Effect of pretreatments and drying methods on some qualities of dried mango (*Mangifera indica*) fruit

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Abstract: The effect of pretreatments and drying methods on some qualities of dried mango fruits was studied. The fruit slices were pretreated with three pretreatments – ascorbic acid dip at 31% w v^{-1} concentration, honey dip at 20% v v^{-1} concentration and steam blanching at a temperature of 120 ℃ and dried using three drying methods (sun, solar and oven drying). In sun and solar drying the mango was dried for eight hours, while for oven drying six hours at an average temperature of 32 ℃, 41 ℃ and 65 ℃ respectively. Sliced mango fruits were soaked in the prepared solutions for four minutes, while the blanching was done for two minutes. There were control samples for each drying methods. Drying curves were generated and the drying rate, proximate composition, vitamin C and β-carotene contents of the dried fruits were determined. The result showed that the pretreatment methods used did not have effect on the drying rate. The nutrient analysis showed that mango samples treated with honey solution had the highest retention of vitamin C (140.35 mg per 100 g) in sun drying method compared to ascorbic acid treated, steam blanched and control samples. Also, for β-carotene, honey treated samples had the highest value of 5921.90 μg per 100 g across the drying methods. Proximate composition of the pretreated dried mango samples revealed that they are rich in vitamin C and β-carotene (antioxidant) which makes them healthy and nourishing and also important ingredient in the food industry for the production of food supplements and other functional foods.

Keywords: mango, pretreatments, drying methods, qualities, vitamin C and β-carotene

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1 Introduction

Mango, *Mangifera indica*, is one of the most important tropical fruits. It is a fleshy stone fruit belonging to the genus Mangifera, consisting of numerous tropical fruiting trees in the flowering plant family Anacardiaceae. The mango is native to South Asia, from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics (Márcio et al., 2004). It was ranked as fifth in total world production by FAO in 2009 among the major fruit crops with world's annual production of 33.5 million metric tonnes (FAO, 2011). Mango has a lot of health-promoting properties which have also made it be listed at the top of the super fruits list (Gross, 2010).

Many of the Mangifera species such as *Mangifera caesia*, *M. foetida*, *M. odorata*, and *M. pajang* are grown locally and often underutilized leaving the specie *Mangifera indica* – the 'common mango' or 'Indian mango' – as the only mango tree commonly cultivated in many tropical and subtropical regions. However, studies have shown that their physical characteristics are almost the same (Gross, 2010). *Mangifera* species are rich in dietary fiber and phytochemicals in all their parts as reported by many studies (Vergara-Valencia et al., 2007; Ajila et al., 2008; Al-sheraji et al., 2011; Hassan et al., 2007) and they also play an important role as antioxidants (Ajila et al., 2010; Abu Bakar et al., 2009). Mango is considered as a fruit with high commercial value and contains high amount of sugars and considerable amount of vitamin C and provitamin A. Increased consumption of fruits such as mango fruit has been widely accepted to improve and preserve the quality of life by reducing the

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risk of cardiovascular diseases and certain cancers (Halvorsen et al., 2006; Vasco et al., 2008). Mango fruit, like other fresh fruits, contains more than 80% water which makes it highly perishable with limited shelf life and thereby susceptible to deterioration. Therefore, preservation technique such as drying is most suitable to remove the water content of the fruit to enhance its shelf life.

Drying is one of the oldest methods for the preservation of food products and it is the process of removing water from food by circulating hot air through it to reduce the moisture content to a level which prohibits the growth of microorganisms. Drying of food materials has advantages such as control of product quality, achievement of hygienic conditions, and reduction of product loss (Corzo et al., 2008). Dennis (1999) also stated that by reducing the moisture content of fruit to be between 10% and 20%, bacteria, yeast, mold and enzymes can be prevented from spoiling it and the flavour and most of the nutritional value can be preserved and concentrated.

