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Full Length Research Paper

Blanching and drying period affect moisture loss and vitamin C content in *Ziziphus mauritiana* (Lamk.)

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Wider utilization of *Ziziphus mauritania* (Lamk) Ber fruits in sub-Saharan Africa is hindered by the rapid deterioration of the fresh fruits and darkening of sun-dried fruits. This study was undertaken to determine the effect of pre-drying treatment, drying method and the subsequent duration of storage on the quality attributes of *Z. mauritiana* fruits harvested from the Zambezi Valley. The vitamin C content was high at the beginning of the drying period and progressively decreased as the drying increased, and was lowest at three weeks for all drying methods. Effect of drying method was not significant (P > 0.05). The purity (chroma) and lightness (value) of fruit colour decreased ($P < 0.001$) with increasing drying duration irrespective of the drying method. Blanching fruits before drying significantly ($P < 0.001$) decreased the colour chroma of the fruits (6.4) in comparison with non-blanched fruits (6.6). Further work to determine the causes of darkening in drying *Z. mauritiana* fruits and sensory evaluations to determine the level of darkening that is acceptable to consumers is warranted.

Key words: Pre-storage treatment, drying duration, colour chroma, fruit darkening, quality attributes.

INTRODUCTION

Rural dwellers in southern Africa cope with serious food shortages often caused by climatic risks by diversifying their food and income sources, such as growing a variety of crops and opportunistic gathering of fruits from wild, semi-domesticated and domesticated stands for consumption and sale (Akinnifesi et al., 2006, 2008). One major challenge to the world's food security problems is how to reduce losses that occur during the production, harvesting, post-harvest and marketing processes of fruits. Fresh fruits are perishable and incur loss of quality and nutrients from the time after their harvest until they reach the consumer. Postharvest losses of 20 - 50% have been estimated for developing countries (Kordylas, 1991), and nearly 10 - 40% of the crops harvested never reach the intended consumers due to post harvest losses along the supply chain (Esper and Muhlbauer, 1998). Losses of more than 50% have been recorded in indigenous fruits in Tanzania (Mumba et al., 2002). This is due to lack of knowledge in harvesting, handling, storage, processing and marketing of fruits. This translates to reduction in the quantity and quality of food available for family consumption and sale (Saka et al., 2001).

Ziziphus mauritiana (Ber) is an important naturalized fruit in sub-Saharan Africa contributing to food security and household income. The fruit has the common problem of rapid deterioration of fresh fruits after harvest (Kadzere et al., 2006, 2007; Saka et al., 2007). The fresh fruits can keep for 4 - 10 days under ambient conditions (Abbas, 1997; Kadzere et al., 2001; Morton, 1987). Farmers generally process or dry fresh fruits in order to 1) increase the palatability of product, 2) preserve the products, and 3) obtain products that can be converted into other by products or uses. Fruit is preserved by sun drying by the rural communities in Southern Africa (Kadzere et al., 2001; Saka et al., 2004). Traditional processing and drying of fruits in Zimbabwe is common in the drier part of the country (Zambezi Valley, Chipinge and Gokwe) (Kadzere et al., 2001). The fruits are dried

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Plate 1. The solar dryer.

for varying periods depending on the intended use of the dried product and prevailing climatic conditions.

Considerable losses can occur during sun drying. Over drying, insufficient drying, contamination by foreign materials such as leaves, dust, rain, insect as well as discoloration by ultra-violet radiation characterize sun drying (Esper and Muhlbauer, 1998). Loss of moisture can be intermittent or irregular and the rate of drying is generally low and this increases the risk of spoilage during the drying process. Generally, sun drying will not lower moisture of fruit below 15% (Potter and Hotchkiss, 1998). Also the direct exposure to ultra violet radiation can greatly reduce the level of vitamins in the dried product particularly vitamin C (Brenndorfer et al., 1985; Kordylas, 1991). The use of improved but relatively cheaper drying techniques to reduce spoilage and improve on fruit quality is vital.

