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Effect of Ripening Stages and Drying Method on the Physico-chemical and Sensory Properties of Keitt Mango (Mangiferaindica L.) Sliced Chips

Techane T *

Department of Post-Harvest Management, Jimma University, Ethiopia

***Corresponding author:** Tolcha Techane, Department of Post-Harvest Management in Food Science and Post-Harvest Technology Program, Jimma University, Ethiopia, Tel:+251937453404; Email: tttolche@gmail.com

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Abstract

Fruits (30-50%) harvested in developing countries does not reach consumer due to using inappropriate method of processing. The objective of this study was to investigate effect of ripening stage and drying methods on physicochemical and sensory properties of dried sliced mango chips. mango rich as sources of vitamins A, B and C and consumed for pleasant taste and flavor. This study was lied down with two factors on completely randomized design. Different drying methods (solar drying and oven drying) and ripening stage (unripe, intermediate and fully ripe) were evaluated for physicochemical quality. The effect of factors on properties determined by Analysis of variance and significance at ($p < 0.05$). The data was collected from oven dry and solar drying with three replication and analyzed by using SAS software. The solar dried mangoes were evaluated for changes in moisture content (8, 8.83 and 9.83), ash content (3, 2.33 and 2.5), pH (4.02, 5.02 and 6.11), TSS (2.45, 2.83 and 3) rehydration capacity (50.83%, 63.93% and 58.65%), ascorbic acid (3.24, 1.82 and 1.47) and titratable acidity (0.05, 0.02 and 0.02) with unripe, intermediate and fully ripe mango respectively. The result showed that, for solar drying methods the best ripening stage was fully ripen. Other parameters also best for physicochemical qualities of solar-dried samples than oven-dried samples. Generally, present study showed that, solar dried samples was the highest in rehydration capacity at unripe, intermediate, and fully ripen and higher in other physicochemical properties at ripening stage (unripe, intermediate, and fully ripen) compare with oven dried. However, because of some constraints, some parameters were not included. Therefore, based on the limitation of the work, further research is needed to study the effect of Ripening Stages and Drying Method on (vitamin (A and B) and minerals) and (protein, carbohydrates, fat), and betacarotien of mango fruits which are not conducted in this research due to budget and time limitations, large scale drying room needed.

Keywords: Chips; Mango; Physico-chemical; Quality; Sensory

Introduction

Mango (Mangifera indica L), a fruit native to the tropics and sub-tropics of worlds belongs to the family Anacardiaceous Madrid [1] and usually consumed for its pleasant taste and flavor [2-3]. According to Hussen S, et al. [4] reported, the total amount of mango production in the world is around 35 million tons by the year 2009. Mango (Mangifera indica L.) as an emerging tropical export fruit is produced in over 90 countries worldwide with a production of over 28.51 million metric tons Akurugu, et al. [5]. Asia continent accounts for approximately 77% of global mango fruits production. America and Africa continents account for approximately 13% and 10%, respectively Kummu, et al.

[6]. Ethiopia countries has a diverse agro-ecology that can grow various fruit crops with a huge potential for mango production as well Berhe, et al. [7]. More than 47 thousand hectares of land is under fruit crops in Ethiopia and mangoes cover 12.61% of the fruit crop area Yeshitela, et al. [8].

However, current export share of mango in Ethiopia is very small due to low productivity. Therefore, Growing and marketing of fresh produce in Ethiopia is limited by post-harvest losses both in terms of quantity and quality between harvest and consumption. According to Kader [9] post-harvest loss of mango fruits in Ethiopia exceeds 26.3%.

Mango is the leading fruit produced in most parts of eastern, southern and south-western Ethiopia both in area coverage and quantities produced [10]. Mango being a highly perishable fruit possesses a very short shelf-life and reach to respiration peak of ripening process on 3rd or 4th day after harvesting at ambient temperature [11].

According to Appiah, et al. [12] point out, the quality of processed mango depends on many factors including quality of fruit at harvest after harvesting. Mangoes are processed at three stages of maturity. During ripening, the fruit softens due to increased activity of cell wall-degrading enzymes such as pectin methyl esterase and polygalacturonase [13]. Ripe mangoes are processed as canned and frozen slices, purée, juices, nectar, jam, jelly and various dried products [14].