Mango and fruits in general can be dried by using different types of dryers and drying methods. The basic types of drying methods which may be used in the drying of fruits include sun and solar drying, atmospheric drying including batch (kiln, tower, and cabinet dryers) and continuous (tunnels, belt, belt-trough, fluidized bed, explosion puff, foam mat, drum, and microwave heated) methods and sub-atmospheric dehydration (vacuum, belt/drum and freeze dryers). Recently the scope has been expanded to include use of low-temperature and low-energy methods like osmotic dehydration. Since drying is a process involving transient heat and mass transfer, the choice of the method to be used depends on various factors which should be taken into account. These factors include raw material and its properties, desired physical form and characteristics of the product, necessary operating conditions, and operation costs (Prakash et al., 2004)

Pretreatments are usually performed precede drying of fruits in order to minimize the adverse changes occurring during drying and subsequent storage. Pretreatments are recommended techniques used to enhance quality of dried fruits. This is because they prevent darkening of the cut fruit surface and cause the destruction of pathogens that could cause foodborne illness. Karim (2005) explained the different pretreatment methods that have been developed for fruit drying which include lemon juice treatment, ascorbic acid dip, salt solution, honey dip, sulfuring, osmotic pretreatment, and blanching (steam and water blanching). In literature, various pretreatments have been used which include sulfuring or sulfite dip (Susan and Williams, 1993), salt solution (Gambella et al., 2000), blanching, chilling, and freezing (Rak et al., 2003), blanching, dipping and sulfiting (Swanson, 2003), sucrose, blanching and sulfiting (Karim et al., 2008), dipping in 0.5% ascorbic acid solution; 0.3% l-cysteine solution; 0.1% 4-hexyl resorcinol solution; 0.5% sodium meta bisulfite solution; mixed solution of 0.05% 4-hexyl resorcinol and 0.5% sodium meta bisulfite; blanching in hot water at 85 ℃ (Jokic et al., 2009), steam, water and oil blanching (Tunde-Akintunde et al., 2011), EPSA (2% ethyl oleat + 4% potassium carbonate + 1% ascorbic acid + 1% citric acid) or EPSM (2% ethyl oleat + 4% potassium carbonate + 2% sodium metabisulfite) (Hasturk et al., 2011), ascorbic acid, lemon juice, salt solution, honey dip(Abano and Sam-Amoah, 2011) and 0.1% KMS (Potassium Meta bisulfite), 0.2% KMS, and 0.3% KMS (Muhammad et al., 2015). This study was carried out to investigate the effect of pretreatments (ascorbic acid dip, honey dip and steam blanching) and drying methods (sun, solar and oven) on some quality parameter of dried mango.

2 Materials and methods

Ripe mango fruit (fresh), honey variety were procured, from the local fruit market in Minna, Niger State. The ascorbic acid and honey for the pretreatments were bought from Mudos Pharmaceuticals, Minna, Nigeria. Other materials and equipment used include fan-circulated oven (Genlab, England model PBS11SF), a box solar dryer, wooden trays with net for sun drying, steamer pot, Weighing balance (Ohaus, AR3130, China, 0.001 g), measuring cylinder, rule and calipers, cutting trays and boards, knives, bowls, hand gloves and towels. The solar dryer was constructed in the department of

Agric and Bioresources Engineering, Federal University of Technology, Minna. It is a direct solar box dryer which consists of a wooden cabinet, a glass cover and trays on which the treated sliced fruit were placed. The interior of the dryer was painted black for maximum collection of solar rays.