Pre-treatment of fruits before dehydration improves the drying process as well as the quality of the dried product. Blanching is one of the pre-treatment methods that are used to arrest some physiological processes before drying fruits. It is heat pre-treatment that inactivates enzymes that cause deterioration in food. It also destroys some micro - organisms that cause food deterioration and thus reducing their population (Potter and Hotchkiss, 1998; Breidt et al., 2000).

The dried fruits are generally stored for periods between one month and 18 months to enhance food security (Saka, 1995; Kadzere et al., 2001; Saka et al., 2007). Farmers have reported deterioration of fruits during storage such as discoloration but the stability of nutrients during drying and storage under Zimbabwe's conditions needs to be evaluated. There is need therefore to further evaluate the effect of the drying method and length of drying period on vitamins and other nutritional attributes of *Z. mauritiana* fruits. The objective of the study was to evaluate the effect of blanching pre-treatment, drying and storage methods and duration on the color and vitamin C content of *Z. mauritiana* fruits.

MATERIALS AND METHODS

Study site description

Fresh fruits were collected from Muzarabani district and transported to Harare. Muzarabani is a district in Zimbabwe which lies at approximately 400 m a.s.l. and is located at a longitude of 16° East and latitude of 31° South. The area receives an annual rainfall between 650 and 700 mm and experiences mean annual tempe-ratures of 32°C. The experiment was carried out at Harare Research Station, which is under the Department of Research and Extension (AREX) to enable easy access to the plots because Muzarabani is 240 km from Harare. Harare is situated at an altitude of 1506 m a.s.l., experiences mean annual temperatures ranging from 10 to 26°C and receives an annual rainfall between 800 about 1000 mm.

Experimental design and treatments

The experiment was set up as a split-plot design in a ran-domized complete block arrangement with three replicates. The main plot was two drying methods (solar drier and open sun drying), the subplot was two blanching levels (blanched and unblanched). The fruits were measured at three drying periods (0, 1.5 and 3 months).

Fruit weight loss during drying

Solar dryers that allow natural circulation or natural convection system (cabinet type) and open sun drying structures were used in this study (Plate 1). Passive solar dryers (natural circulation or natural convection) of the cabinet type were used in this study (Weisis and Buchinger, 2003). These were selected because they are simple to construct with low labor costs and are of a size appropriate for on-farm use. The solar dryer consisted of a large wooden cabinet with slanting roof. The wooden cabinet was covered by clear polythene sheet to create a green house effect. Trays consisting of a wooden frame and polythene were fitted in the cabinet to allow free air circulation onto the fruits. These were selected because they are simple to construct with low labor costs. Sheeting was fitted in the cabinet to allow free air circulation onto the fruits. Below the trays, black plastic sheeting (collector) was installed to absorb heat. The heat was trapped inside the cabinet to create a greenhouse effect. The circulation of hot air dries the fruits. Each dryer measured 4.5 x 1.3 m, and was raised to 0.5 m above the ground and the tray was fitted at a height of 1 m above the ground.

Freshly harvested fruits were sorted to remove unripe and damaged fruits. The sorted fruits were thoroughly mixed to make a composite sample of 300 kg. Of these, 216 kg were subdivided into 108 samples each weighing 2 kg. The fruits were weighed before drying, at every sampling period. Each sampling subdivision measured 50 by 65 cm and the fruits were spread on a single layer. A push button maximum and minimum thermometer was used to record temperature inside each solar dryer and outside on the open sun drying structure. The atmospheric temperatures at 0800, 1400 h and at 1600 h were recorded daily at the meteorological station of the Harare Research Station. The low cost open sun traditional drying structure was constructed by erecting 4 poles on each corner and then placing sticks across to make a flat surface where the fruits were dried (Plate 2). The dyer measured 4.5 + x1.3 m and was raised to 1 m above ground.

Blanching pre-treatment

The blanching process was done by placing the fruits representing

Plate 2. Open sun drying structure.

a sampling period in woven polythene bags and then submerging the bags in boiling water for 4 min. The blanching water was boiled in a 30 L pot under an open fire. The temperature of the boiling water was 94°C beyond which the fruits are boiled and become unsuitable for drying. The fruits were weighed before blanching and soon after blanching before drying as well as after drying.

