

## IMPACT OF RIPENING STAGE AND DRYING ON SELECTED QUALITY ATTRIBUTES OF APPLE MANGO CUBES AND LEATHERS

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## ABSTRACT

Apple mango is an improved cultivar that has been widely adopted by farmers in Kenya for use in the fresh market and processing. However, its production and consumption are adversely affected by high postharvest losses, which result from the perishable nature of the fruit, especially during glut periods. This is partly due to limited availability of information on alternative product use. The aim of this study was to evaluate the impact of ripening stage and drying on the physico-chemical quality and sensory acceptability of Apple mango fruit grown in the upper Athi River region of Kenya. Moisture, crude ash, crude fibre, titratable acidity, total soluble solids, colour, total carotenoids and ascorbic acid of the unripe and ripe fresh mangoes were determined. Subsequent experiments involved drying of ripe and unripe mango cubes (8mm) in a windy oven (at 60°C) and, in parallel, drying of ripe mango puree (mixed with sucrose-glucose solution, citric acid and pectin) in a windy oven at three different temperatures (50, 60 and 70°C) which resulted in mango leathers. Analysis of total carotenoids, ascorbic acid content and colour was done for all dried samples, followed by sensory evaluation using the nine-point hedonic scale. The moisture content, crude ash and total soluble solids increased significantly ( $P < 0.05$ ) with ripening while titratable acidity decreased significantly ( $P < 0.05$ ). Ascorbic acid content decreased from 98.03 to 86.45 mg/100g with ripening while total carotenoids content approximately doubled from 768 to 1436  $\mu\text{g}/100\text{g}$ . Drying resulted in high retention of total carotenoids, whereas, ascorbic acid content decreased. The mango samples became darker and redder in all cases. Dried mango cubes and leathers derived from ripe mangoes had higher scores in the sensory analysis compared to those obtained from unripe mangoes. In conclusion, the stage of ripening and drying technique employed are critical in determining the nutritional and sensory characteristics of dried Apple mango cubes and leathers. Drying Apple mango leathers at 60°C is the best method that can be adopted.

**Key words:** Apple Mango, Drying, Ripening, Fruit Leather, Fruit Cubes, Physico-chemical, Sensory

## INTRODUCTION

The mango fruit has great economic and nutritional importance around the world. In Kenya, mango fruit production increased approximately by 130% between 2000 and 2010 [1]. Alongside this, was a shift from growing local varieties such as Ngowe and Dodo to improved cultivars such as Apple, Tommy Atkins, and Kent. This was to cater for the fresh fruit market and for processing purposes, as observed in Eastern province and other regions of the country [2].

However, one great challenge many farmers face lies in how to cope with production gluts during the short harvest periods which leads to approximately 45% of post-harvest loss [3]. Farmers are often not well linked to markets and the extent of exploitation by middlemen is high due to their inadequate knowledge in food preservation techniques. Moreover, the industrial capacity to process this highly perishable fruit is limited in Kenya. A few large scale processors (Milly Fruit Processors, Malindi Mango Processors, Kevian) pulp the ripe fruit and transform it into concentrate, ready to drink juice or jam [2]. Therefore, the identification of simple, innovative, inexpensive, farm/village-level adoptable technologies is critical if post-harvest losses are to be reduced. One such technology that can result in shelf-stable, high quality, affordable products is drying [4, 5] of mango fruit cubes and leathers.

Fruit leathers are made by drying a thin layer of fruit puree on a tray resulting in pectic gels that are shiny, flexible and chewy. They have various advantages such as being nutritious, easy to store (as they require no refrigeration), allow for the later use of left over fruit and have become increasingly popular on the international market [6].

Drying refers to the removal of water from food and can be done naturally or artificially under controlled conditions. It works on the principle that by lowering the water content of foods below a certain threshold level, the growth of many spoilage microorganisms is prevented thus preserving the food. The proper choice of mango variety [7] and post-harvest ripening stage is essential during processing since both sucrose and reducing sugars (which play a role in Maillard reactions) increase with increasing ripening [8]. This determines the final product quality and sensory characteristics. Unripe mango fruits are acidic, astringent and rich in vitamin C while ripe mangoes contain moderate levels of vitamin C [9]. It has been reported that the content of  $\beta$ -carotene and xanthophylls esters, carotenoids, in mango fruit increases exponentially during ripening [10].

