International Journal of Food Science and Biotechnology
2022; 7(3): 47-57
http://www.sciencepublishinggroup.com/j/ijfsb
doi: 10.11648/j.ijfsb.20220703.11
ISSN: 2578-9635 (Print); ISSN: 2578-9643 (Online)

Processing Effects of Drying Methods on Quality Attributes of Mango Chips

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To cite this article:

Mengisst Kassaw Melesse, Shimelis Admassu Emire. Processing Effects of Drying Methods on Quality Attributes of Mango Chips. *International Journal of Food Engineering and Technology*. Vol. 7, No. 3, 2022, pp. 47-57. doi: 10.11648/j.ijfsb.20220703.11

Received: May 10, 2022; **Accepted**: June 15, 2022; **Published**: July 13, 2022

Abstract: The purpose of the study was to determine processing effects of drying on quality attributes of mango chips using a computer-controlled based tray dryer and fluidized bed dryer. Mango is abundantly harvested all year in most poor nations. Fresh mangoes were dried at 60, 70, and 80°C with a slice thickness of 3, 4.5, and 6mm. The ideal drying temperature was 65.72°C, the drying period was 91.53 minutes, and the slice thickness was 5.15mm. The moisture content of thinly sliced mango was well-described ($R^2 \geq 0.099$) using Page model in fluidized bed drying procedures. In addition, it was discovered that employing a fluidized bed to dry at equilibrium took less time (90 minutes) than using a tray dryer (180 min). The texture of the chips was significantly ($P < 0.05$) different with its slice thickness and drying temperature. The longer drying brought harder in texture. The optimum breaking strength was calculated as 6.94 N. The mango chips fried at 150°C with a slice thickness of 5.15mm were likewise highly received by the panelists in terms of color, taste, chewiness, flavor, and overall acceptability, according to the sensory analysis results.

Keywords: Mango, Drying, Kinetic Model, Microstructure, Chips

1. Introduction

The drying method for mango pulp is one of the inherent methodologies to preserve mango fruits. Lately, numbers of different products from mango display prominent due to the markets to increase the value of low price mango due to overproduction in mango season and low-quality mango fruits [5]. The mango pulp contains the fragrance components. It is a fantastic source of vitamins A and C, as well as fiber [2].

The world production of mango is estimated at over 45.22 million tonnes, with a production area of 5.64 million hectares. The normal yield per hectare is 8 tones (Babege & Haile, 2017). Mango fruits are considered as highly perishable food due to their high moisture content. Drying is a proper alternative for post-harvest control particularly in countries like India where exist inadequately stabilized low-temperature passage and styling equipment (Pragati & Preeti, 2016). Physical attributes of mango fruits play a major role in their choice as a raw material for fresh consumption and processing. The weight of the fruit has an economical union on the fruit selling depending on who is to pay for the fruit. Yellow / orange color gives an attraction to fresh fruit consumers thus determining the kind of processed product the pulp can be used for like juices, nectar, jam, dried mango chips, and slices [10].

Postharvest control is essential for prolonging the destruction period of fruits, for improving their supply to the market, and for transporting them over long gaps. Therefore, the right postharvest processing invasion is required to prolong the shelf-life of mangoes. The application of preservatives is essential to boost the global economy which is essential for the inhibition of the post-production and conveyance losses of the fruit world widely [14].

Despite the large amount of fruit cultivated in the nation, Ethiopia's mango fruit processing sector is extremely poor [7]. Mango is currently seen as a viable crop for both the export and domestic markets [4]. In overall, Ethiopia has a lot of potential and a good strategy to increase fruit production for the fresh market and processing for both internal and external trade.

2. Materials and Methods

2.1. Experimental Chemicals and Equipment

The chemicals and reagents used for this research were solvents like distilled water and solutions such as citric acid, Stainless steel containers, refrigerator, stainless steel knife, glass jar, beaker, water bath, spoons, thermometer, aluminum foil, computer-controlled based tray dryer, fluidized bed dryer, plastic containers to wash fruit, spoons, chopping boards, fruit pulper, pH meter, large sealable food grade bins for intermediate storage of pulps, and electronic devices were used in this study.

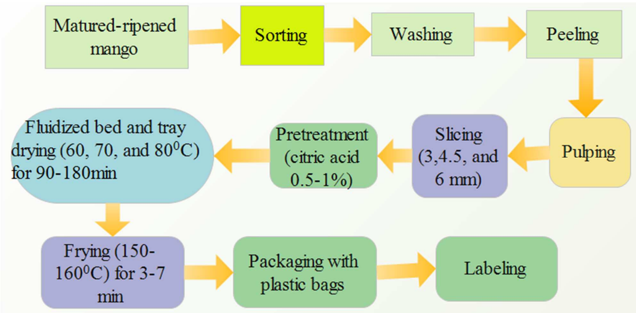

Figure 1. *Processing methods of mango chips (on source).*

2.2. Methods for Proximate and Physicochemical Examination of Mango Pulp and Chips

The All moisture content, protein, fat, crude fiber, carbohydrate, and ash were assessed using AOAC techniques at Addis Ababa Science and Technology University (AASTU), College of Chemical and Biological Engineering, Department of Food Process Engineering laboratory.

All of the chemicals and reagents used in mango analysis.

2.2.1. Moisture Measurement

The sample's moisture content was determined using the methods specified in method 925.09. (AOAC, 2000). The moisture level of mango pulp and chips was determined immediately following each processing stage. Empty porcelain drying plates were dried in a drying oven for 1 hour at 105°C. The plates were placed in desiccators with granular silica gel and chilled for 35 minutes, then weighed to the closest milligram using a computerized analytical balance (W_1). In dried and pre-weighed drying dishes, about 4 g of fresh samples were weighed (W_2).