Though mango fruits are much, appreciated when harvested after full ripening, harvesting at the half-ripe stage is generally recommended. The importance of the stage of ripening at harvest is critical as notable changes occur in the fruit during ripening. Mango at various stages of ripening can be dried and consumed.

Consuming mango fruits have different purpose. The main purpose of Mangoes fruits is used as food in all stages of its development. According to Pamplona [1] report that, Mango is one of the cherished fruit not only for taste but also for nutritional values. Mango fruits are very delicious with an excellent flavor, attractive fragrance and rich in food composition both macro (carbohydrates, proteins, fats), and micro minerals,(iron and phosphorus) (Malik, 2008) and vitamins particularly vitamin A (beta carotene), vitamin B1, vitamin B2, and vitamin C (ascorbic acid) nutrient, source of energy [2,3]. Tharanathan, et al. [15] observed that green or unripe mango contains a large portion of starch, which gradually changes into glucose, sucrose, and maltose as the fruit begins to ripe. Also in different countries like India, use mangoes fruits, as a blood builder, because of their high iron contents. They are suggested for treatment of anaemia and beneficial to women during pregnancy and menstruation.

People who suffer from muscle cramps, stress and heart problems can benefit from high potassium and magnesium contents that also help those with acidosis. Mango fruit is also beneficial in the treatment of nephritis as well as other kidney troubles [16].

It contains more vitamin C than unripe or fully ripe mangoes and it is also a good source of vitamins B1 and B2 and contains sufficient quantity of niacin [17].

Approximately, half of percent of fruits and vegetables harvested in developing countries are never consumed due to inappropriate harvesting stage, processing and as well as drying. This draws its importance from not only a moral obligation to avoid waste, but also because the cost of preventing food losses in general is less than producing a similar amount of food of the same quality. Considering the production of mango and major means of maintaining longevity of the commodity shelf life, both consumers and the producers have to take into account certain qualities in order to keep specific varieties in the market.

In Ethiopia Food security, both in terms of availability and access to food, poses a challenge to rapidly growing populations, in environments of declining land and water resources. Finally, in order to attain a high nutritional status, improved post-harvest management, reduced postharvest losses, production of value added products, effective and efficient research programs on the post-harvest sector must be strength and promoted. In Ethiopia, mangoes fruits are not harvesting at proper stage of ripening. And also they handling it using sacks and in some extent, palletizing and large mass of commodity is tightly packed for a shorter seasonal savings. However, this result in a mass of product loss and the product cannot be stored after one or two weeks of harvesting. Because of mango is a climacteric fruit with high respiration rate and this results in loss of quality. Drying mango is a means of eliminating seasonal shortages, providing a technologically sound base for leveling out food surpluses and shortage within rural and urban areas. Therefore, this study sought to investigate the effect of ripening stage and drying method on physicochemical and sensory quality of sliced mango chips.

In this Research, the Problems were Addressed

1. Which ripen stage mango and drying method that can affect the composition and sensory qualities of sliced mango chips?
2. What is the possible ripening stage and drying method to maintain the sensory and nutritional quality of sliced mango chips?
3. What are the best ripening stages and drying method that informs the consumer acceptability of the sliced

mango chips(in terms of Physico-chemical and sensory properties).

Materials and Methods

Description of the Study Area

The study was conducted in Jimma University College of agriculture and veterinary medicine (JUCAVM), located at 356Km southwest of Addis Ababa at about 70 33”N latitude and 360 57”E longitude and altitude of 1710 M.A.S.L. The mean maximum and minimum temperature are 26.80C and 11.40C, respectively and the mean maximum and minimum relative humidity is 91.4% and 39.92% respectively (www.ju.edu.et).

Sample Collection

Fully mature (yellow internal color) mango fruits were collected from research center and it was transported in to Department post-harvest management, at Jimma University Ethiopia.

