African Journal of Food Science Vol. 3(10) pp. 307-315, October, 2009
Available online http://www.academicjournals.org/ajfs
ISSN 1996-0794 © 2009 Academic Journals

Full Length Research Paper

Influence of blanching on the drying and rehydration of banana slices

K. A. Taiwo* and O. Adeyemi

Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, 220001, Osun State, Nigeria.

Accepted 31 August, 2009

This study examined the effect of blanching (60°C; 10 min) followed by drying (50 - 80°C) and rehydrating at 100°C for 15 – 60 min on product characteristics (shrinkage, dry matter loss, moisture loss, electrical conductivity and rehydration capacity) of ripe and unripe banana samples. Increasing drying temperature resulted in greater moisture loss, higher shrinkage and higher rehydrating capacity with time. Changes in thickness were greater than the radial changes and mathematical equations gave a good fit when related to moisture content using a linear model. The electrical conductivity of the rehydrating solution increased as the initial temperature of drying increased and this resulted in greater dry matter loss, indicating greater loss of membrane integrity. Blanching improved moisture loss compared to untreated samples. The effect of product ripeness was not significant on product attributes (shrinkage, dry matter loss, moisture loss, electrical conductivity and rehydration capacity). Blanched samples had reduced ascorbic acid content.

Key words: Pretreatment, drying temperature, moisture loss, shrinkage, rehydration characteristics, electrical conductivity.

INTRODUCTION

Banana is a highly perishable and bulky fruit, which requires processing into a more stable and convenient form. Drying brings about a substantial reduction in weight and volume; thereby minimizing packaging, storage and transportation cost and also enable storability of the product under ambient temperature especially in developing countries (Senadeera et al., 2005). Dried fruits are unique, tasty and nutritious. They are easy to handle and can be easily incorporated during food formulation and preparation. Dried fruit can be eaten as a snack or added to cereals, muffins or ice cream (Etsey et al., 2007; Reynolds, 2007).

Traditionally, fruits are sun dried as slices but conventional dehydration leads to undesirable changes in quality of the dried product (dark color, leathery texture and poor flavor with a loss of nutritive values) (Maskan, 2000). Pre-drying treatments such as blanching, sulphiting, starching, freezing, sucrose or sodium chloride dipping (osmotic dehydration), etc. have contributed to the improved mass and heat transfer as well as product characteristics (colour, texture, vitamin retention, etc) of various fruits – carrots, apple, kiwifruit, red and green peppers, etc. (Mazza, 1983; Nieto et al., 1998; Kaymak-Ertekin, 2002; Taiwo et al., 2002a).

Drying is a complex process accompanied by physical and structural changes. There is a continuous change in the dimensions of differently shaped food particulates during drying as a result of water removal and internal collapse of the particulates (Senadeera et al., 2005). Shrinkage is one of the major changes taking place during the drying process and it is observed as changes in the outer dimensions of foods. The dimensional changes are needed in evaluating heat and mass transfer during drying, flow resistance through the drying bed, predicting structural loads in bulk storage systems and determining packaging volume. Maskan (2001) reported that shrinkage of kiwi fruits during microwave drying was greater than in hot air drying. The volume of plantain cylinders was reduced to about 60% of its initial value within 3 – 5 h of drying at 40°C (Johnson et al., 1998). These authors described change in volume by a core-drying model, while change in dimensions was related linearly with moisture content.

*Corresponding author. E-mail: Kehindetaiwo3@yahoo.com, ktaiwo@oauife.edu.ng.

