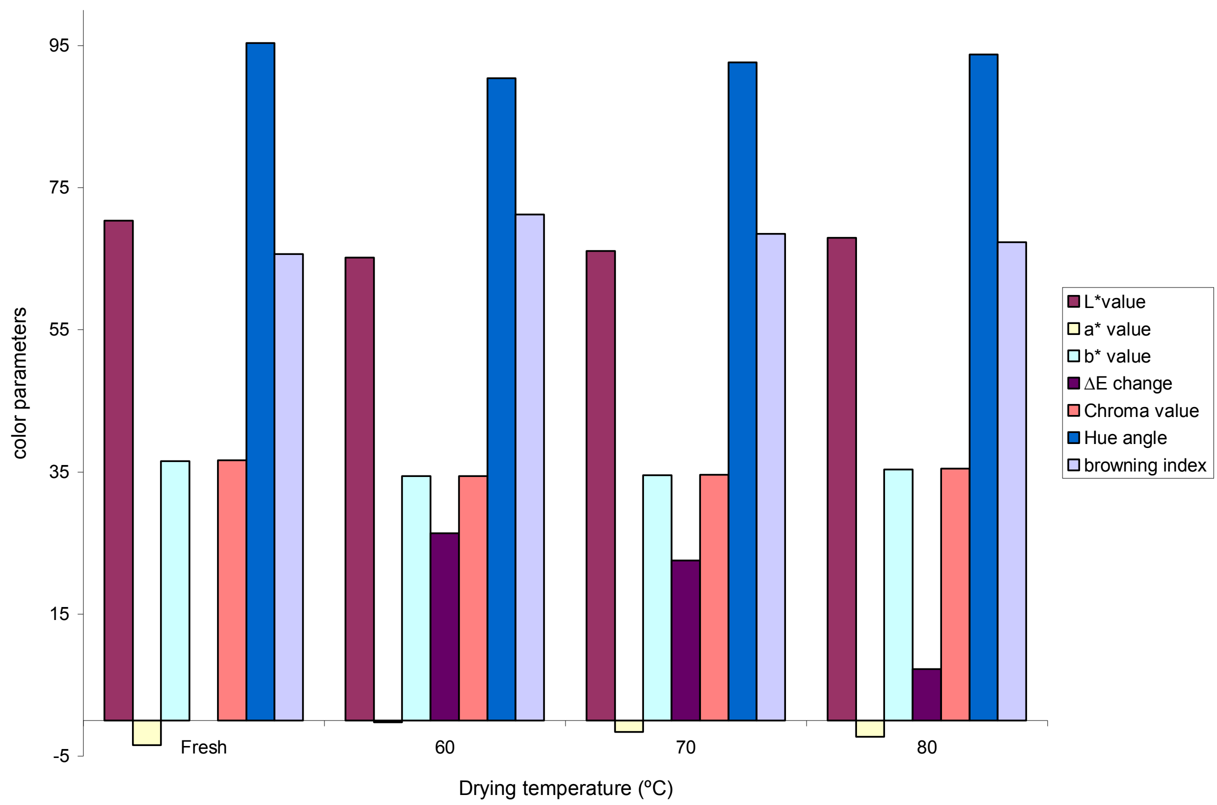

Fig. 2. Effect of drying temperature on color parameters

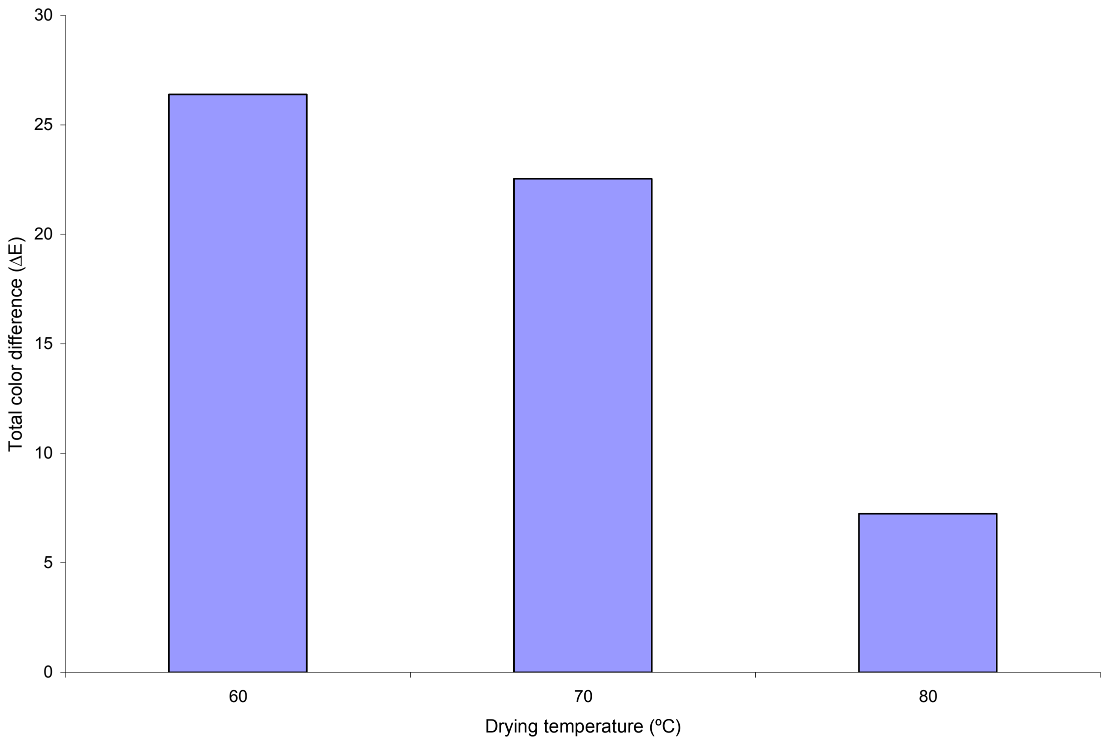

Fig. 3. Effect of drying temperature on total color change (ΔE)