Physico-chemical analysis

At every sampling period, fruits were analyzed for the content of vitamin C. A sample of fruit pulp was pulverised in ≥ 100 mL of extracting solution (0.38 M metaphosphoric acid + 1.38 M acetic acid) for 2 min and the supernatant was allowed to settle before determination of vitamin C using the titrimetric method with 2.6 dichlorophenolindophenol as per AOAC (1990).

Fruit colour was determined using the Munsell colour chart. The Munsell colour chart is based on the colour dimensions of hue, value and chroma (Kadzere et al., 2006). Chroma is the purity, intensity, saturation or richness of colour, value refers to the lightness or darkness of a colour and hue is the colour as perceived by the eye (Potter and Hotchkiss, 1998). Fruits were assessed for darkening during drying. The fruits were graded into 2 main groups based on fruit colour as perceived by the eye (hue). Fruits that fell into dark red, dark reddish brown and dusky red were placed into the darkened group and fruits that fell into red, reddish yellow and yellowish red were placed into the light coloured group.

Statistical analysis

Data were analyzed using Genstat version 8.1. Analysis of variance (ANOVA) was carried out for the overall treatment effects and pair wise comparison between means were determined using the least significant difference (LSD) at $P = 0.05$. Square root transformations were carried out on proportions before they were subjected to analysis of variance to normalize the data.

RESULTS

Fruit weight loss during drying

The method of drying x drying duration interaction on weight loss after drying was significant ($P < 0.001$). The three way interaction was not significant. The solar drying method was more efficient than the open sun drying method as determined by the final moisture attained (Figure 1). Fruits dried under the solar dryer lost significantly more weight ($P < 0.001$) than the fruits dried under the open sun drying system. This was dependent on the drying duration. Weight loss increased with an increase in drying duration. The highest percentage weight loss of 73.3% was attained when the fruits were dried for three weeks in the solar dryer. The daily mean temperatures were higher in the solar dryer than in the open sun drying systems. Mean daily temperatures were 28.5 and 20.5°C for the solar dryer and open sun drying systems respectively.

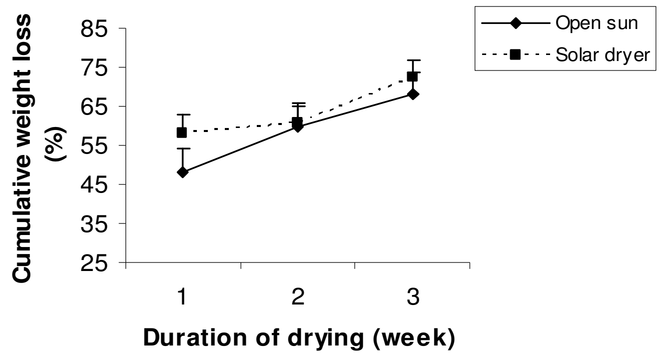

Figure 1. Effect of drying method and duration of drying on the weight loss (%) by the fruits during drying (vertical bars represent standard errors of means).

Weight loss with blanching

Fruits blanched before drying lost significantly ($P < 0.001$) less weight than the fruits dried without blanching (un-blanched) in both the open sun and solar drying method (Figure 2). The weight lost by the fruits increased with the duration of drying.

During storage, after drying the fruits continued to lose weight (Figure 2) and the loss depended on the pre-drying treatment, the drying method and duration of drying. Fruits dried under the open sun lost ($P < 0.05$) more weight during storage compared to those that had been solar dried. However those fruits that had been blanched before drying and had lost less weight during drying were found to lose more weight during storage compared with the un-blanched ones.

Colour attributes of the fruits during drying

There were significant ($P < 0.01$) interactions among pre-drying treatment, drying method and drying duration with respect to chroma of the fruits. The purity of colour (chroma) was high before the drying process for both

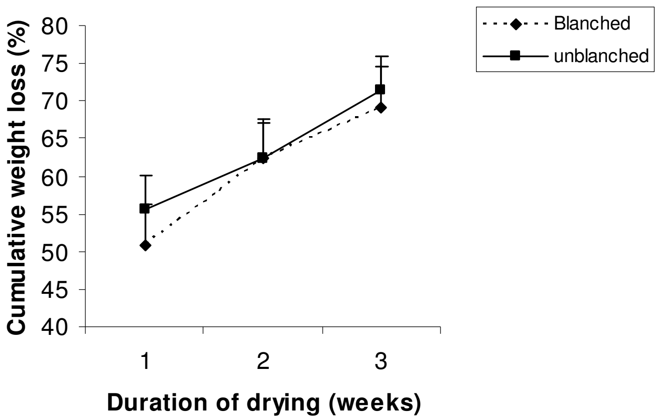

Figure 2. Effect of blanching pre-drying treatment on the weight loss (%) at during drying (vertical bars represent standard errors of means).