There are many studies that have employed a different range of drying methods to determine the impact of drying on the physico-chemical properties of mangoes. It has been reported that air drying results in significant changes in colour while freeze drying results in products with superior colour [11]. Drying at high temperatures causes increased darkening of mango fruits [12]. Empirical evidence shows that drying could either increase carotenoids content [12] or reduce it [13]. High losses in the ascorbic acid contents of mango fruits after drying have been reported [13]. Despite extensive research on mango slices of various other varieties [11, 14, 15, 16] there is limited

information on the impact of convectional air drying on Apple mango cubes and leathers.

The aim of the current study, therefore, was to evaluate the impact of ripening stage and drying on the nutritional (vitamin C and total carotenoids), physical characteristics (colour) and sensory acceptability of Apple mango fruits.

## MATERIALS AND METHODS

### Source of mangoes for the study

Mature green Apple mangoes were obtained from a grower in Makueni County in Eastern Kenya. The mangoes were handpicked from the trees and stacked into ventilated plastic crates of dimension 40cm by 22cm by 57cm (width x height x length) respectively and transported to the laboratory for analysis on the same day. The samples were grouped into two; (1) Unripe mangoes that were analyzed immediately, and (2), unripe mangoes that were ripened progressively at  $25\pm 2^{\circ}\text{C}$  and approximately 70% relative humidity. The two stages of ripening were objectively determined based on flesh colour ( $L^*a^*b^*$ ) [17].

### Preparation of Mangoes for drying

The mangoes were washed thoroughly in solution of approximately 3% acetic acid to kill surface microorganisms and rinsed in clean tap water. They were then peeled and de-stoned using a stainless steel knife.

### Preparation of Dried Mango Cubes

To obtain ripe and unripe mango cubes, the mango flesh was diced into cubes of approximately 8mm in dimension. The unripe and ripe mango cubes were spread onto separate stainless steel trays in a single layer and put in a pre-heated EYELA windy oven (Model WFO – 1000ND, Rikakikai Co. Ltd, Tokyo, Japan) at  $60^{\circ}\text{C}$  and dried. Moisture loss was monitored on an hourly basis.

### Preparation of Mango Leather

First, in order to produce the mango leathers, a glucose-sucrose syrup was made. It constituted equal amounts of glucose and sucrose dissolved in distilled water to make a solution of 30% concentration (w/w). Then approximately, 70% ripe mango pulp and 30% of the syrup were mixed homogeneously. Citric acid (0.2% w/w) and pectin (0.1% w/w) were also added to the mango leather mixture. The ratios of pulp, syrup, citric acid and pectin were optimized during a preliminary study. Secondly, mango leather controls, with no additives, were also produced. Approximately 100g of the mango leather mixture and separately 100 g of mango puree was evenly spread on a 9cm by 20 cm stainless steel trays resulting in a  $0.56\text{g}/\text{cm}^2$  load and dried at  $50^{\circ}\text{C}$ ,  $60^{\circ}\text{C}$  and  $70^{\circ}\text{C}$  in the pre-heated windy oven. Moisture loss was monitored on an hourly basis until constant moisture content was obtained.

**Changes in Selected Physico-chemical Constituents****Determination of Moisture, Crude Ash, Total Titratable Acidity (TTA) and Crude Fibre**

Moisture, crude ash and total titratable acidity (as malic acid) determinations were done according to standard methods as described in AOAC 2000 [18]. Determination of crude fibre content was done as described in the standard method of AOAC 1995 [19].

**Determination of Total Soluble Solids (TSS)**

The TSS was determined using an Atago hand refractometer (Model RX 5000, Atago, Tokyo, Japan). A drop of the homogenized mango pulp was placed at the prism of a hand held refractometer, which had been calibrated, the lid closed and TSS read directly from the digital scale at 20°C±1 and results expressed in °Brix.

**Determination of Total Carotenoids**

Approximately 5 g of the fruit pulp or a spatula of hyflosupercel (celite) added to 2 g of dried sample were crushed in a pestle with a mortar in 50 ml of cold acetone to extract the carotenoids and filtered. Partitioning was done using 25ml petroleum ether in a separating funnel to obtain the carotenoids rich upper layer. Acetone residues were removed from the carotenoids layer by washing 3-4 times with distilled water discarding the lower phase. Residual water was removed from the upper phase using anhydrous sodium sulfate. Sample bottles were stored in the dark. Total carotenoids content was determined using UV-Vis spectrophotometer (Model UV mini 1240, Kyoto Shimadzu) and absorption at 450nm (which is the absorption wavelength of β-carotene) [20].