Sample Preparation

One hundred eight fruits were selected from mature mango fruits pluck from the same tree. Selected fruits were uniformed and undamaged with no visible symptoms of infection. Fruits were cleaned and randomly group into three that studied on unripe, intermediate and fully ripe stages (36 mangoes per group). Then the fruit in each group was sub divided into two subgroups (sun drying and oven drying) with each subgroup having eighteen fruits. Each subgroup divided to three (replicates) having six fruit. Fruits were allowed ripening under room conditions (30-33^{o}C). The first groups (36 fruits) were considered as unripe, the second group considered in intermediate stage and the last group analyses fully ripe. The procedures for determining the stage of ripening of mango fruits were determining the following method. Fruits were consider unripe when firm with no depression when thumb press. Fully ripe fruits had strong perfume, and indented upon pressing with the thumb while half-ripe depressed slightly. This procedure was repeat for all treatments.

Chips Production

Apple mango fruits were washed with tap water to remove dusts. The fruit was packed in plastic and blanched in water at the temperature of 900C for two minute and immersed cold water (70C) for minimize of over cooking. The mango fruits were then peel using knife and cut into two equal halves and the seeds removed.

The pulps were then cut into slices approximately (2cmx4cmx0.5cm) and divide into two. One-half will solar dried for five days (more than 25^{o}C) while the other half was dry in an oven at 60^{o}C for 12 hours. Then the chips was packed with polyethylene and stored in desiccator.

Juice Preparation from Mango Chips

The juice was prepared from mango chips after milling. Ten grams mango chips powder was taken from each type of drying and dilute with hundred ml of distilled water. The juice was thoroughly mixed and filters using muslin cloth. The TSS, TA and ascorbic acid was measure from this juice.

Experimental Run	Description
T1	Unripe mango with oven dry
T2	Unripe mango pulp with solar dry
T3	Intermediate mango pulp with oven dry
T4	Intermediate mango pulp with solar dry
T5	Fully ripe mango pulp with oven dry
T6	Fully ripe mango pulp with solar dry

Table 1: The treatment combinations of the experiment.

Research Design

To carry out the study, the design was on CRD, because the experiment was carried out in homogeneous condition, since it was conducted in laboratory. There are two factors (ripening stage and drying method) and for those two factors, the ripening stage has three levels (unripe, intermediate and fully ripe) and the drying method has two levels (oven dry and solar dry) that makes the experiment to have six treatment combinations and each treatment combinations was duplicated in three times. This makes the total experimental unit to 18 samples.

No	Treatments	Replications		
	X	R1	R2	R3
1	T1	T1R1	T1R2	T1R3
2	T2	T2R1	T2R2	T2R3
3	T3	T3R1	T3R2	T3R3
4	T4	T4R1	T4R2	T4R3
5	T5	T5R1	T5R2	T5R3
6	T6	T6R1	T6R2	T6R3

Table 2: The combination of treatment (vertical) and replication (horizontal).

Data were Collected

Physico-Chemical Analysis

Standard procedures of the AOAC were used for proximate determinations, pH, total soluble solids, titratable acidity, Vitamin C and ash content. pH was measured using a Suntex electronic pH meter (model FF 701, Suntex Instruments Co. Ltd, USA). Total soluble solids were determined with a Bellingham and Stanley Delta hand refractometer. The moisture content analysis of samples for was carried out for the chips produced by the standard methods described by AOAC [18].

Determination of ash content: According to AOAC [18], total ash content of the samples was determined by gravimetric method. Crucibles were clean and dr+y and ignite at 550°C for 1 hour and weight (m1). Ground sample (5 g) and crucible were weight (m2). The sample with crucible is dry in oven at 120°C or 1 hour. Then the dried sample was carbonized over a blue flame and ignited in a muffle furnace at 550°C until ashing complete (over 12 hrs). After being ignite, the sample was cooled to in desiccator and weight (m3). Finally total ash content was calculated as follows:

$$\text{Percentage Ash Content} = \frac{m_3 - m_1}{m_2 - m_1} \times 100$$

Where m1 = weight of empty crucibles, m2 = weight of crucible + food sample before ashing and m3 = weight of crucible + ash.