The dishes and their contents were then placed in a drying oven for 5 hours at 105°C. The dishes and their contents were chilled to room temperature in desiccators before being weighed (W_3). The equation formula may be used to compute the percentage moisture content.

$$\%\text{moisture} = \frac{M_2 \times 100}{M_1} \quad (1)$$

$$\%\text{Total solid} = \frac{M_3 \times 100}{M_1} \quad (2)$$

Where: M_1, M_2, and M_3 are located in the wet base.

M_1 = weight of the wet sample.

M_2 = loss of weight.

M_3 = weight of the dry sample.

2.2.2. Crude Protein

The protein content of the sample was determined based on total nitrogen content by standard Kjeldahl method 979.09 (AOAC, 2000) of crude nitrogen determination. About 0.5 grams of dried sample was digested in 100 mL Kjeldahl digestion flask by boiling with concentrated sulfuric acid (0.1 N) for 2-3 hours and 3 g of Kjeldahl digestion tablet (copper; potassium sulphate mixture) as a catalyst and boiling point raising agent. About 3.5 mL of 30% hydrogen peroxide was added to the digestion mixture after which the teccator tube containing the mixture was set with teccator. The ammonia produced by sodium hydroxide alkalinization is steam distilled into boric acid and titrated with sulfuric acid.

$$\text{Nitrogen molar mass} = (V\text{-}S) \times N \times 14$$

$$\text{g of Nitrogen/100g sample} = \frac{\text{mg of Nitrogen} \times 100}{\text{mg of sample}} \quad (3)$$

$$\text{Total Nitrogen\%} = \frac{(V-S) \times N \times 1.4}{W} \times 100 \quad (4)$$

$$\text{Crude Protein} = \text{Total nitrogen (\%)} \times 6.25 \quad (5)$$

Where V denotes the volume of sulfuric acid solution used in the test material titration.

S=Volume of sulfuric acid solution used in the blank titration.

N denotes the acid's normalcy.

14 = nitrogen equivalence.

W denotes the sample's weight.

2.2.3. The Fat Content

The fat content of the sample was determined using AOAC method 963.15 (AOAC, 2000); fat is extracted with petroleum ether (peroxide free) from dried samples in a soxhlet device, and the remaining fat is evaporated from the extraction flask. The quantity of fat is determined by dividing the weight of the extraction flask before and after extraction by two.

Formula:

$$M = M_2 - M_1$$

$$\text{Fat g/100g fresh sample} = \frac{M \times (100 - \%\text{moisture})}{W_D} \quad (6)$$

Where: M= weight of fat (g);

M_2 = weight of extraction flask after extraction (g);

M_1 = weight of extraction flask before extraction (g);

M_D = weight of the dried sample (g).

2.2.4. Crude Fiber

The crude fiber content of the mango sample was determined using method 991.43 (AOAC, 2003); a fat-free or low-fat content sample is treated with boiling sulfuric acid, followed by boiling potassium hydroxide or sodium hydroxide, and the residue after ash removal is considered fiber.

$$\text{Formula: g/100g crude fiber} = \frac{(M_1 - M_2)(100 - M)}{M_3} \quad (7)$$

Where M_1 denotes the crucible weight before drying (g);
M_2 denotes the weight of the crucible after drying (g);
M_3 denotes the dry weight of the sample (g);
M denotes the sample's moisture content (percent).

2.2.5. The Ash Content

The organic matter is burnt at a low temperature, and the leftover inorganic components are cooled and weighed. Heating is done in phases, first to extract the water, then to fully char the product, and finally to ash at 550°C for 1 hour in a muffle furnace according to AOAC 900.02 procedure (1984).

$$\%\text{Ash} = \frac{M_{2\times 100}}{M_1} \quad (8)$$

Where M_1 is the weight of the sample and M_2 is the weight of the ash.

2.2.6. Carbohydrates

The difference was used to calculate the overall percentage of carbohydrate content using the AOAC's approved technique (2000). This technique includes combining the total values of the mango sample's crude protein, crude fat, and crude fiber, moisture, and ash constituents.

$$\text{Formula: } 100 - (CP + C_1F + CF + A + M) \quad (9)$$

Where: CP = The weight of the crude protein;
C_1F = The weight of crude fat;
CF = The weight of crude fiber;
A = The weight of ash;
M = Moisture content (%).

2.3. Physicochemical Analysis of Mango Chips

The physicochemical analysis for the mango chips (including moisture content, oil content, textural force, total color difference, and vitamin C content) was undertaken at Addis Ababa Science and Technology University (AASTU), College of Chemical and Biological Engineering, Food process Engineering lab. A pH meter was used to measure the pH. At Addis Ababa Science and Technology University, the TSS was estimated using a hand refractometer, the titrable acidity was obtained using the titration technique, the °Brix/acidity ratio was computed, and the vitamin C content was evaluated using the Spectrophotometric method.

2.3.1. Determination of Oil Content of Mango Chips

The oil content was determined using the Soxtec System HT extraction equipment (Pertorp, Inc., Silver Spring, MD) using the AOAC 963.15 [2000] technique as the solvent. The oil content of mango chips was calculated using the ether solubility solvent extraction method (Kemper 2013). In this procedure, about 4 grams of pulverized chip samples were placed in a test tube and 50 mL of ether was added to the test tube. The test tubes containing ether and chip samples were put in a 65°C water bath with constant moderate shaking for 3 hours. The supernatants (oil and ether combination) were placed onto known-weight Petri plates and dried in an oven at 105°C until full desorption. The weight of the Petri-dishes with extracted oil was measured, and the weight of extracted oil content was determined by dividing the weight of the Petri-dishes with extracted oil by the weight of the Petri-dishes without extracted oil. All samples were taken in duplicate.

$$\text{The oil content of mango chips} = \frac{\text{Weight of ether extracted}}{\text{Weight of chips}} \times 100 \quad (10)$$

2.3.2. An Examination of the Texture of the Mango Chips

Texture analysis was performed at Addis Ababa Science and Technology University (AASTU), College of Chemical and Biological Engineering, Food process Texture Analyzer in Engineering Laboratory (Model: TA-Plus, LLOYD instrument, England). NEXYGEN Plus was the program used to analyze the texture. The Volodkevitch biting test was utilized in this laboratory experiment. The greatest shear force necessary to cut the mango chips was used as the dried product's texture index. The force-displacement and energy needed to cut the chips were measured [11].