Total carotenoids content calculated as follows:

$$\text{Total Carotenoids content } \left( \frac{\mu\text{g}}{\text{g}} \right) = \frac{A * \text{Volume (ml)} * 10^4}{A1\%1\text{cm} * \text{sample weight (g)}} \dots \dots \dots \text{equation 1}$$

Where A= absorbance; volume = total volume of extract (50 or 25 ml); A1%1cm = absorption coefficient of β-carotene in PE (2592).

**Determination of Vitamin C (Ascorbic Acid)**

L-ascorbic acid was determined using the HPLC method [21]. Approximately 20 g of the fresh sample or 2 g dried sample products were homogenized in 20ml of 0.8% metaphosphoric acid then centrifuged for 10 minutes at 10,000 revolutions a minute at 4°C. The supernatant was filtered through a Whatman no. 4 filter paper, 1 ml of the filtrate was diluted with 1 ml of 0.8% metaphosphoric acid and filtered through a 0.45 millipore filter. Approximately 20 µl of the sample was injected into the HPLC (model shimadzu). L-Ascorbic acid standards (ascorbic acid analytical grade) were prepared from a stock solution and used to quantify the L-ascorbic acid content of samples. The HPLC conditions were as follows; Column was a C18 (ODS) 5 M x 15 cm; Mobile phase was 0.8% metaphosphoric acid (isocratic): and Detection – UV Detector was set at 266 nm.

### Determination of Colour

The colour measurements ( $L^*a^*b^*$ ) of the fresh and dried mangoes were determined using a hand held colorimeter (Model: Minolta Chroma Metre CR-200, Tokyo, Japan). The colorimeter was calibrated before taking measurements of each sample on a standard white plate (Minolta Calibration plate no. 15033256).

### Determination of Drying Rate

First order kinetics model was used to describe the rate of moisture loss during drying:

$$\frac{\partial m}{\partial t} = -km$$

$$\frac{\partial m}{m} = -k \cdot \partial t$$

$$\ln M - \ln M_0 = -k \cdot t$$

$$\ln M = \ln M_0 - k \cdot t \dots \dots \dots \text{Equation 2}$$

Where  $m$  is moisture loss,  $M_0$  is initial moisture,  $M$  is the amount of residual moisture,  $t$  is time and  $k$  is the drying rate constant ( $\text{h}^{-1}$ ).

### Sensory Analysis

The consumer acceptability of the dried mango cubes and leathers was assessed based on colour, taste, texture and overall acceptability. Sensory evaluation involved a panel of 30 untrained individuals, male and female students and staff members of the Faculty of Agriculture, Jomo Kenyatta University of Agriculture and Technology aged 20 to 38 years. The nine point hedonic scale was used, where 9 denoted like extremely and 1 denoted dislike extremely. The ratings for the sensory attributes were analyzed [22].

### Statistical Analysis:

All tests were run in triplicate and the results averaged to determine the mean and standard deviation. Least square difference (LSD) test was used to determine differences between means. The statistical package used to carry out the analysis was GenStat for Windows® Discovery Edition 4, 2011.

## RESULTS

### Changes in Selected Physico-chemical Constituents of ‘Apple’ Mangoes with Ripening

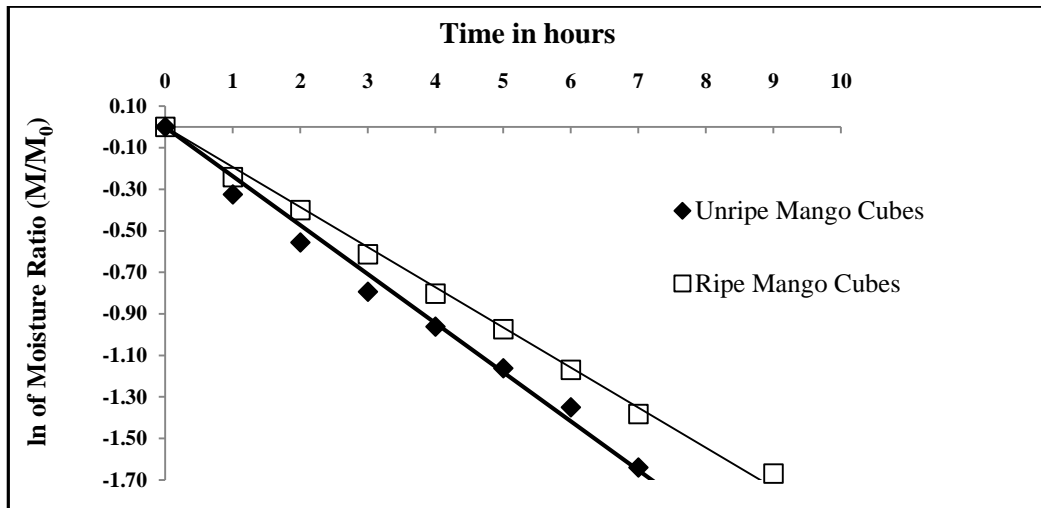
The changes in moisture content, crude ash, crude fibre, TTA and TSS with increasing ripening are as indicated in **Table 1**, whereas the changes in total carotenoids, ascorbic acid and colour are as indicated in **Table 2**. The moisture content, crude ash, TSS and total carotenoids of fresh Apple mangoes increased significantly ( $P < 0.05$ ) with increasing ripening. On the other hand, the crude fibre content of Apple mangoes decreased slightly ( $P > 0.05$ ) with increasing ripening while the TTA and ascorbic acid decreased significantly ( $P < 0.05$ ). In the determination of colour, the  $L^*$  value of the unripe mangoes was significantly higher while the  $a^*$  and  $b^*$  values were significantly lower ( $P < 0.05$ ) than that of ripe mangoes.