Moisture content determination: Moisture content of the samples was determined according to AOAC [18]. Clean and dry moisture dish was prepared and the weight was weight as W1. Representative sample (5g) was placed on the dish and the weight taken (W2). It was placed in a hot air drying air, dried at 100°C for 6 hours, and cooled to room temperature by putting in desiccator. The weight after drying was measured as W3. The moisture content of sample was calculated by using the following formula:

$$\%\ \text{moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where: W1 = Weight of moisture dish, W2= initial Weight of the sample and moisture dish before drying.
W3 = Weight of moisture dish and sample after drying.

pH and titrableacidity: Titratable acidity as percentage of citric acid of fresh tissue was measured following the standard methods [19]. pH of the fruit juice which is the equilibrium measure of hydrogen ion concentration in a juice was measured with a standard calibrated pH meter (CP-50-5).The electrode of the pH meter was inserted into the partly settled suspension.

Titratable acidity of the juices was determined using method of AOAC [20]. About 5 ml of filtrate was dissolved in distilled water until the volume will reach 50 ml. Then 5 ml aliquot of sample solution was taken and titrates with 0.1N NaOH using phenolphthalein solutions as indicator until the orange color of the juice sample will be changed into pink. Triplicate measurement was taken and calculate as percent of citric acid using the equation:

$$TA(\%) = \frac{\text{mls NaOH used} * 0.1\text{NNaOH} * \text{D.F} * \text{equivalent factor}}{\text{Volume of sample}} \times 100$$

The dominant acid of mango is citric acid, therefore, the mill equivalent factor for citric acid is 0.064 and D.F stand for dilution factor.

Total soluble solids: The concentration of dissolved sugars were determined using Refractometer as addressed in AOAC [21] method. After calibrating with distilled water, 2 drops of sample was introduced on the prism and triplicate measurement was taken from the Refractometer. Result was expressed as °Brix (the amount of total dissolved solids in 100 g of juice product).

Ascorbic acid

i. **Preparation of vitamin c standard solution:** Vitamin C was determined using method described by Rahmawati and Bundjali [22]. Briefly, 1% starch indicator solution was prepared in a beaker by adding 0.50g soluble sugar to 50 ml distilled water-near boiling. The mixture was mixed well and allows cooling before use. Iodine solution was prepared in a beaker by dissolving 5 g potassium iodide and 0.268 g potassium iodate in 200 ml of distilled water. Thirty ml of 3M sulfuric acid was added to the solution and the solution was diluted to final volume of 500 ml with distilled water.

Finally, the solution was labelled as Iodine Solution. Vitamin C standard solution was prepared in a beaker by dissolving 0.250 g ascorbic acid in 100 ml distilled water and diluted to 250 ml with distilled water in a volumetric flask. Finally, the flask was labelled as Vitamin C standard solution.

ii. **Determination of vitamin c (ascorbic acid):** Vitamin C of the sample was determined by titrating 10ml of the extract with Iodine solution until the end will reach. Ten (10) ml of the sample was taken to volumetric flask that contains fifty milliliters of distilled water and 10 drops of 1% starch solution was added and shaken properly until the end will reach.

The endpoint of the titration is the first permanent trace of a dark blue-black color due to the starch-iodine complex that persists after 20 seconds of swirling the solution. The volume of Iodine solution used up for titration was recorded by subtracting the starting volume from final volume. The volume of titrate required for the standard was calculated and recorded. Finally, the amount of vitamin C found in the samples was estimated from the volume of titrate required for standard solution 2.5grams of standard Vitamin C takes 40 ml of iodine solution, and this was taken as a reference for the subsequent samples.

Finally, the ascorbic acid value was determine from the volume of water and sample (dilution factor) and from the standard volume of iodine in the titration and the formula from the standard solution.2.5grams of vitamin C was taken 40ml of iodine solution)

And dilution factor (DF) = Total volume / sample volume

Where, total volume is Volume of sample + volume of water used for dilution.