2.1 Pretreatments

The fruits were inspected and sorted to see if there is any physical damage and to ensure that they are in good condition before drying. The selected fruits were washed, hand-peeled and cut into about 5 mm thick slices for quick drying. The initial moisture content and initial weight of the fruit samples were determined. The sliced mango fruits were divided into 400 g each and treated with steam blanching (SB), ascorbic acid solution dip (AAD) and honey solution dip (HD) before drying; one sample was untreated and served as the control. For steam blanching, the sliced fruit samples were placed in a steamer pot in a thin-layer and put over boiling water at 120°C for two minutes. The fruit was covered tightly to allow circulation of the steam and afterward cooled, drained and dried immediately. For the ascorbic acid dip pretreatment, 3000 mg of ascorbic acid was mixed with 660 mL of distilled water to form 31% w v^{-1} ascorbic acid solution according to the method used by Abano and Sam-Amoah (2011). Fruit slices were soaked in the solution for four minutes, drained well and placed on trays for drying while in honey dip; honey-water solution was prepared using one part of honey to four parts of water to form 20% v v^{-1} solution (Andress and Harrison, 2006). The fruits were dipped into the solution immediately after slicing and left for four minutes and then drained well before drying.

2.2 Drying methods

Three drying methods were used in the experiments which are sun drying, solar drying and oven drying. Sun drying of the fruits was carried out by placing the treated sliced fruits on drying trays in a thin layer. The trays were placed on a raised platform and left in the sun to dry. The raised platform enables adequate air circulation around the fruit, the average temperature during drying was 32 ℃. For the oven drying the oven was preheated before the fruit were placed into it and temperature was set to 65 ℃. In the solar drying the pretreated samples were kept on trays in thin layer and kept inside the solar dryer. Then, the dryer was kept under the sun and solar rays were trapped with the help of the solar collector, the average temperature in the solar dryer was 41 ℃. During the experiment all the samples were weighed at an interval of one hour until a constant weight was obtained. Temperature in the solar dryer and the ambient temperature were also monitored regularly. The experiment was carried out in the department of Agricultural and Bioresources Engineering departmental laboratory, Federal University of Technology, Minna, Nigeria

2.3 Proximate and vitamin analysis

Proximate values for moisture, fat, protein, ash, and crude fiber of dried fruit samples were determined according to AOAC (1990); carbohydrate content was calculated by difference, vitamin C and β-carotene contents of dried fruit samples were determined by titration method of Osborne and Voogt (1978) and spectrophotometric method based on Ultraviolent (UV) inactivation respectively as described by Onwuka (2005).

2.4 Drying rate determination

Drying rate is the rate of moisture removal per time during the drying process. It was obtained by determining the moisture content of samples as drying progresses Odewole et al. (2014). Mathematically it is expressed as:

$$DR = \frac{w_1 - w_2}{t} \tag{1}$$

where, w_1 = Weight of product before drying (g); w_2 = Weight of product after drying (g); t = Drying time (h); DR = Drying rate (g h^{-1}).

2.5 Statistical analysis

The experimental runs were conducted in triplicate. Analysis of variance (ANOVA) was done at significance level of 0.05 using the IBM statistical package SPSS 20.0. Mean differences in the treatments were tested for significance using the Duncan Multiple Range Test (DMRT).

3 Results and discussion

3.1 Drying curves for mango

The moisture content of the pretreated fruits was plotted against time of drying to generate the drying curves. Figures 1-4 show the drying curves for mango with each pretreatment across the drying methods. It can be observed from these curves that as the time of drying increases, the moisture content of the fruit sample decreases until a constant moisture content is reached.

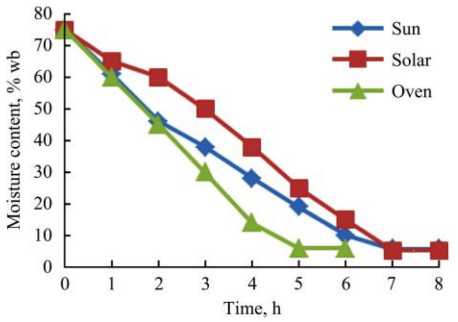

Figure 1 Drying curves of dried mango samples (control) across the three drying methods