Rehydration of dried foods is a complex procedure influenced by several factors (product chemical composition, drying techniques and conditions, composition of the immersion medium, temperature, etc.), which play a major role on the quality attributes of the product. There are reports on the nature and extent of pre-treatment on rehydration characteristics of different fruits (Lima and Cal-Vidal, 1983; Mazza, 1983; Kaymak-Ertekin, 2002; Taiwo et al., 2002b; Nieto et al., 1998 etc.). Microwave dried kiwifruit slices exhibited lower rehyd-ration capacity and faster water absorption rate than hot air dried samples (Maskan, 2001). Loss of water soluble-solids during rehydration was affected by the pre-drying treament of carrots. The presence of sucrose or salt on the surface of cubed carrots impaired moisture uptake and removal (Mazza, 1983). Electrical conductivity measurement of the rehydrating medium provides information on the cellular integrity of the sample and high conductivity values are indicative of leakage of intracellular ions (Tregunno and Goff, 1996).

The aim of this study is to investigate the effects of blanching and ripeness on the dehydration of banana slices dried at different temperatures and to determine the physico-chemical characteristic of the rehydrated banana slices.

MATERIALS AND METHODS

Sample preparation

Matured green banana (*Musa acuminata colla*) bunches were obtained from the University in Ile-Ife, Nigeria to minimize variability in raw materials. Some bunches were stored in dark cupboards to initiate ripening. The banana was peeled manually and then cut into discs using a cutter, vernier caliper and a knife. Samples had an average diameter of 20 ± 0.05 mm and thickness of 10 ± 0.05 mm. At least ten measurements of the thickness were made at different points and only slices that fell within a 5% range of the average thickness were used. Unripe samples had average moisture content of 75.3 ± 1.2% while ripe samples had an average moisture content of 78 ± 0.5%. To account for variability in the moisture content of the pulp, the initial moisture content was measured before the slices were pretreated. The Precision Universal Penetrometer (Stanhope-Seta Ltd, Surrey, England) was used to determine the force needed to cut through the banana samples stored for up to three days. The penetrometer depth (10^{th} mm/m) for unripe samples averaged 12.3 ± 1.0 and 8.2 ± 0.5 for firm ripe samples. Penetration depth decreased with ripening. At optimal ripening, there was no smearing of the knife during cutting (Etsey et al., 2007).

Blanching: Sliced samples were blanched by direct immersion in water at 60°C for 10 min to avoid loss of product firmness. The samples were then withdrawn dabbed gently with a blotting paper to remove adhering surface water and weighed (Borges and Cal-Vidal, 1994; Agunbiade et al., 2006). Sample weight, thickness and diameter were taken before and after pre-treatment. Untreated samples were used as the control.

Drying: After blanching, samples were spread thinly in the air oven drier (DP/DK-600, MRC Ltd., Israel) at 50, 60 or 80°C on a metal tray. The weight, thickness and diameter of each sample were monitored at 1h interval for 6 h then left to complete dryness. Drying curves of moisture versus time were constructed and from these drying rate curves were obtained by method of tangents (Johnson et al., 1998).

Rehydration: Dehydrated samples were placed in glass beakers containing distilled water in a ratio 1:30 (w/w) at 100°C for 15, 30, 45 and 60 min as described by Taiwo et al. 2002a), Etsey et al., 2007). Analysis of data on the rehydrated samples was computed using the equations described by Levi et al. (1988):

Electrical conductivity measurement: A conductivity meter (model CG 858, Schott Geräte GmbH, Hofheim, Germany) was used in determining the electrical conductivity of the rehydrating medium at rehydrating temperature of 100°C at the end of each soaking period to give information on the cellular integrity of the sample and a high conductivity value is indicative of leakage of intercellular ions (Tregunno and Goff, 1996). The experiment was replicated three times.

Dry matter loss: At the end of rehydration, samples were removed from the rehydrating solution, blotted with tissue paper and weighed. The samples were dried in the air oven drier at 80°C for 27 h to determine the solid content.

$$\text{Dry matter loss (\%)} = \left[\frac{(M_g - S_r)}{M_g}\right] x100 \qquad (2)$$

M_g = weight of air dried sample before rehydration
S_r is the weight of dried solids after rehydration

Dimensional changes (Shrinkage): Sample thickness and diameter before and after drying were measured with a steel caliper. Measurements were made at six different places on each sample. Shrinkage was expressed as the percentage change in thickness and diameter (Kawas and Moreira, 2001; Barat et al., 2001).

$$S = \frac{d_o - d_t}{d_o} x100 \qquad (3)$$

Where d_o is the initial diameter of the sample and d_t is the diameter after time (t) of drying.