## Impact of Drying on 'Apple' Mango Cubes and Leathers

### Drying Kinetics of 'Apple' Mango cubes and Mango leathers

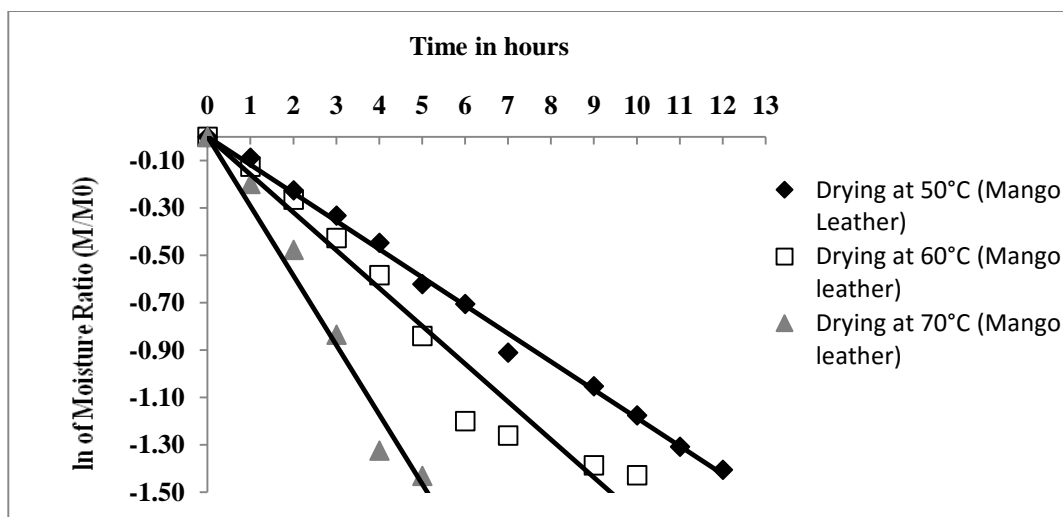
Drying of unripe and ripe 'Apple' mango cubes and 'Apple' mango leathers followed first order kinetic model ( $R^2 > 0.97$ ) for all cases (**Figure 1-3**). The final moisture content for all mango cubes and leathers ranges between 10.53% and 16.53%.

The unripe mango cubes dried faster than the ripe mango cubes (**Figure 1**).



**Figure 1: Influence of ripening stage on the drying rate of 'Apple' mango cubes drying in a Windy Oven at 60°C (Where ln represents the natural logarithm of the moisture ratio  $M/M_0$ .)**

Increase in temperature resulted in a faster drying rate in the mango leathers and mango leather control samples (**Figures 2 and 3**).