Mango Chips Color Determination

A Hunter Lab Color Flex-EZ Colorimeter was used to measure the color parameters (Hunter Associates Laboratory Inc., Reston, Virginia, U.S.A.). The "L" value (lightness/darkness), "a" value (redness/greenness), and "b" value (yellowness/blueness) of fresh and fried mango samples were determined using the Hunter Lab Colorimeter. The samples' colors were measured six times, and the mean value was computed. The total color difference (E) of the chip samples was computed using the formula:

$$\text{The overall color difference, } \Delta E = \sqrt{(L - Lo)^2 + (a - ao)^2 + (b - bo)^2} \quad (11)$$

Where Lo, ao, and bo represent the color values of fresh mango slices, while L, a, and b represent the color values of fried mango chips.

2.4. Drying Rate Determination of Mango Slice (Drying Curves for Mango Slice)

Equations (12) and (13) are used to calculate the immediate and initial moisture content of dried chips. Using Microsoft Office Excel, drying curves were created (2010).

$$M_{cx} = \frac{W_x - W_f}{W_x} \times 100 \quad (12)$$

The weight recorded at a given time during drying determines the instantaneous moisture content, Mcx (percent wb). The final weight measured while drying is denoted by wx (g) and wf (g).

$$M_i = \frac{W_i - W_f}{W_f} \times 100 \quad (13)$$

The dry base moisture content is given as M_i (percent wb), the initial weight is given as wi (g), and the final weight is given as wf (g).

2.5. Rate of Drying

Equation was used to calculate the drying rate (2-14). Microsoft Office Excel was used to create drying rate curves (2010).

$$M_R = \frac{M_{t+dt} - M_t}{d_t} \quad (14)$$

DR ($kg.hr^{-1}$) denotes the drying rate, M_{t+dt} (percent wb) denotes the moisture content at time t+dt, M_t (percent wb) denotes the moisture content at time t, and t (hr) is the drying duration.

2.6. Kinetic Modeling of the Mango Slice During the Drying Process

Equation was used to calculate the experimental moisture ratio of the sample (15).

The goodness of fit of the chosen models, presented in (Table 1), to the experimental moisture ratio was determined using non-linear regression. The drying coefficients and coefficient of determination (R^2) for the various drying models were estimated using the Microsoft Office Excel (2010) solver tool. Using equations (15 and 16), the Chi-square (x^2) and Root Mean Square (RMSE) were calculated. The greater the goodness of fit, the higher the R^2 values and the lower the x^2 and RMSE. The drying kinetics of mango chips were represented using empirical models, with experimental data displayed as a dimensionless moisture ratio (MR) vs drying time in minutes. The mango chips' MR was calculated using the following formula:

$$MR = \frac{M_{cx} - M_e}{M_i - M_e} \quad (15)$$

Where MR stands for moisture ratio, M_{cx} stands for instantaneous moisture content, M_e stands for equilibrium moisture content, and M_i stands for initial moisture content (Perumal, 2007).

$$x^2 = \frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{N - Z} \quad (16)$$

x^2 (dimensionless) represents chi-square, $MR_{pre,i}$ (dimensionless) represents the anticipated moisture ratio, $MR_{exp,i}$ (dimensionless) represents the experimental moisture ratio, N represents the number of observations, and z represents the number of constants (Akhijani et al., 2016).

$$RMSE = \frac{(\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})2)^{\frac{1}{2}}}{N} \quad (17)$$

x^2 (dimensionless) represents chi-square, $MR_{pre,i}$ (dimensionless) represents the anticipated moisture ratio, $MR_{exp,i}$ (dimensionless) represents the experimental moisture ratio, N represents the number of observations, and z represents the number of constants [1].

2.7. Moisture Diffusivity That Works

Fick's law of diffusion is often used to explain drying in 11 the decreasing rate, where diffusion is the primary fruit drying mechanism (Hashim et al., 2014). Crank (1975) created Fick's equation solution, which assumes that during the drying time, there is uniform starting moisture distribution, moisture movement is by diffusion, and external resistance is low.

$$MR = \frac{M_{cx} - M_e}{M_i - M_e} = \frac{8}{\pi^2} \exp\left(\frac{-\pi^2 D_{eff}{}^t}{4L^2}\right) \quad (18)$$

As shown in (19), the moisture ratio, MR (dimensionless), Mcx (percent wb) is the instantaneous moisture content, Me (percent wb) is the equilibrium moisture content, Mi (percent wb) is the initial moisture content, Deff ($m^2.s^{-1}$) is the moisture diffusivity, t (s) is the drying time, and L(m) is the half slab thickness (2015). To calculate t, the slope of the lnMR against time graph was utilized.

$$K = \frac{\pi^2 D_{eff}{}^t}{4L^2} \quad (19)$$

The slope, K (dimensionless), was calculated using the lnMR vs time graph given in equation (19) (Olanipekun et al. 2015).

Table 1. *Drying Models selection.*

Model's surname	Model equation	References
Lewis	MR = exp(-Kt)	Deshmukh et al. (2014)
Page	MR = exp(-Kt^n)	Wang et al. (2007)
Pabis and Henderson	MR = aexp(-Kt)	Motevali et al. (2011)
Midilli et al.	MR = aexp(-Kt^n) + bt	Hayaloglu et al., 2002; Midilli et al., 2002 (2007)

The anticipated moisture ratio is MR (dimensionless), the drying constant is k (hr^{-1}), the drying duration is t (hr), and the drying model coefficients are a, b, and n.

2.8. The Microstructure of Mango Chips

An environmental scanning electron microscope was used to examine the microstructure of both treated and untreated mango chips (Model XL30 ESEM-FEG). The ESEM microscope allows for the imaging (under vacuum and with an electron beam) of a wet system (sample) without the need for prior specimen preparation [12].