Finally Vitamin C was determined as, Vitamin C= (Yml × 2.5gr40ml) ×DF

Where, Y ml means the amount of iodine solution consumed to reach the endpoint during titration. 40ml was the amount consumed in 2.5 gram of standard vitamin C to reach the end during the titration.

iii. Rehydration Capacity: The products ability to rehydrate properly under cooking, are important for the consumers and was called the rehydration capacity (RC). Dried mangos were usually boiled together with other ingredients and salt in stews, soups and sauces [23].

Dried mango slices were weight (W0) and immerse for 20 min in distilled water (100 mL of water per 5 gram of slice dried mango) at room temperature. Following this, the water was drained during 2 min and the slices will weight again (W1). According to Abou and Ibraheem [24] the rehydration ratio was calculated as the ratio of the weight of gained water (W1- W0) over the initial sample weight (W0).

$$\text{Rehydration ratio\%} = \frac{W_1 - W_0}{W_0} \times 100$$

Sensory Analysis

Sensory evaluation was carried out after the production of mango chips. The evaluation was carried out using 50 untrained panelists. The sensory attributes of the different ripening stage mango chips was performed separately. The sensory attributes to be assessed would be; the taste, aroma, color, flavor and the overall acceptability. The panelists were selected randomly from the staff and FSPT students of the university. They were allowed to determining sensory of randomly coded samples under controlled environment to avoid biased results. The panelists were rate the quality based on five hedonic scales where 1=Dislike it very much;2 =dislike moderately; 3=nor like neither dislike; 4=like; 5=like much. The raw scores was assemble and statistically analyzed using the method described by Ihekoronye and Ngoddy [25].

Statistical Analysis (Methods of Analysis)

The physicochemical and sensory properties of mango chips were statically analyzed using analysis of variance. For this analysis, SAS 9.2 software for windows (SAS ver., 2008) statically package was used. The statistical package sample was tested at P<0.05 and the differences between the mean were compared using least significant (LSD).The result was expressed as mean±SE.

Results and Discussion

Physicochemical Analysis

The experimental results were generally produced with the P<0.05 value with their respective standard error of mean and coefficient of variation. The results given below the table were mainly the appropriate means of the interaction of ripening stage and drying methods, since except for the ash content all the other parameters were significantly different at only the interaction the other factors were non-significant as shown in the appendix. However, in the case of the ash only the main factor (ripening stage) was significant.

Ripening Stage	Drying Method	Moisture	Ph	TA	Ash	TSS	Vitamin C/100gram	Rehydration Capacity
Unripe	Oven	6.17^{B}	3.79^{C}	0.05^{A}	2.17^{A}	2.33^{C}	1.64^{B}	51.89^{C}
Unripe	Solar	8.00^{BA}	4.02^{C}	0.05^{A}	2.00^{A}	2.45^{CB}	3.24^{A}	50.83^{C}
Intermediate	Oven	8.33^{BA}	4.78^{B}	0.01^{B}	2.23^{A}	2.6^{B}	1.13^{CB}	55.73^{BC}
Intermediate	Solar	8.83^{BA}	5.04^{B}	0.02^{B}	2.33^{A}	2.83^{A}	1.82^{B}	58.00^{B}
Fully Ripe	Oven	8.67^{BA}	5.15^{B}	0.01^{B}	2.50^{A}	2.94^{A}	1.00^{C}	58.65^{BA}
Fully Ripe	Solar	9.83^{A}	6.11^{A}	0.02^{B}	2.50^{A}	3.00^{A}	1.47^{CB}	63.93^{A}
LSD		3.2003	0.41	0.01	3.02	0.16	0.73	5.83

Table 3: Result of Physico-chemical properties of mango chips.

Means that do not share a letter are significantly different. Results are mean values of triplicate determination and means with the different letters across the column are significantly different ($p<0.05$).

Moisture content, ash and pH the mango sample: The result of moisture content was shown in the above table 3.The moisture content obtained from mango chips was found value in the range of 6.17%-9.83% for the interaction effect between ripening stage and drying method. The moisture contents of solar dried mango samples at all level of ripening stages were significantly higher (8%-9.83%) than the oven drying methods (6.17%-8.67%) at all levels of ripening stage. It has been indicated that oven drying removes moisture as quickly as possible at a moderate temperature [26] this result is agree with the above statement.