**Figure 2: Influence of temperature on drying rate of 'Apple' mango leathers during drying in a Windy Oven at 50°C, 60°C & 70°C**

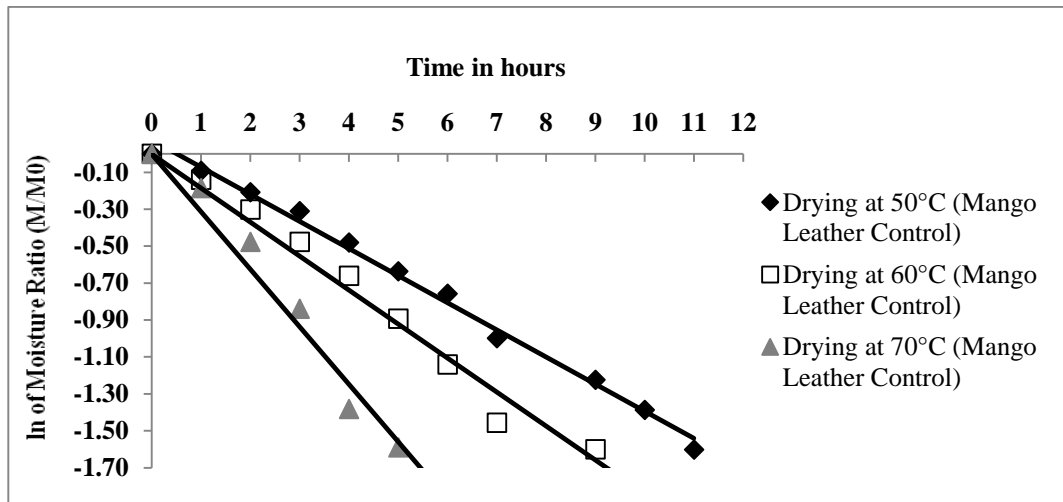


Figure 3: Influence of temperature on drying rate of 'Apple' mango leathers controls during drying in a Windy Oven at 50°C, 60°C & 70°C

### Changes in ascorbic acid, total carotenoids and colour after drying of 'Apple' mango cubes and leathers

There was a significant loss ( $P < 0.05$ ) in ascorbic acid content after drying unripe and ripe mango cubes. The ascorbic acid content of the mango leathers decreased significantly ( $P < 0.05$ ) with increasing drying temperatures. The highest residual ascorbic acid value was obtained by drying mango leathers (with sucrose-glucose solution, pectin and citric acid) at 50°C. The mango leathers and mango leather controls dried at 50°C and 60°C had significantly higher ( $P < 0.05$ ) ascorbic acid content than the mango cubes dried at 60°C. Whereas there were no significant differences ( $P < 0.05$ ) between dried mango cubes and mango leathers dried at 70°C (**Table 2**).

The total carotenoids content of unripe mango cubes decreased significantly while that of ripe mango cubes increased significantly ( $P < 0.05$ ) after drying. Total carotenoids content of the mango leather samples was higher for leathers dried at higher temperatures (**Table 2**).

Drying resulted in significant colour changes ( $P < 0.05$ ) in both unripe and ripe mango cubes. The  $L^*$  values of the mango leathers decreased significantly ( $P < 0.05$ ) with increase in drying temperatures. In all cases, the  $a^*$  values (redness) increased significantly ( $P < 0.05$ ) with increase in drying temperature, the highest  $a^*$  value being observed in the case of the mango leather control sample dried at 70°C (**Table 2**).

### Sensory Analysis

The colour score ranged respectively from 4.0 (dislike slightly) to 7.96 (like very much) for unripe dried mango cubes and mango leather control samples dried at 60°C. It was noted however, that the best score in colour did not differ significantly from the dried ripe mango cubes and the other mango leathers. The dried mango samples taste scores ranged from 3.4 (dislike moderately) to 7.68 (like very much), which were the scores of the dried unripe mango cubes and the dried ripe mango cubes respectively. The mango leather dried at 60°C score was the second highest, however, as previously



observed the two best samples in taste did not differ significantly from the other mango leathers and mango leather controls. Mango leathers dried at 50°C scored the highest in the texture category but these results only differed significantly from the dried unripe mango cubes. The best results were obtained for mango leather dried at 60°C and mango leather dried at 50°C (**Table 4**).

## DISCUSSION

### Changes in Selected Physico-chemical Constituents with Ripening of 'Apple' Mangoes

Increase in moisture content with increasing ripening of mango fruits has been reported [15, 23]. During ripening, starch in unripe fruits is broken down to simple sugars, which increase osmotic transfer of moisture from peel to pulp [15]. Additionally, increase in moisture content could be attributed to alterations in cell wall metabolism increase the cell wall's affinity for water to facilitate the solubilization of pectin during fruit softening and development of juiciness hence the observed increase in moisture content.

No distinct pattern in crude ash content of mangoes at different stages of ripening has been reported. This is may be so because crude ash is influenced by variables like soil composition and climate condition, the area of mango growth, the variety and the level of farm management practices [24].