2.9. Sensory Quality Evaluation of Mango Chips

The sensory evaluation of Tommy Atkins mango chips was carried out by utilizing the 9-point hedonic scale defined by Larmond (1977). The color, flavor, taste, and general acceptability of Tommy Atkins mango chips were examined at random by the arbitrators. The judges were given specific questionnaires to fill out in order to document their views. The performance information gained was as follows: 9 = Like exceedingly; 8 = Like very lot; 7 = Like moderately; 6 = Like somewhat; 5 = Neither like nor dislike; 4 = Deplore slightly; 3 = Dislike pretty; 2 = Dislike not at all. 1 = Dislike extremely. Between people, the panelists expectorated the sponge and rinsed their mouths with clean water.

Observable testing was conducted in a board room devoid of food/chemical odor, undesired sound, and sunshine mixing [1].

Table 2. *The effect of slice thickness on mango chip proximate composition.*

Slice thickness (mm)	**Proximate composition**					
	Moisture (%)	**Protein (%)**	**Fat (%)**	**Fiber (%)**	**Ash (%)**	**Carbohydrate (%)**
3	15.453^{a}	2.241^{a}	2.187^{a}	6.782^{a}	2.102^{a}	71.235^{a}
4.5	16.786^{b}	2.298^{b}	2.206^{b}	6.798^{b}	2.897^{b}	72.015^{a}
6	16.935^{c}	2.352^{c}	2.574^{c}	6.823^{c}	2.894^{c}	72.422^{a}

$^{a-c}$Means in the same column with the same letters are not substantially different (P>0.05).

Table 3. *The effect of drying temperature on mango chip proximate composition.*

Drying temperature (°C)	**Proximate composition**					
	Moisture (%)	**Protein (%)**	**Fat (%)**	**Fiber (%)**	**Ash (%)**	**Carbohydrate (%)**
60	17.058^{a}	2.203^{a}	2.587^{a}	6.282^{a}	1.802^{a}	70.068^{a}
70	16.216^{b}	2.602^{b}	2.306^{a}	7.298^{b}	2.097^{b}	69.481^{b}
80	15.243^{c}	2.501^{c}	2.274^{a}	6.387^{c}	2.194^{b}	71.401^{c}

$^{a-c}$Means in the same column with the same letters are not substantially different (P>0.05).

3. Discussion and Results

3.1. Tommy Atkins Mango Fruit Chips Proximate Analysis

3.1.1. Moisture Value

The proximate analysis results reveal a significant difference (P<0.05) between the moisture content means of the mango chips as a function of drying temperature and drying period. The drying temperature affects the average moisture content of chips. The average moisture content falls as the drying temperature rises from 60°C to 70°C, then to 80°C, to 17.058%, 16.216%, and 15.243%, respectively (Table 3). The results in (Table 2) also show that the moisture content varies with slice thickness.

The moisture content of the chips increased to 15.453%, 16.786%, and 16.935% when the slice thickness was 3mm, 4.5mm, and 6mm respectively. Mangoes' moisture content is reduced by drying from 80-85% to 12-25% [9]. As a result, mango chips have an average moisture content within the specified range.

3.1.2. Protein Concentration

The proximate analysis revealed a significant difference (P<0.05) in average protein content across all drying air temperatures and slice thicknesses. As shown in (Table 3), the average protein content of the chips was 2.602% at 70°C drying temperature, compared to 2.203% and 2.501% at 60°C and 80°C, respectively. Tables 2 clearly demonstrate that as slice thickness increases, so does the average protein level. As a result, at slice thicknesses of 3mm, 4.5mm, and 6mm, the average protein levels of the chips were 2.241%, 2.298%, and 2.352%, respectively.

3.1.3. Fat Content

The proximate analysis results reveal that the fat contents of the chips differed substantially (P<0.05) as a function of the drying air temperature and slice thickness, as stated in (Table 2, 3). As indicated in (Table 2), it can be observed that when the slice thickness increase from 3mm, 4.5mm, and 6mm, the average fat content of the chips increases from 2.187%, 2.206, and 2.574% respectively. Table 3 also shows that the average fat content of the chips decreases from 2.587%, 2.306%, and 2.274% when the drying air temperature increase from 60°C, 70°C, and 80°C respectively.

3.1.4. Fiber Content in Its Purest Form

The mean crude fibers of mango chips differed substantially from one another (P<0.05).

The composition of the chips was influenced by the drying air temperature and slice thickness.

The mean difference of the crude fiber for all drying air temperatures was found to be substantially different. As shown in (Table 3), the average fiber content of 7.298% at 70°C drying temperature was greater than the fiber contents of 6.282% and 6.387% at 60°C and 80°C drying temperatures, respectively. Tables 2 indicate that when slice thickness rises from 3mm to 4.5mm to 6mm, the average fiber content increases by 6.782%, 6.798%, and 6.823%, respectively.

3.1.5. Ash Content

The drying air temperature and slice thickness had a significant (P<0.05) effect on the ash content of the mango chips. The average ash level of the fruit chips reduced from 2.102%, 1.897%, and 1.894% when the slice thickness extended by 3mm, 4.5mm, and 6mm, respectively, as shown in (Table 2). As indicated in (Table 3), the drying air temperature increased from 60°C, 70°C, and 80°C, the ash content of the fruit chips also increased by 1.802%, 2.097%, and 2.194% respectively.

3.1.6. Carbohydrate Composition

The results of the proximate analysis revealed that drying air temperature has a significant influence on the average carbohydrate content of Tommy Atkins mango chips (P<0.05). Table 3 showed that the greater average carbohydrate content of 71.401 percent was detected at 80°C drying air temperature compared to 60°C and 70°C drying air temperatures of 70.068% and 69.481%, respectively. The carbohydrate amount of Tommy Atkins mango chips is significantly affected by the thickness of the slices. As shown in (Table 2), the carbohydrate content rises from 71.235% to 70.015% to 69.422% whether the slice thickness is 3mm, 4.5mm, and 6mm, respectively.