Since the movement of hot air with in the oven is restricted, it makes the condition to become over warming and the samples to become lose their moisture quickly. There were significant differences at $P<0.05$ between all the stages of ripening. The increase in moisture content of the fruits during ripening could be increase due to the attributed to hydrolysis of storage carbohydrates into simple sugars that increased osmotic transfer of moisture from peel to pulp [27].

The ash content was not having a significant difference on the drying method rather the ash content was changed due the ripening stage of the mango. The ash content of the fully ripen was higher than the intermediate and unripe.

Baiyeri, et al. [28] reported higher ash content in ripe fruits suggesting that tissue breakdown during ripening causes some mineral elements to be free and more available. The pH of samples were ranges from 4.02 -6.11 for solar and 3.79 -5.15 for oven dried samples. The oven-dried samples were generally lower in pH content than the solar dried samples. This result was agreed with the research findings done by Tovar, et al. [29]. Increase in pH during ripening of mango fruits and was similar to what was observed in the present study. According to the authors, there is an inverse relationship between titratable acidity and pH. The increase in pH (decline in acidity) could be due to utilisation of acids as respiration substrates [12].

TSS and TA: The TSS mango that dried in oven was ranges from 2.33-2.94obrix between unripe to fully ripen and the solar dried sample were 2.45, 2.83 and 3.00obrix for unripe, intermediate and fully ripe mangoes fruits respectively. Soluble sugars of mango pulps are mainly composed of fructose, with about 30% sucrose and 20% glucose [30]. Similarly, sucrose has been reported to be the major sugar in mango [31]. Significant increase in sucrose content of mango has been observed during ripening and this has been attributed to an increase in total soluble solids during ripening. This is due to transformation of starch into soluble sugars as the carbohydrates in the fruit are broken down under the action of phosphorylase enzyme during ripening into simple sugars.

On the other hand, hydrolysis of starch in the ripening mango fruit has been associated with amylase activity [32].

The increase in total soluble solids during ripening was expected and this suggests the extent of sweetening. The effect of increased total soluble solids was observed in the taste of chips produced as it correlated positively with taste. However TSS of mango chips that obtained by oven dry (2.33-2.94obrix)with respect to unripe to fully ripen was lower than the solar dried sample was 2.45,2.83 and 3.00obrix with unripe, half ripen and fully ripe mango chips respectively. The lower the TSS of the mango chips that was dried in oven dry was, due to the higher temperature in the oven due the restriction of the air, that cause for the breakdown of sugar to the other components.

The TA of the mango in the oven dry decrease from 0.05-0.01 from unripe to fully ripe and 0.05-0.02 for solar dried mangos. Similarly, a decrease in titratable acidity of mango fruits during ripening has been reported [31]. Citric acid is known to be the major acid in mango [33]. The decline in acidity could be due to susceptibility of citric acid to oxidative destruction as impacted by the ripening environment [29]. The decreases in acidity suggest reduction in sourness with the potential of improving the sweet taste as it was observed in chips produced in this study. Increase in pH during ripening of mango fruits has been reported by other authors Gale, et al. [23] and was similar to what was observed in the present study. According to the authors, there is an inverse relationship between titratable acidity and ph. The increase in pH (decline in acidity) could be due to utilisation of acids as respiration substrates.

Vitamin c and rehydration: The Ascorbic acid of mango at unripe, intermediate and fully ripen were 1.64, 1.53 and 1.00 respectively. However, the ascorbic acid content of the mango that dried in solar ware 3.24, 1.82 and 1.47 with increase ripening stage, which was greater than the oven dry at each stage of ripping.

The different in drying methods reduced the ascorbic acid as also found by Islam, et al. [34] also reported that a decrease in Vitamin C content at different drying conditions.