Proximate analysis: Association of Official Analytical Chemists Approved methods of (AOAC, 1996) were used to determine moisture, ash, crude protein crude fat and ascorbic acid contents.

Moisture content: The moisture content of the banana sample was determined gravimetrically by drying the sample at 105°C until a constant weight was obtained. The result was expressed as percent moisture loss (wet basis).

Ascorbic acid content: Banana (5 g) sample was mashed in 100 ml of distilled water of which 10 ml was pipetted into a flask and 2.5

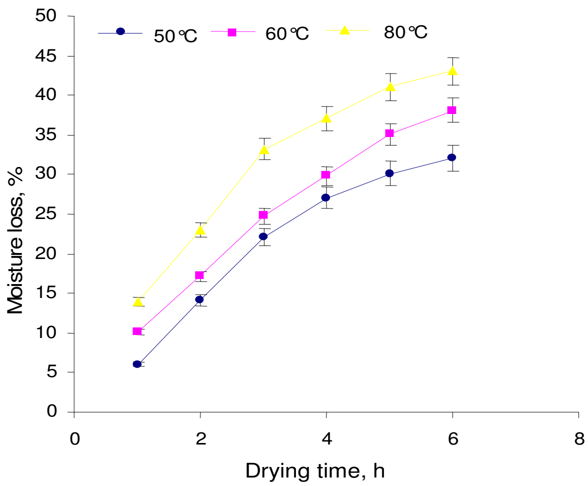

Figure 1a. Effect of drying temperature on percent moisture loss of untreated banana slices with time.

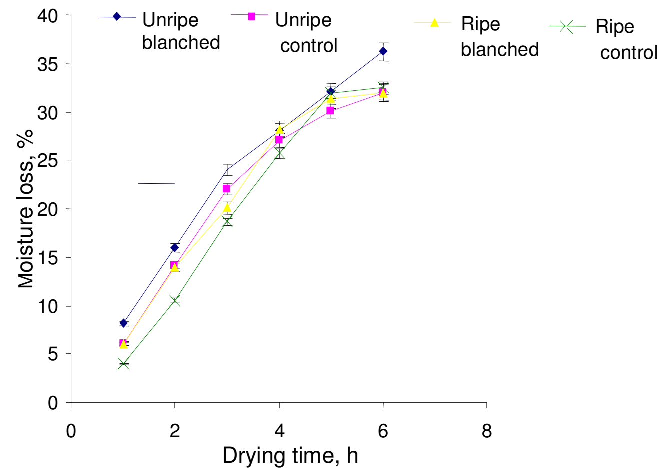

Figure 1b. Effects of blanching and ripening on moisture loss of banana slices dried at 50℃ with time.

ml of acetone added. The solution was titrated against dicholoroindophenol solution until a faint pink colour persisted for 5 s. Vitamin C content was calculated in mg per 100 ml or 100 g.

Ash content: Banana sample (2 g) was weighed into a crucible and placed in a mottle furnace at 550℃ for 3 - 5 h until a whitish substance was obtained. Weight of ash was expressed as a percentage of the initial sample weight.

Crude fat: Soxhlet extraction method was used.

Crude protein (N × 6.25): Was determined using the Kjeldahl method.

Statistical analyses

All experiments were performed at least in triplicates. As no specific replication effect was detected for the experimental data (P > 0.05), therefore the data from total measurements were averaged and average values were reported. Statistical analyses were carried out using PlotIT software (SPE, 1993). Data were subjected to analysis of variance (ANOVA) followed by Tukey´s comparison of means.