The results obtained for crude fibre were similar to the observations of other studies [15, 23, 24].

The decrease in fibre content with increasing ripening may be explained by the breakdown of indigestible and insoluble polysaccharides such as cellulose, hemicelluloses, pectin and lignin to simpler, more soluble compounds by enzymes such as pectinesterase, polygalacturonase and cellulase among others.

The content of TSS at the ripe stage was similar to those observed in another study [25]. The increase in TSS with ripening could be as a result of hydrolysis of starch (associated with amylase activity) to simple sugars; glucose, fructose and sucrose.

The reduction of TTA with ripening was similar to what has been reported by other authors [23, 24]. The TTA content may be attributed to the presence of organic acids which are important intermediate products of metabolism. Therefore, acid content decreases during ripening may be due to utilization of organic acids during respiration or their conversion to sugars and amino acids among other constituents.

The decrease in ascorbic acid could be attributed to its susceptibility to oxidative destruction as impacted by ripening environment [25].

The results obtained for total carotenoids were lower than the observations of another study but had a similar trend with respect to increasing carotenoids with increased ripening [26].

The colour results indicate that the ripe Apple mangoes were darker, redder and yellower than unripe Apple mangoes. This could be attributed to the decrease in chlorophyll content and increase in anthocyanins and carotenoids contents during increasing ripening.

### **Impact of Drying on 'Apple' Mango Cubes and Leather**

#### **Drying Kinetics of 'Apple' Mango cubes and Mango leathers**

The higher drying rates in unripe mango cubes compared to the ripe mango cubes can be attributed to the comparably lower sugar contents. During drying, sugar becomes sticky and thus has lower moisture diffusivity than water. According to the observations of another study [27], a final moisture content of 17% ( $a_w = 0.6$ ) in untreated mangoes was considered to be desirable as it does not support microbial growth nor lead to excessive colour deterioration.

The drying rate of mango leather controls dried at 70°C was 2.2 and 1.7 times higher than the drying rates of mango leather controls dried at 50°C and 60°C respectively. This could be attributed to the increase temperature difference between the drying air and mango samples that increases the heat transfer coefficient which influences the heat and mass transfer rate.

The residual moisture content of the mango fruit leathers in this study were similar to the observations of another study [28], which reported that the mango leathers were found to be stable for 6 months without need for chemical preservatives due to combination of low water activity ( $a_w=0.62$ ) and low pH (3.8).

#### **Changes in ascorbic acid after drying of 'Apple' mango cubes and leathers**

The losses in ascorbic acid of unripe and ripe mango cubes were similar to the observations of another study [13]. The higher loss of ascorbic acid content in ripe mango cubes compared to the unripe mango cubes could be explained by the longer drying time the ripe mango cubes underwent.

The range of ascorbic acid content of the mango leathers was found to be similar to the observations reported from another study [14]. The higher ascorbic acid contents in the mango leather controls and mango leathers than ripe mango cubes could be explained by the shorter drying times and addition of sugar that has a protective effect respectively. The significant decrease in ascorbic acid as a result of drying could be attributed to the high sensitivity of L-ascorbic acid to increase in temperatures above ambient.

#### **Changes in total carotenoids after drying of 'Apple' mango cubes and leathers**

Dried ripe mango cubes had higher total carotenoids content. This is because mangoes with higher carotene content when fresh will have higher carotene content when dried [16].

Total carotenoids retention in the mango fruit leathers based on dry matter basis was found to be higher for samples dried at higher temperatures. In the mango leather

controls, for instance, total carotenoids retention was found to be 58.24%, 51.41% and 41.76% for samples dried at 70°C, 60°C and 50°C respectively. These observations are similar to the ones reported by another study [29]. This may be explained by exposure of samples to air which leads to the oxidation of carotenoids hence the higher carotenoids loss with longer drying times (as in drying at lower temperatures) and increased surface area (as in mango leathers compared to the mango cubes).

### **Changes in colour after drying of mango cubes and leathers**

Changes in  $a^*$  values, have been associated with undesirable browning by unsuitable drying processes. The mango leather dried at 50°C differed insignificantly ( $P>0.05$ ) in colour with the fresh, ripe Apple mango thus suggesting 50°C as the temperature that caused the least colour changes. Colour degradation may be attributed to enzymatic and non-enzymatic degradation of carotenoids that occur during drying [30].