3.2. Physicochemical Analysis of Mango Chips

3.2.1. Determination of Oil Content of Mango Chips

One of the most significant product quality criteria for fried food is oil content. Finding ways to decrease oil absorption while maintaining color and texture is a problem in the frying process. Visual inspection revealed that oil absorption was caused by the mechanism of rapid water evaporation, which created holes in the meal, resulting in regions where oil could accumulate in the chips. The oil content of mango chips samples was estimated as a percentage using the following equation. All samples were taken in duplicate.

$$\text{The oil content of mango chips} = \frac{\text{weight ether extracted oil}}{\text{weight of chips}} * 100 \quad (20)$$

Table 4. *Results of oil content of mango chips.*

Factor	Sample code		
Frying temperature	A	B	C
150°C	14.13±0.74^{b}	23.35±5.94^{c}	17.60±2.03^{b}
155°C	17.60±2.03^{a}	28.35±2.69^{a}	14.45±0.79^{c}
160°C	24.32±0.88^{c}	16.75±1.2^{b}	21.25±2.48^{a}
Mean	18.68±0.46^{bc}	22.82±0.4^{b}	17.77±2.48^{b}

All values are the means ± standard deviation of duplicate runs

i^{a-c} Within a column, the means followed by the difference superscript letters differ substantially (P <0.05).

3.2.2. Texture Analysis of the Mango Chips

The texture of mango chips is one of the most significant quality aspects to consider when evaluating the quality of fried chips. Mango chips' textural characteristics are further affected by packing, shipping, and storage. The breaking stress of the mango chips was measured to determine the texture. The maximum breaking strength (load) determined was 9.02N, while the lowest was 4.86N. The texture of mango chips was significantly (P<0.05) different with its slice thickness and the longer the drying or higher brought harder in texture. The lower the slice thickness results the weaker texture and the higher slice thickness results harder to break. The anvil height of the probe was set to 3-6 mm before beginning the compression test, depending on the height of the tested samples.

Table 5. *Texture analysis results for mango chips.*

Sample code	Texture analysis results				
	Time (s)	Load (N)	Hardness	Fracurability (N)	Chewine Ss (J)
A	6.36	8.06	8. 03 ±0.6^{b}	4.05 ±0.7^{c}	8.12 ±0.15^{b}
B	3.52	5.09	4.86±0.4^{a}	2.97 ±0.3^{a}	3.98 ±0.58^{c}
C	6.64	10.89	9.02 ±0.8^{c}	3.56 ±0.8^{b}	8.89 ±0.45^{a}
Mean	5.51	8.01	7.30 ±0.9^{bc}	3.53 ±0.5^{b}	7.00 ±0.48^{b}

*All values are the means ± standard deviation of duplicate runs

i^{a-c} Within a column, the means followed by the difference superscript letters differ substantially (P <0.05).

3.2.3. Determination of Color of Mango Chips

Color is one of the physical properties that is often used by food customers and manufacurers to qualitatively assess the quality of food materials (Turner, 1995; Liang and Ramaswamy, 2012). The pretreatment and frying temperature had a significant (P<0.05) effect on the color of the chips. Processing conditions during frying of lead to color change by non-enzymatic browing which results from Maillard reactions or by caramelization between proteins and reducing sugars. Table 6) shows the results for lightness (L), redness (a), and yellowness (b). The dried mango chips product had a significant variation (P<0.05) owing to pretreatment, slice thickness, and drying temperature. Mango chips had L*values ranging from 23.08±2.35 to 42.35±0.09, which were lower than the L*values of fresh pulps. The mango chips is light in color result in the L*values. The L*values in measure of lightness/yellowness of the product. The other color parameter a*value is range from 19.99±0.12 to 24.88±9.92 for the mango fruit.

Table 6. *Color profile of mango chips.*

Sample	Color profile		
	L	B	A
Raw mango	45.87±1.57[ab]	25.02±0.38[ab]	26.04±0.15[a]
A	23.08±2.35a	16.87±0.59[d]	19.99±0.12[a]
B	42.35±0.09[c]	26.84±0.38[b]	21.07±0.28[c]
C	35.35±5.41[b]	12.04±0.68[c]	24.88±9.92[a]
Mean	33.59±3.05[bc]	18.58±0.26[b]	21.98±0.32[b]

*All values are means±standard deviation of duplicate runs

i[a-c]Within a column, the means separated by various superscript letters differ substantially (P <0.05).

*Note Sample A, B, and C respectively from left to right

Figure 2. *Color of the three samples prepared from at optimum drying temperature, time, and slice thickness.*

The total color difference (ΔE) of the chip samples was computed using the formula: Total color difference,

$$\Delta E = \sqrt{(L - Lo)^2 + (a - ao)^2 + (b - bo)^2} \quad (21)$$

Where Lo, ao, and bo represent the color values of fresh mango slices, while L, a, and b represent the color values of fried mango chips.