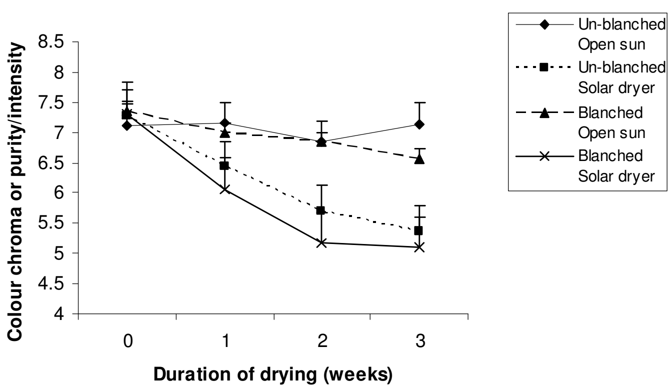

Figure 3. Colour chroma of *Z. mauritiana* fruits as influenced by drying method, blanching and drying duration (vertical bars represent standard errors of means).

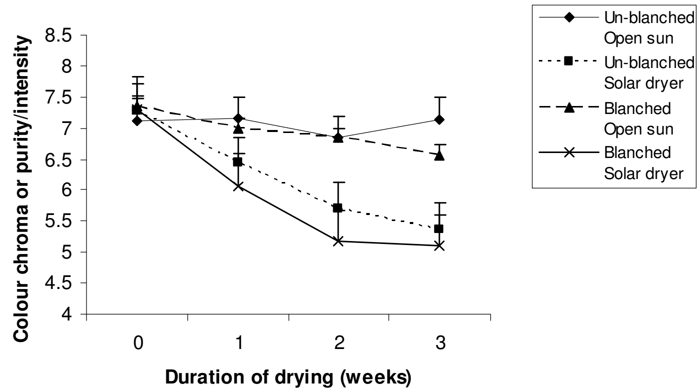

Figure 4. Influence of drying method, pre-drying treatment and drying duration on the darkening of fruits during drying (vertical bars represent standard errors of means).

blanched and un-blanched treatments and it decreased significantly ($P < 0.001$) as the drying time increased. Both the blanched and un-blanched fruits dried under open sun had significantly higher ($P < 0.01$) chroma compared with those dried under the solar dryer (Figure 3). Blanching had a significant influence ($P < 0.01$) on the chroma of the fruits where the blanched fruits tended to have lower values of chroma than those dried without blanching. An increase in drying duration reduced the chroma values for both blanched and un-blanched fruits regardless of the drying method ($P < 0.001$). The lower values of chroma indicate reduced purity of colour (darkening). The browning increased as the drying duration increased. The same trends were observed with the lightness of color (value).

There was a significant interaction ($P < 0.05$) among drying method, pre-drying treatment and drying duration for the proportion of darkened fruits during drying. Fruits dried in the solar dryer had a significantly higher ($P < 0.001$) proportion of darkened fruits than fruits dried under under the open sun drying method across all drying durations. Blanching fruits before drying resulted in high proportions of darkened fruits (Figure 4) and these also increased with an increase in drying duration.

There were significant interactions ($P < 0.05$) between pre-drying treatment, drying method and drying duration and storage duration for the chroma. The general trend showed decreasing chroma values as the storage duration increased regardless of the drying method (Figure 5a). Blanching fruits before drying significantly reduced ($P < 0.01$) the chroma of the fruits during storage compared to un-blanched treatments. The chroma decreased more in the solar dried fruits than in the open sun dried fruits. Increasing the drying duration reduced the chroma of the fruits during storage ($P < 0.001$) (Figure 5b), implying continued darkening during storage. However, the blanched fruits had lower chroma values than un-blanched fruits, an indication of further fruit darkening of blanched fruits during storage.