From the data in table 3, the solar dried samples had higher ascorbic acid values than the oven-dried samples. This confirms the finding of Chang, et al. [35] who reported that hot air oven dried tomatoes have higher loss of vitamin C than other drying methods used. Retention of ascorbic acid in samples dried in solar could be because of radiation used. This could have inhibited or destroyed completely enzymes responsible for the destruction ascorbic acid as reported by Hsieh, et al. [36]. The vitamin C content also varies with the ripening stage of mango and the highest vitamin C retention was observed at unripe mango with solar dried sample.

The observed decrease in Vitamin C content of the mango fruits during ripening is of concern as it is an important vitamin for both consumer healths [23]. Other authors Troftgruben J, et al. have observed a similar trend during ripening of different mango varieties [26]. This decrease is attributable to susceptibility of Vitamin C to oxidative destruction during ripening. The reduction in Vitamin C content during ripening coupled with heat treatment (oven drying during chip production) suggests that the chips would need to be fortified with Vitamin C to meet the US daily reference intake of 75 and 90mg/day for women and men, respectively [29]. The rehydration capacity of oven-dried samples at all levels of oven dried with half ripen mango chips was (63.93%) was significantly higher than solar dried samples this was also the same as in the case of Wrolstad [37]. This is because the rehydration capacity is in proportional with the moisture content of dried sample.

Sensory Properties of Mango Chips

Ripening	Drying Stage	Color	Taste	Flavor	Aroma	Over All. Acceptability
Unripe	Oven	1.87^{F}	1.69^{F}	1.74^{D}	1.79^{D}	1.80^{E}
Unripe	Solar	2.65^{D}	2.94^{D}	1.77^{D}	1.78^{D}	1.68^{E}
Intimidated	Oven	2.65^{D}	2.94^{D}	2.67^{C}	2.26^{C}	2.84^{D}
Intimidated	Solar	3.11^{C}	3.33^{C}	3.24^{B}	2.67^{C}	3.35^{C}
Fully Ripe	Oven	3.52^{B}	3.49^{B}	3.45^{B}	3.26^{B}	3.62^{B}
Fully Ripe	Solar	4.47^{A}	4.39^{A}	4.47^{A}	4.38^{A}	4.40^{A}
LSD		**0.12**	**0.13**	**0.44**	**0.46**	**0.14**

Table 4: The result sensory properties of mango chips.

Means that do not share a letter are significantly different. Results are mean values of triplicate determination and means with the different letters across the column are significantly different ($p<0.05$).

Color: Color is one of the quality parameters of mango fruit chips. The color of the mango fruit chips was significantly affected ($P < 0.05$) by the interaction effect. Chips produced from full-ripe solar mango fruits scored highest for color (4.47) as compared to those from the unripe with solar dry (2.65) and half-ripe mangoes (3.11),however the color of the oven dried mango was lower than solar dried mango sample due to the higher temperature that leads to ceremilaztion reaction. During ripening, the intensity of yellowing increased in the mango fruit. This might have contributed to the attractiveness of full-ripe chips. There were significant differences observed in the appearance between the different chips produced from the green-mature, half-ripe and full-ripe mango fruits.

Taste: There were significant differences in taste of chips produced from the three ripening stages and drying methods ($p<0.05$). Taste of chips produced from the full ripe with solar dry mango fruits was most preferred (4.39) compared to both the unripe with solar dry (2.94) and half-ripe with solar dry (3.49).However the taste of mango that was dried in solar is greater than oven dry in all stage of ripening stage. Full-ripe chips performed better probably due to their reduced acidity and increased total soluble solids (sweetness) since there was a strong positive correlation between taste to total soluble solids as well as taste and pH. However, there was an inverse relationship with titratable acidity. From the observation, it could be inferred that the taste of the mango chips was closely related to their sweetness and acidity as has been reported [9]. Taste improved with increasing sweetness and decreasing acidity. This explains why the ripe chips were preferred. However, as far as taste was concerned, fully-ripe best from all. Acids are known to be responsible for the taste in most fruits with low ph. As starch in fruits was transformed into sugars during ripening, the taste becomes sweet due to increased sugar levels contributing to the taste of the fruit. The panelists however, did not like the taste of chips made from the unripe fruits due to their sourness (acidic).The typical sour-sweet taste of citrus fruits is determined by the relationship between the soluble solid content (SSC) and the titratable acidity (TA). Organic acids predominate in unripe citrus fruits, which give them a sour taste unacceptable to consumers. In contrast, the content of organic acids is low in ripe fruits, which are perceived as sweet. Sugars and acids are the main markers of citrus fruit quality. These compounds can serve as respiratory substrates.