3.3. Kinetic Modeling of the Mango Slice During the Drying Process

Table 7. *Model coefficients and constants for mango slice drying.*

Model	A	K	N	R^2	X^2	RMSE
Page	-	0.01289	0.9799	0.9907	0.0085	0.0038
Newton	-	0.0068	-	0.9728	0.0152	0.0378
Modified Page	-	0.0069	0.989	0.9828	0.0035	0.0305
Herderson and Pabis	0.8017	-	0.0057	0.9609	0.0116	0.0518

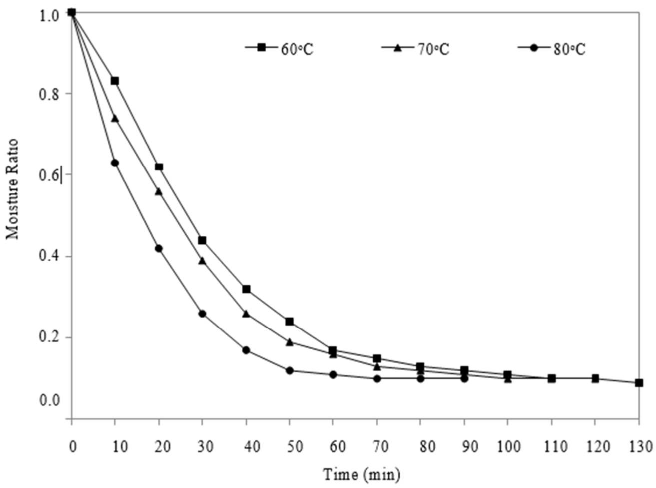

Figure 3. *Effect of drying air temperature for 3mm slice thickness.*

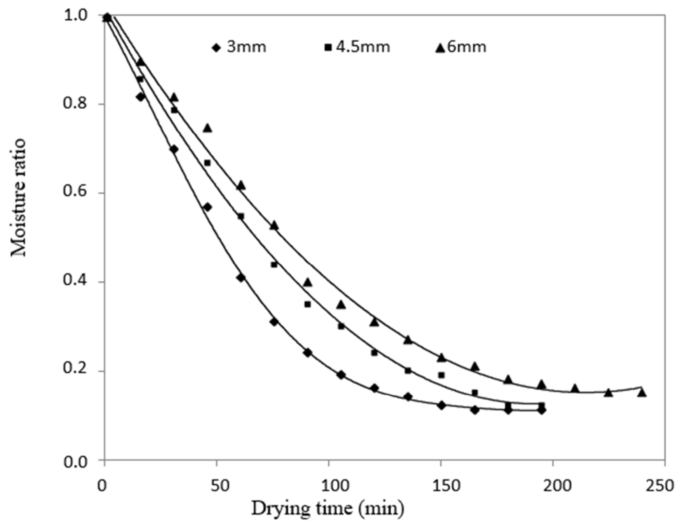

Figure 4. *Effect of slice thickness on drying at 70°C drying temperature.*

3.4. Drying Rate Determination of Mango Slice (Drying Curves for Mango Slice)

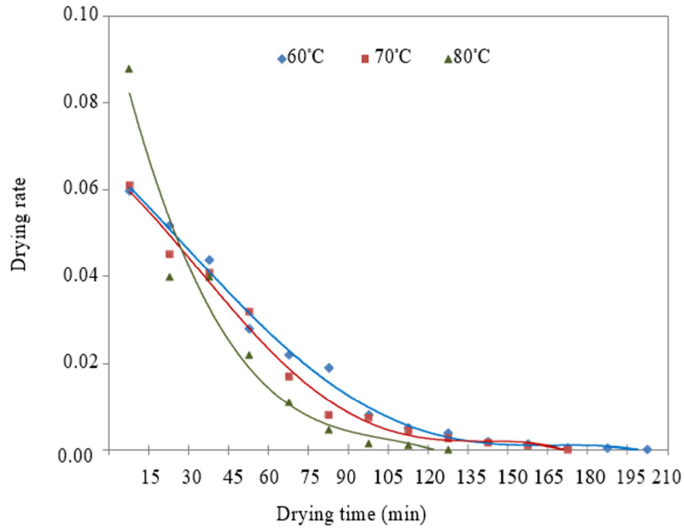

Figure 5. *Drying rate for mango slices at different temperature setting.*

3.5. The Microstructure of Mango Chips

The effect of pretreated and untreated on mango microstructure is shown in Figures 3 to 5. To visualize the structure of the material, environmental scanning electron microscopy of the surface and cross-section was conducted in all cases. Because more water was eliminated, raw mango slices prepared with a concentration of a citric acid solution (Figure 4) had a more packed surface in the fruit than untreated mango slices (Figure 5) [12]. The treated mango slice chips were more compact than the untreated raw mango slice chips (Figure 6), indicating a more consistent structure. When raw mango slices are treated with citric acid solution, the cellular area (diameter, roundness, and compactness) of the resulting chips decreases. Mango slices cooked under vacuum (Figure 6) have a more homogeneous (fewer bubbles) and spongy structure than those fried in conventional frying.