Vitamin C content of the dried fruits

There were no interactions ($P > 0.05$) among the factors for vitamin C content. There were significant differences ($P < 0.001$) for the vitamin C content of the *Z. mauritiana* fruits among the drying periods (Figure 6). The vitamin C content was high at the beginning of the drying period and progressively decreased significantly as the drying increased (Figure 6). Fruits dried for three weeks had the lowest vitamin C content regardless of the drying method. However, method of drying did not significantly affect ($P > 0.05$) the level of vitamin C during the drying process.

DISCUSSION

The solar dryer was more efficient than the open sun dryer in terms of final weight and moisture reduction of

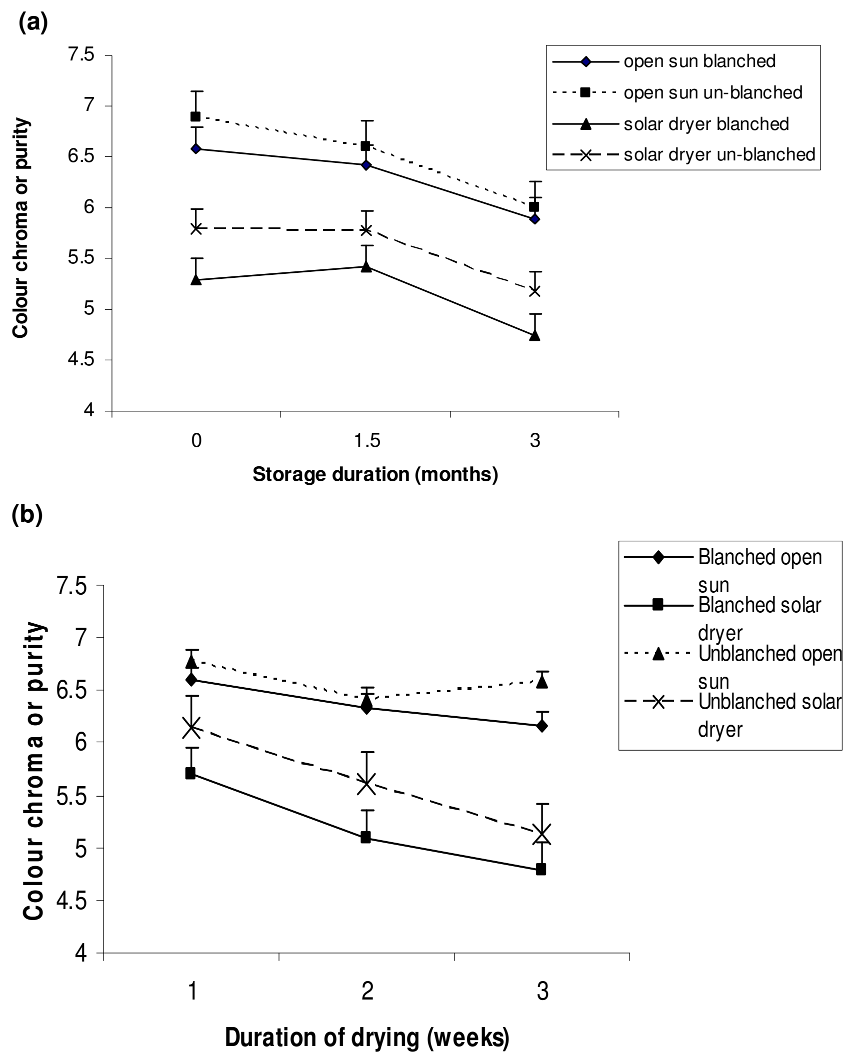

Figure 5. Changes in the chroma of *Z. mauritiana* fruits dried under open sun and solar drying systems and stored for 0, 1.5 and 3 months (vertical bars represent standard errors of means).