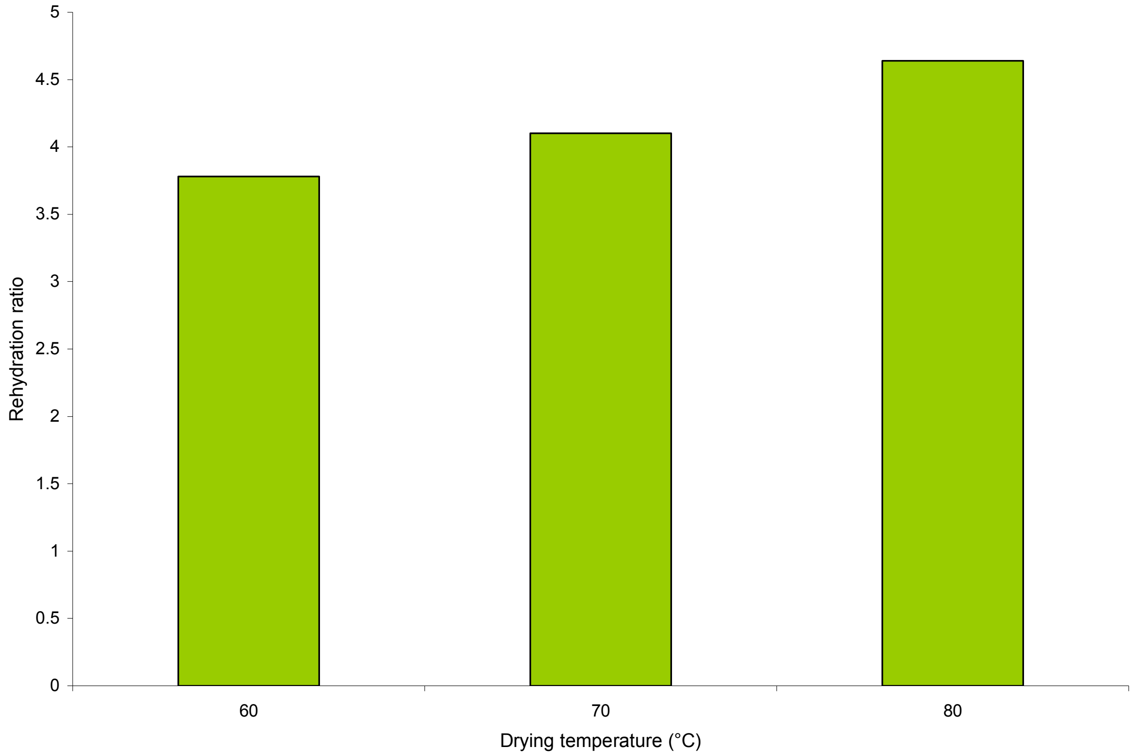

Fig. 4. Effect of drying temperature on rehydration ratio of the dried mango slices.

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