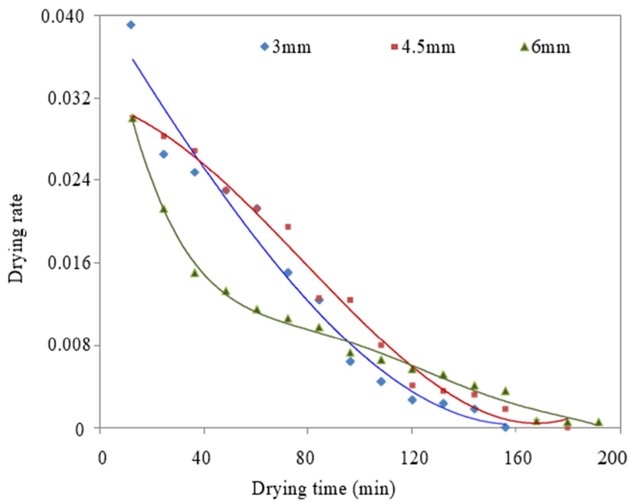

Figure 6. *Drying rate curves for mango at different slice thicknesses.*

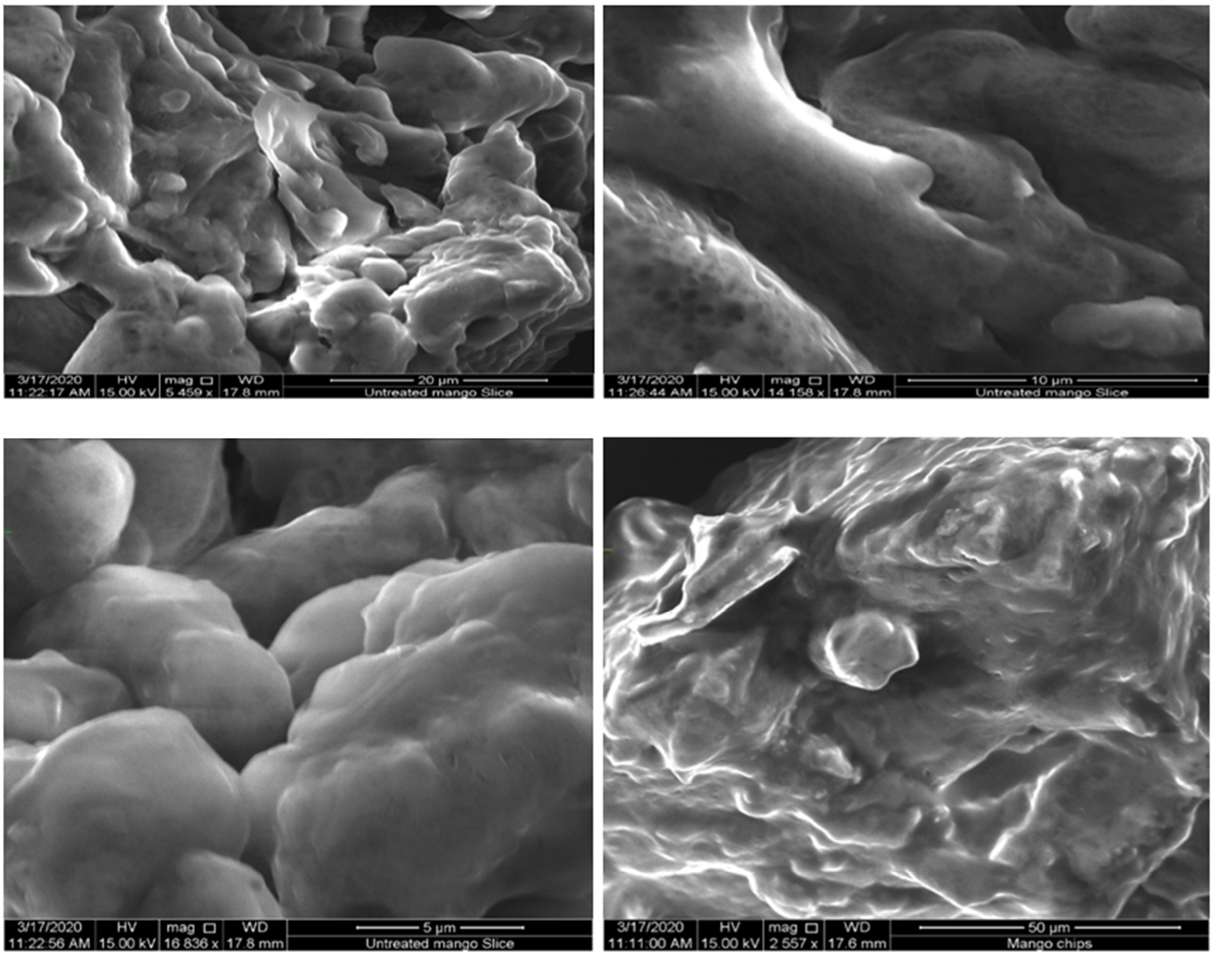

Figure 7. *Environmental scanning electron photomicrographs of untreated mango slice.*

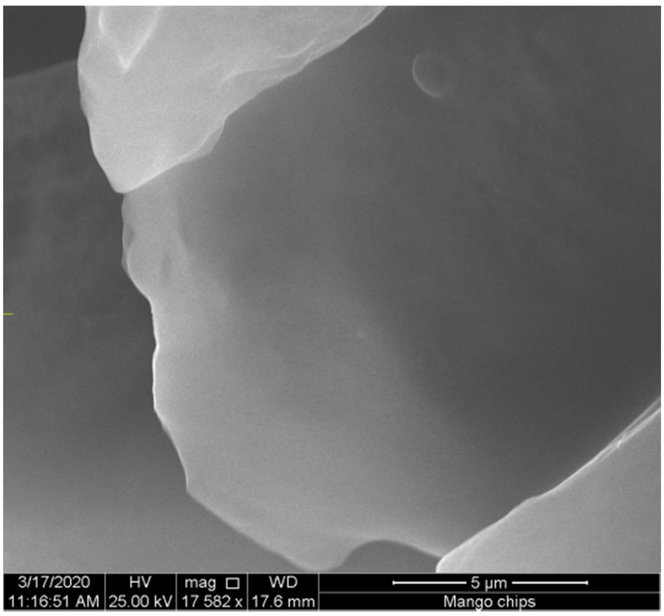

Figure 8. *Environmental scanning electron photomicrographs of mango chips.*

3.6. Sensory Quality Evaluation of Mango Chips

According to consumer feedback, chips with a high oil content received low odor ratings. The maximum odor score was 6.56 ±1.34 when mango slices were prepared for citric acid solution and fried at 150°C.

Table 8. *Sensory analysis results for mango chips pretreated with the citric acid solution at three different frying temperatures.*

Test (Temperature-Time)	Color	Oder	Flavor	Overall quality
150°C -3min	7.16±1.18[a]	6.45±1.50[a]	7.05±1.41[a]	7.20±1.07[a]
155°C -3min	6.54±1.74[a]	6.35±1.47[a]	6.48±2.07[a]	6.54±1.74[a]
160°C -3min	6.58±1.46[a]	6.13±1.53[a]	6.74±1.19[a]	6.66±1.14[a]
150°C -5min	7.34±1.20[a]	6.56±1.34[a]	7.59±1.07[a]	7.50±0.95[a]
155°C -5min	7.22±1.2[a]	6.50±1.29[a]	6.75±1.77[a]	7.06±1.29[a]
160°C -5min	6.40±1.56[a]	6.34±1.18[a]	6.59±1.68[a]	6.62±1.28[a]
150°C -7min	7.23±1.25[a]	6.30±1.31[a]	6.60±1.45[a]	6.96±1.21[a]
155°C -7min	6.40±1.81[a]	5.90±1.44a	6.70±1.39[a]	6.86±1.56[a]
160°C -7min	5.96±1.92[b]	6.13±1.33[a]	6.44±1.35[a]	6.58±1.36[a]

[a-b] Means within a column with different letters differ substantially (P<0.05).