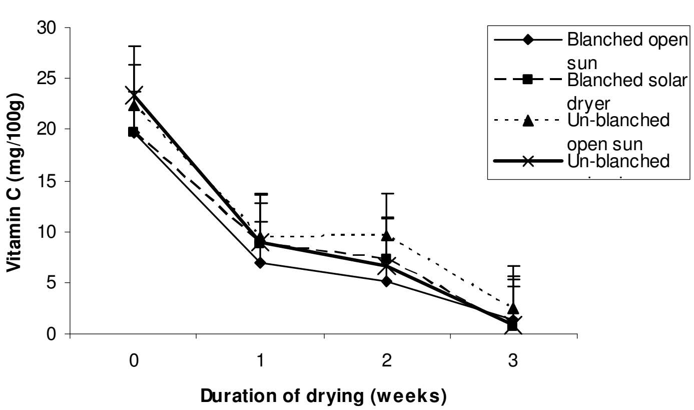

Figure 6. Concentration of vitamin C of *Z. mauritiana* fruits dried for three weeks under open sun and solar dryer (vertical bars represent standard errors of means).

dried fruits. This is attributed to higher temperatures in the solar drying (28.5°C) compared to open sun drying (20.5°C) and this accelerated moisture removal from the fruits. The target weight reduction for this study was 60% and this was attained after drying un-blanched fruits for 1 week in the solar dryer and it took 2 weeks of drying to attain the target weight reduction using the open sun method. Blanched fruits dried in the solar dryer attained the target weight after 2 weeks of drying and fruits dried in the open sun structure took up to 3 weeks to attain the desired weight reduction. The blanching process may have reduced respiratory activities, which in turn may have increased the rate of moisture and weight loss during drying (Lu et al., 2002). Blanched fruits and fruits dried under the open sun method retained more moisture after drying and therefore continued to lose more moisture during storage.

Blanching fruits before drying reduced both the lightness and intensity of colour during drying indicating the development of darkening. The fruits may have been over-blanched which could result in 'cooking' and fruit browning. The colour value (3.2 and 3.8) for blanched fruits dried in the solar dryer and open sun respectively was very low as per the Munsell colour scale and had expressed itself in development of fruit browning observed in the study. The chroma (purity of colour) was relatively high for both the blanched and un-blanched fruits. In some dehydration processes, browning of fruits is caused by the chemical interaction between sugars and proteins (Maillard reaction) (Potter and Hotchkiss, 1998).

The vitamin C content in fruits during drying decreased rapidly with duration from 18 - 23 mg/100 g at the first week to less than 3 mg/100 g at three weeks. Naggy (1980) found vitamin C response to elevated temperatures to be dependent on the acid content of the fruits and vitamin C loss was lower in citrus than in vegetables because vitamin C is stable to heat under acidic conditions. This could explain the low vitamin C response in Z. *mauritiana* fruits to drying method because the difference in temperature between the two drying methods was masked by the acidic nature of the fruits. Blanching of fruits before drying significantly reduced ($P < 0.05$) the vitamin C content of the fruits during drying. Lee and Kader (2000) reported high losses of vitamin C in blanched of spinach than in un-blanched samples. Vitamin C determined immediately after blanching, was lower in all blanched broccoli than the un-blanched broccoli (Brewer et al., 1995). Water blanching results in more vitamin C losses through both leaching into the surrounding water and thermal breakdown. Vitamin C losses increased as the duration of drying was extended. This is because vitamin C is very unstable when exposed to ultra-violet radiation and high temperatures as those experienced in the solar dryer.

Conclusion

Although the solar dryer was more effective than the open sun drying method in reducing fruit moisture content during drying and subsequent storage, however, drying the fruits under the solar dryer caused the development of fruit darkening. There study did not confirm a clear advantage in solar drying over open sun if the vitamin C retention and acceptable colors are the main interest, and where there is no urgency in drying. Similarly, blanching fruits before drying reduced the vitamin C concentration of the fruits as well as increasing the development of darkening of the fruits during drying, indicating that there is no nutritional advantage in blanching fruits before drying. Since fruit dealers are accustomed to blanching, further studies are warranted to better understand the causes of darkening and the blanching time that is appropriate for reduced darkening and reduced loss of vitamin C in future studies.

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