### **Sensory Evaluation**

The higher sensory scores for mango samples dried from ripe mangoes than samples dried from unripe samples were similar to those reported in an earlier study [15]. This may be explained by the sugar/acid ratio in the samples. Ripe mangoes had a higher sugar/acid ratio hence scored better in the overall acceptability [15]. Mango leathers dried at 50°C and 60°C were the most accepted samples.

## **CONCLUSIONS**

Moisture, crude ash, TSS, total carotenoids, redness and yellowness of Apple mangoes increase with increased ripening. On the other hand, crude fibre, total titratable acidity and ascorbic acid of Apple mangoes decrease with increasing ripeness. The drying rates of Apple mango cubes and leathers depend on the stage of ripening and drying temperature, respectively. Apple mango leathers dried at higher temperatures have higher amounts of residual total carotenoids and brown more. Whereas Apple mango leathers dried at lower temperatures have higher amounts of residual ascorbic acid. Additionally, ripe Apple mangoes are better raw material for the production of cubes and leathers compared to unripe mangoes with respect to final sensory characteristics of the samples. Finally, drying of mango leathers derived from ripe Apple mangoes at 60°C to a moisture content of approximately 17% is the best method that can be adopted according to this study.

## **ACKNOWLEDGEMENTS**

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**Table 1: Effect of ripening on the chemical composition of Apple mango**

| <b>Ripening Stage</b> | <b>Moisture content (%)</b> | <b>Crude Ash (%)</b>   | <b>Crude Fibre (%)</b> | <b>Titratable Acidity (%)</b> | <b>Total Soluble Solids (Brix)</b> |
|-----------------------|-----------------------------|------------------------|------------------------|-------------------------------|------------------------------------|
| <b>Unripe</b>         | 83.96±0.47 <sup>a</sup>     | 0.16±0.01 <sup>a</sup> | 0.75±0.20 <sup>a</sup> | 1.20±0.02 <sup>b</sup>        | 10.53±0.25 <sup>a</sup>            |
| <b>Ripe</b>           | 85.5±0.76 <sup>b</sup>      | 0.35±0.01 <sup>b</sup> | 0.67±0.04 <sup>a</sup> | 0.56±0.02 <sup>a</sup>        | 15.1±0.1 <sup>b</sup>              |
| <b>L.S.D. 5%</b>      | 0.740                       | 0.035                  | 0.327                  | 0.046                         | 0.434                              |

Values are represented as mean ± Standard Deviation

n=3

Means with different superscripts in the same column are significantly different at P<0.05

L.S.D. stands for least square difference

**Table 2: Effect of drying on colour, total carotenoids and ascorbic acid contents of fresh (unripe and ripe) and dried mango cubes and leather**

| Dried Mangoes                          | L* value                | a* value                | b* value                 | Total<br>carotenoids<br>µg/100g | Ascorbic<br>acid<br>mg/100g |
|--|-------------------------|-------------------------|--------------------------|---------------------------------|-----------------------------|
| Unripe – fresh                         | 86.53±0.35 <sup>g</sup> | -8.37±0.75 <sup>a</sup> | 57.07±0.90 <sup>f</sup>  | 768±51.8 <sup>b</sup>           | 98.03±0.25 <sup>g</sup>     |
| Ripe – fresh                           | 68.87±0.57 <sup>f</sup> | 0.97±0.21 <sup>b</sup>  | 59.23±0.38 <sup>g</sup>  | 1436±54.8 <sup>c</sup>          | 86.45±2.07 <sup>f</sup>     |
| Windy Oven dried cubes<br>unripe(60°C) | 64.97±0.49 <sup>d</sup> | 2.93±0.74 <sup>c</sup>  | 19.37±0.29 <sup>a</sup>  | 508.6±38.4 <sup>a</sup>         | 22.43±1.66 <sup>b</sup>     |
| Windy Oven dried cubes<br>ripe(60°C)   | 53.17±0.59 <sup>a</sup> | 9.90±0.53 <sup>f</sup>  | 18.87±0.81 <sup>a</sup>  | 6484±23.6 <sup>j</sup>          | 14.45±0.25 <sup>a</sup>     |
| Mango Leather (50°C)                   | 68.83±0.65 <sup>f</sup> | 3.63±0.06 <sup>c</sup>  | 53.73±0.58 <sup>de</sup> | 1768±65.1 <sup>d</sup>          | 62.17±0.87 <sup>e</sup>     |
| Mango Leather (50°C)<br>control        | 66.30±0.44 <sup>e</sup> | 9.57±0.47 <sup>f</sup>  | 59.40±0.40 <sup>g</sup>  | 3203±18.4 <sup>f</sup>          | 35.93±1.49 <sup>d</sup>     |
| Mango Leather (60°C)                   | 60.06±0.81 <sup>c</sup> | 5.2±0.79 <sup>d</sup>   | 43.33±1.16 <sup>c</sup>  | 2492±28.2 <sup>e</sup>          | 30.76±1.19 <sup>c</sup>     |
| Mango Leather (60°C)<br>control        | 60.80±0.44 <sup>c</sup> | 12.56±0.47 <sup>g</sup> | 52.53±0.50 <sup>d</sup>  | 3943±20.17 <sup>h</sup>         | 28.32±0.46 <sup>c</sup>     |
| Mango Leather (70°C)                   | 55.87±0.60 <sup>b</sup> | 6.8±0.36 <sup>e</sup>   | 52.87±0.46 <sup>d</sup>  | 3554±67.2 <sup>g</sup>          | 23.13±0.44 <sup>b</sup>     |
| Mango Leather (70°C)<br>control        | 53.57±1.55 <sup>a</sup> | 13.1±0.72 <sup>g</sup>  | 54.60±0.91 <sup>e</sup>  | 4467±28.8 <sup>i</sup>          | 20.03±1.07 <sup>b</sup>     |
| L.S.D. 5% S.L.                         | 1.236                   | 0.957                   | 1.184                    | 1.310                           | 4.817                       |