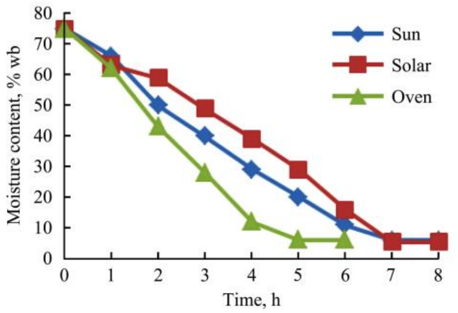

Figure 2 Drying curves of treated (AAD) and dried mango samples across the three drying methods

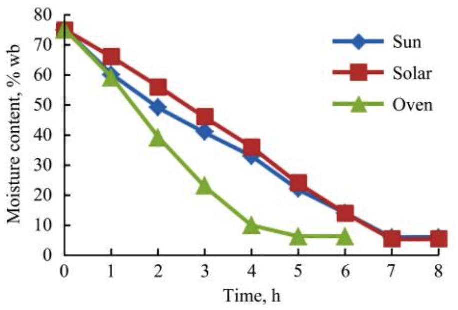

Figure 3 Drying curves of treated (HD) and dried mango samples across the three drying methods

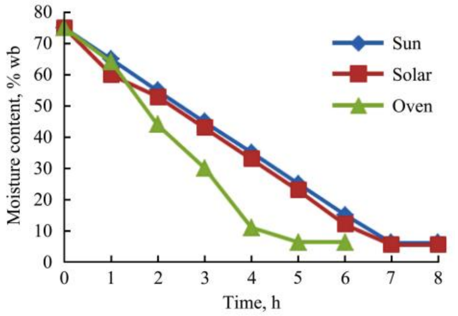

Figure 4 Drying curves of treated (SB) and dried mango samples across the three drying methods

Figure 1 and Figure 2 show the drying curves for untreated (control) and ascorbic acid treated mango samples across the sun, solar and oven drying methods respectively. It can be observed that for the control samples, the rate of moisture removal was the same for both the sun and oven drying methods for the first two hours while solar dried samples followed a different path. Also, the time of drying varies according to the drying methods. It took eight hours for both sun and solar drying to reduce the moisture content from 85% w.b. to about 5%-6% w.b. while for oven drying, it took just six hours. These results show that the drying methods have significant effect on the drying rate of mango slices. The curves are similar to those gotten by Kaddumukasa et al. (2005) where they examined the effect of drying methods on the quality of green banana flour and Jokić et al. (2009) on apple samples. The curves for honey treated and steam blanched samples across the different drying methods also followed similar trend as shown in Figure 3 and Figure 4.

According to this study, pretreatments do not have a significant effect on the drying rates of mango slices. This implies that irrespective of the pretreatment applied to mango slices prior to drying, as long as the samples were dried using the same drying methods, the effect of the pretreatments were not significant. This can be seen in Figures 5-8. The treated samples and the control dried almost at the same time; about eight hours for sun solar drying method and six hours for oven drying method. However, this is not in agreement with Odewole et al. (2014) who considered varying concentration of treatment has effect on the drying rate. Thus there is a need to further study the effect of various concentrations of ascorbic acid and honey solution treatments.

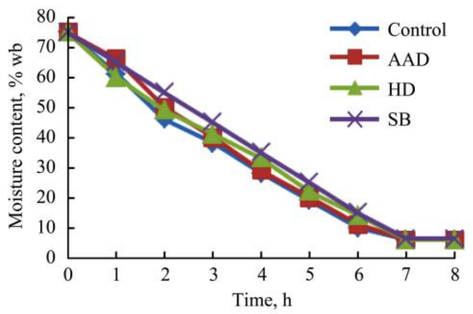

Figure 5 Drying curves of sun dried mango samples with four pretreatments (control, AAD, HD, SB)