RESULTS AND DISCUSSION

Moisture loss

Figures 1a and b show the effects of ripeness, blanching and drying temperature on amount of moisture loss in banana with drying time. The higher the temperature of drying, the higher the amount of moisture lost. At the end of 6 h of drying, samples at 50℃ had lost between 30 - 36.2% of the moisture, while at 60 and 80℃, the amount of moisture lost ranged between 37 - 39.4% and 42.3 – 44.5% respectively. These curves are typical of the drying curves obtained for all the samples. These curves

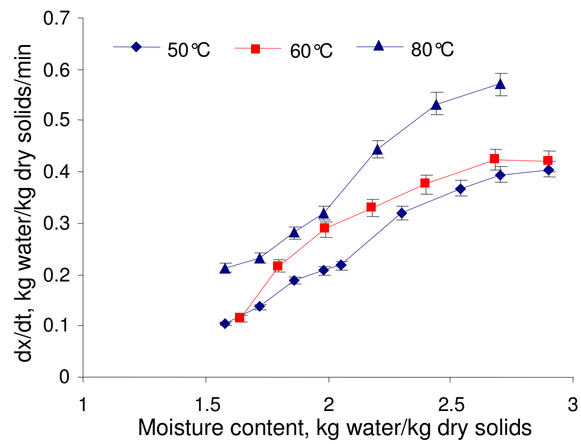

Figure 1c. Drying rate curves of blanched unripe banana at different temperatures.

did not exhibit a constant rate period (Figure 1c), which agrees with the results of other studies on basil, banana and plantain (Johnson et al., 1998; Maskan, 2000; Rocha et al., 1993). The entire drying process for the samples occurred in the range of falling rate period under the conditions studied.

Although Johnson et al. (1998) reported that diffusivities of plantain samples increased with higher drying temperature, the result of this study showed that the effect of increasing drying temperature from 50 to 80℃ did not affect percent moisture lost (P > 0.05). With prolonged drying time, drying rate decreased probably due to collapse (shrinkage) of the banana structure resulting in low transport of moisture (Maskan, 2000). Unripe banana (both blanched and control) lost more moisture than the ripe samples at all temperatures of drying.

Blanched samples lost higher amounts of moisture although not significantly (P > 0.05). The influence of

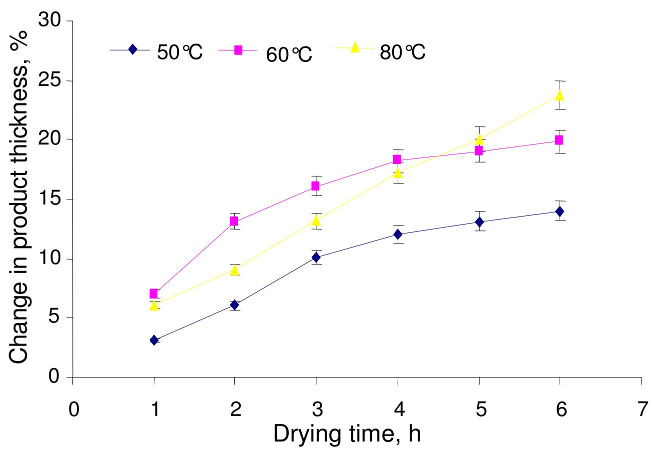

Figure 2a. Effect of drying temperature on change in product thickness of blanched banana slices.