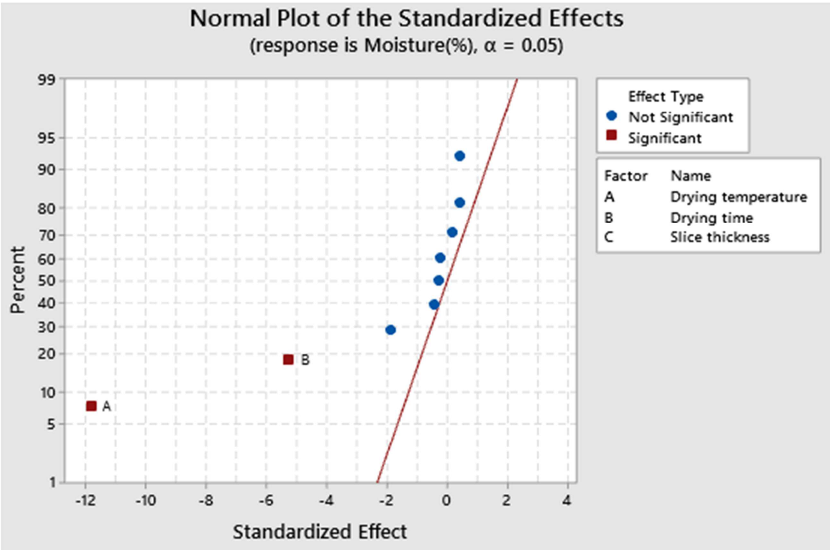

Figure 9. *Normal plot of the standardized effects (response is moisture (%) α = 0.05).*

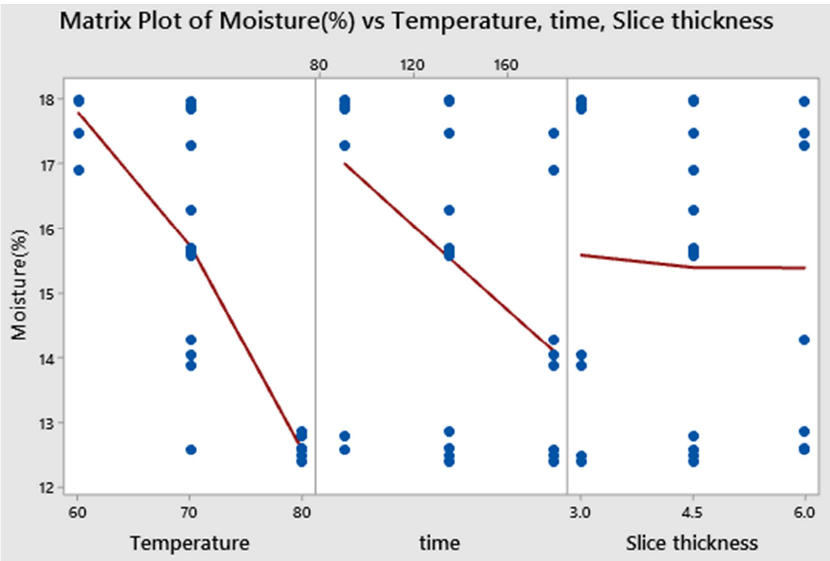

Figure 10. *Matrix plot of moisture VS temperature, time, and slice thickness.*

Table 9. *ANOVA for regression models for mango chips moisture content, oil content, texture (peak force), and overall color difference.*

Model Source	Sum of square	DF	Mean square	F-value	F-cri value	P-value	Adequate precision	R^2
Moisture content	3176.45	9	398.05	21.89	3.15	0.0001		0.97
Oil content	891.07	9	99.01	8.8	3.15	0.0001	10.73	0.89
texture (peak force)	7000.02	9	780.05	8.15	3.15	0.0017	8.34	0.90
Total color difference	860.01	9	95.11	3.05	3.15	0.0489	7.25	0.85

4. Conclusions

The drying behavior of mango slices happens during the decreasing rate phase, according to this study, and the Page model best explains the drying features. The ideal conditions for drying mango, a high moisture product, are a thinner thickness of 3 mm and a higher temperature of 80°C. The moisture removal rate of mango prepared with a citric acid solution was not increased as compared to no pretreatment with the citric acid solution tested. Drying time was typically reduced at higher temperatures due to the rapid elimination of moisture.

The drying time was similarly impacted by the thickness of the slices at all drying temperatures. The texture of the chips differed considerably ($P<0.05$) depending on the slice thickness and drying temperature. The longer the drying time, the tougher the texture. Mango chips have a weaker textural profile due to their thinner slice thickness (peak) force.

In fluidized bed drying processes, the moisture content of the thinly sliced mango was well characterized ($R^2 \geq 0.99$) by the model. The temperature increment of 60°C to 80°C increases the drying constant and decreases the equilibrium moisture content of the dehydrated mango samples. Also, it was observed that the drying time at equilibrium by using a fluidized bed was lower (90 min) than the tray dryer (180 min). Therefore, a fluidized bed dryer was the best method for drying of fruits.

When the mango was dehydrated in a fluidized bed drier with a citric acid solution at 65.72°C and a slice thickness of 5.15mm, the hue closest to the original color of fresh mango was achieved.

With an increase in drying temperature and time, the oil content of the chips raised while the moisture content of the chips reduced.

The sensory study also revealed that the mango chips cooked at 150°C with a slice thickness of 5.15mm were highly received by the panelists in terms of color, odor, taste, chewiness, flavor, and overall acceptability.

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Biography

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