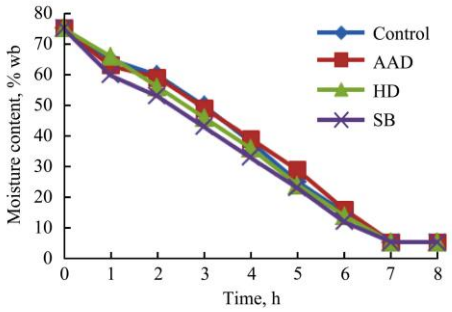

Figure 6 Drying curves of solar dried mango samples with four pretreatments (control, AAD, HD, SB)

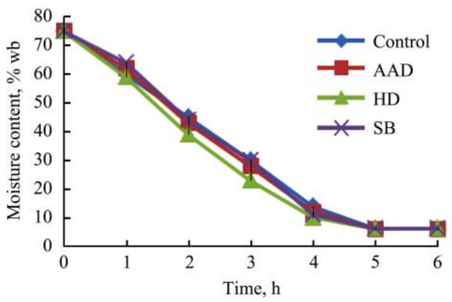

Figure 7 Drying curves of oven dried mango samples with four pretreatments (control, AAD, HD, SB)

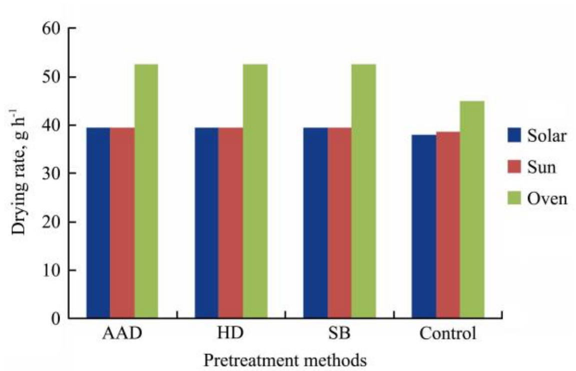

Figure 8 Drying rate for the three drying method and all the treatments

3.2 Effect of pretreatments and drying methods on proximate composition of dried mango

The proximate compositions of dried mango samples were determined and the results are shown in Table 1. These values are close to those obtained in the studies carried out by Gopalan et al. (2000).

The results of the analysis show that there is no significant difference (p>0.05) in the moisture content of the dried mango. These moisture values were lower than those obtained by Abano et al. (2013) who studied the effects of ascorbic acid, salt, lemon juice, and honey on drying kinetics and sensory characteristic of dried mango. For the fat content, honey treated mango sample was significantly different (p<0.05) from other samples in the solar drying method. The protein, carbohydrate, and fibre contents of the dried mango also showed various levels of significance (at $\alpha = 0.05$) across the pretreatments and drying methods while there was no significant difference in the ash content. This shows that pretreatment and drying methods have effect on some of the proximate qualities of dried mango. Similar studies have been carried out by Mudau et al. (2013) and Omayma and Khaled (2012) on mango; Karim (2010) and Karim et al. (2008) on pineapple slice.

Table 1 Proximate composition of pretreated dried mango

Samples	MC, %	Fat, %	Protein, %	Ash, %	Fibre, %	Carbohydrate, %
Sun control	5.80^{a}	5.21^{a}	4.36^{a}	3.89^{a}	10.96^{b}	69.78^{a}
AAD	5.90^{a}	5.22^{a}	4.45c	3.88^{a}	10.34^{a}	70.21^{b}
HD	5.91^{a}	5.49^{ab}	4.36^{a}	3.86^{a}	10.32^{a}	70.06^{b}
SB	6.12^{a}	5.36^{a}	3.63^{b}	3.70^{a}	10.58^{a}	70.61^{b}
Solar control	5.28^{a}	5.20^{a}	3.45^{b}	3.39^{a}	11.26^{b}	71.42^{b}
AAD	5.36^{a}	5.28^{a}	3.63^{b}	3.61^{a}	10.42^{a}	71.70^{b}
HD	5.32^{a}	5.45^{b}	4.64^{b}	3.56^{a}	10.59^{a}	70.44^{a}
SB	5.41^{a}	5.28^{a}	2.90^{a}	3.59^{a}	10.49^{a}	72.33^{b}
Oven control	6.00^{a}	5.62^{b}	4.00c	3.81^{a}	10.38^{a}	70.19^{a}
AAD	6.14^{a}	5.52^{b}	3.82^{b}	3.30^{a}	10.93^{b}	70.29^{a}
HD	6.31^{a}	5.83^{b}	4.36c	3.60^{a}	10.42^{a}	69.48^{a}
SB	6.29^{a}	5.63^{b}	3.63^{b}	3.59^{a}	10.63^{a}	70.23^{a}