Aroma: The aroma of the chips was significant at p<0.05.The fully ripe mango chips with solar dry(4.38) was best from the half ripen(2.67) and unripe mango chips(1.67) with respect to solar dry. However the oven dry chips were lower than the solar dried due the volatile compound was escape from the chips at high temperature. The aroma of fruits improves during ripening and this explains why the aroma of chips produced from the full-ripe mango fruits was preferred to the others by the panelists Szeto YT, et al. [38]. The characteristic aroma of fruits was usually derived from the production of different volatile compounds. Mono- and sesqui-terpene hydrocarbons are known to be the major aroma compounds in mango [39].

Flavor: The flavor of the mango fruit chips was significantly affected (P < 0.05) by the interaction effect. Flavor is an indicator of the sensation of food in the mouth and nose. The results of the study indicated that chips produced using full-ripe mangoes with solar dry gave the most preferred flavor (4, 47). This was followed by half-ripe with solar dry (3.24) and unripe with solar being the least preferred (1.74). However, the flavor the mango chips that dried in oven was lower than solar dried due to the degradation of sugar and the escape volatility compound that gives the odor of the chips. It could be deduced that the total soluble solids content and acidity were important quality parameters that influenced the perception of mouth feel by the sensory panel. Preference for the mouth sensation given by the full-ripe chips could be attributed to their high sugar content and titratable acidity of their pulps since total soluble solids correlated positively to mouth feel and inversely to titratable acidity.

Overall acceptability: As indicated in table four, the overall acceptability of mango fruit chips was significantly affected (P < 0.05) by the interaction effect of ripening stage and drying method of mango fruits. The panelists generally preferred chips produced from the full-ripe Keitt mango fruits to those made from fully ripe mango. This was due to higher total soluble solids content. Regression analysis showed that the taste of the chips contributed significantly to the observed overall acceptability as indicated in the regression analysis. This not with standing, taste could be used as an important determinant of acceptability of Keitt mango chips.

Conclusion and Recommendation

The purpose of this study was to investigate the effect of drying methods and ripening stage on the physicochemical and sensory properties of the slices mango chips, i.e. moisture, ash, pH, total soluble solids, rehydration capacity, vitamin C and Titratable acidity. The result showed that most of physicochemical characteristics of mango chips were significantly dependent on or affected by the ripening stage and drying method of mango fruit chips. Although most of physicochemical characteristics of mango chips were significantly affected by drying method and ripening stage except the ash content, they were significantly affected by ripening stage. As the ripening stage of mango fruits chips increase , the TSS and pH of chips were increased; accordingly, the vitamin C contents and TA values of mango chips were decreased. However, the value solar dried sample higher than oven dried sample.

The parameters like moisture, ash, pH, TSS and vitamin C contents were lower (p<0.05) in oven dried mango chips than the solar dried chips. While the rehydration capacity was higher (p<0.05) in oven dried samples than solar dried samples. This indicating that, solar dried mango chips have better physicochemical properties than the oven dried samples at all levels ripening stage. Nevertheless, in case moisture content oven dried samples were better, because the lower the moisture, the higher will be the shelf life so, a person who needs for better storability can choose oven drying rather than the solar. Generally regarding to this research findings, to have a better physicochemical quality of sliced mango chips, it would be well to use fully ripe for solar drying methods. Since most of the physicochemical qualities are best at those ripening and drying method combinations. Nevertheless, because of some constraints in the research progress, some important parameters were not included in the study; therefore, they should be investigated for the future. Among these parameters that need to be studied are;

- Sensory and shelf life determination of dried mango chips, changes of microbial load and
- The nutritional stability of the same product during drying and the other effects of pre treatments during drying should be investigated.

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