Values are represented as mean ± Standard Deviation

n=3

Means with different superscripts in the same column are significantly different at P<0.05

L.S.D. stands for least square difference

**Table 3: Drying rate constants (k-values) for mango cubes and mango leathers dried at 50-70°C**

| Dried mango samples                   | k – value (h <sup>-1</sup> ) |
|---------------------------------------|------------------------------|
| Unripe mango cubes dried at 60°C      | 0.236                        |
| Ripe mango cubes dried at 60°C        | 0.193                        |
| Mango leathers dried at 50°C          | 0.118                        |
| Mango leather (control) dried at 50°C | 0.137                        |
| Mango leathers dried at 60°C          | 0.167                        |
| Mango leather (control) dried at 60°C | 0.184                        |
| Mango leathers dried at 70°C          | 0.292                        |
| Mango leather (control) dried at 70°C | 0.311                        |

**Table 4: Sensory evaluation scores for colour, taste, texture and overall acceptability of dried mango cubes and leathers**

| Dried Mangoes                          | Colour            | Taste             | Texture           | Overall<br>Acceptability |
|--|-------------------|-------------------|-------------------|--------------------------|
| Windy Oven dried cubes<br>unripe(60°C) | 4.00 <sup>a</sup> | 3.40 <sup>a</sup> | 3.56 <sup>a</sup> | 3.36 <sup>a</sup>        |
| Windy Oven dried cubes<br>ripe(60°C)   | 7.84 <sup>c</sup> | 7.68 <sup>b</sup> | 7.08 <sup>b</sup> | 7.44 <sup>bc</sup>       |
| Mango Leather (50°C)                   | 7.48 <sup>c</sup> | 7.44 <sup>b</sup> | 7.24 <sup>b</sup> | 7.64 <sup>d</sup>        |
| Mango Leather (50°C)<br>control        | 7.52 <sup>c</sup> | 6.84 <sup>b</sup> | 7.16 <sup>b</sup> | 7.32 <sup>bc</sup>       |
| Mango Leather (60°C)                   | 7.4 <sup>c</sup>  | 7.64 <sup>b</sup> | 6.76 <sup>b</sup> | 7.64 <sup>d</sup>        |
| Mango Leather (60°C)<br>control        | 7.96 <sup>c</sup> | 7.04 <sup>b</sup> | 6.28 <sup>b</sup> | 6.84 <sup>bc</sup>       |
| Mango Leather (70°C)                   | 7.64 <sup>c</sup> | 7.28 <sup>b</sup> | 7.04 <sup>b</sup> | 7.40 <sup>bc</sup>       |
| Mango Leather (70°C)<br>control        | 6.64 <sup>b</sup> | 6.72 <sup>b</sup> | 6.36 <sup>b</sup> | 6.64 <sup>b</sup>        |
| L.S.D. 5% S.L.                         | 0.743             | 0.913             | 0.938             | 0.846                    |

Values are represented as mean

n=30

Means with different superscripts in the same column are significantly different at P<0.05

L.S.D. stands for least square difference

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