Note: Values followed by the same letter in the same column are not significantly different (p>0.05). AAD- Ascorbic Acid Solution Dip; HD-Honey Solution Dip; SB- Steam Blanching.

3.3 Effect of pretreatments and drying methods on vitamin C and β-Carotene contents of dried mango

Mango fruit is very vital in human diet due to its vitamin C and β-carotene contents (Tiwari et al., 2013; Fowomola, 2010; Pal, 1998). It is a rich source of carotenoids, with β-carotene accounting for more than half of the total carotenoids content in the majority of its variety (Schieber et al., 2000). It has been reported in literatures ((Mercandate et al., 1998; Barreto et al., 2008; Chen et al., 2004) that β-carotene contains high amount of vitamin A and anti-oxidative capacity which are important to human health.

The effect of pretreatments and drying methods on these vitamins content was studied and the results are shown in Table 2.

As observed from the result, mango samples treated with ascorbic acid and honey solution had higher contents of vitamins C, followed by the steam blanched samples while the control (untreated) samples has the least values. This shows that pretreatments and drying methods had significant effect (p<0.05) on vitamin C content of dried mango samples. For β-carotene, the values were not significantly different (p>0.05). This implies that both pretreatments and drying methods do not influence the β-carotene content in the dried mango samples. Similar observations were also made by Karim et al. (2008) who studied of the effect of pretreatments on quality attributes of air-dehydrated pineapple slices.

Table 2 Vitamin C and β-carotene contents of dried mango samples

Samples	Vitamin C, mg per 100 g	β-carotene, μg per 100 g
Sun control	120.39^{a}	4209.86^{a}
AAD	136.21^{b}	4521.49^{a}
HD	140.35^{b}	4928.32^{a}
SB	124.92^{b}	4128.81^{a}
Solar control	109.89^{a}	5208.34^{a}
AAD	126.89^{b}	5294.46^{a}
HD	121.30^{a}	5461.95^{a}
SB	114.26^{a}	5251.57^{a}
Oven control	109.32^{a}	5429.60^{a}
AAD	158.65^{c}	5655.81^{a}
HD	132.45^{b}	5921.90^{a}
SB	129.61^{b}	5493.95^{a}

Note: Values followed by the same letter in the same column are not significantly different at p>0.05. AAD - Ascorbic Acid Solution Dip; HD - Honey Solution Dip; SB - Steam Blanching.

4 Conclusions

Dried mangoes when compared to their fresh counterparts have valuable nutritional, antioxidant, and health-promoting properties and are good alternatives especially during the off season. These experiments were carried out to investigate the effect of pretreatments and drying methods on the quality of dried mango. The fruits were dried using three different drying methods (sun, solar and oven drying methods) and pretreatments (ascorbic acid dip, honey dip and steam blanching). There was also a control sample. Proximate composition, vitamin C and β- carotene contents of the dried fruits were determined and the results showed that there was retention in the nutrient of the dried mango samples. Honey treated samples had the highest retention of vitamin C (which is a major nutrient in dried mango) when compare with the ascorbic acid treated samples, steam blanched and control samples for all drying methods. Therefore, honey solution is recommended as a good and healthy pretreatment for dried mango. Alternatively, ascorbic acid solution can be used since it enabled a good retention of vitamin C content in dried mango. However, for maximum benefit various concentrations of the two solutions should be further investigated.

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