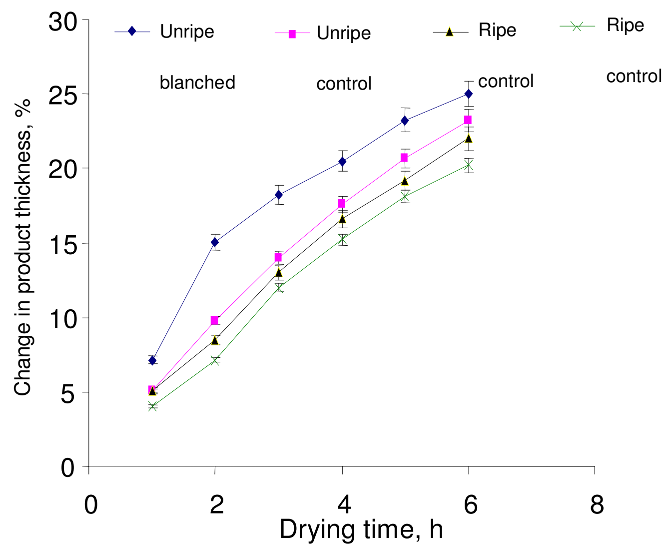

Figure 2b. Influence of blanching and ripeness on the change in product thickness of banana slices dried at 80°C.

blanching on percent moisture loss was most noticeable on samples dried at 50°C. Blanching has been reported to improve the drying rates of carrots, basil and green peppers (Mazza, 1983; Rocha et al., 1993; Kaymak-Ertekin, 2002). Blanching is known to increase the permeability of cell walls, thus favoring faster water migration to the surface for removal (Rocha et al., 1993). Nieto et al. (1998) examined changes produced at the structural level in the fruit flesh tissues subjected to pre-treatments by microscopical studies. In the fresh tissue, cells and intercellular spaces were loosely arranged in a net-like pattern. However, blanched samples showed broken membranes with formation of vesicles, plasma-lemma breakage as well as some cell wall degradation.

Shrinkage/dimensional changes

Changes in the height of banana samples (thickness) are shown in Figures 2a and b. Sample thickness reduced with time and drying temperature had a significant effect on percent change in thickness ($P < 0.05$). At the end of 6 h of drying, percent change in thickness at different temperatures was 14 - 15.1%, 20 - 23% and 23 - 25% at 50, 60 and 80°C respectively. Samples dried at 60°C showed an initial faster shrinkage rate in thickness but after 4 h of drying, samples dried at 80°C exhibited greater shrinkage. This result suggests that the higher the temperature of drying, the greater the product shrinkage which agrees with the result of Johnson et al. (1998) on plantains. Senadeera et al. (2005) reported that both the rate of dimensional shrinkage and maximum dimensional shrinkage might be affected by drying temperature which agrees with the result of this study. Blanched samples exhibited higher changes in product thickness than in control samples ($P > 0.05$). It has been suggested that pectic substances when reduced by blanching may account for the greater change in thickness (Plat et al., 1991). Changes in product thickness of unripe banana were slightly higher ($P > 0.05$) than in the ripe samples Changes in sample diameter are shown in Figures 3a and b. Reduction in diameter increased with time and after 4 h of drying, the influence of drying at 80°C was significant ($P < 0.05$). Blanching prior to drying and the state of ripeness of the samples did not affect the radial shrinkage of the product. The maximum radial shrinkage observed when dried at 50 or 60°C ranged between 14 - 16% while a range of 24 - 28% was observed for samples dried at 80°C. These results suggest that at 50 and 60°C, greater shrinkage occurred axially (along product thickness) than radially which is similar to the report of Senadeera et al. (2005) for potato. Shrinkage of apples due to blanching was reported to be about 23% (Nieto et al., 1998). Maskan (2001) in his study on the drying of Kiwi fruits reported that shrinkage followed typical drying curve patterns with high shrinkage occurring initially and gradual leveling off towards the end of drying so that the final size and shape of samples were fixed before drying was completed. A similar observation was made by Johnson et al. (1998) in their report that the volume of plantain samples was reduced to about 60% of its original value in 3 - 5 h which corresponded to the pattern of reduction in moisture content. The authors related the change in dimension to moisture content by a core drying linear model. The outer layer of the plantain pieces became rigid in the earlier stages of drying but was found to crack internally in the later stages. Similar observations were made in this study.

Figure 3c showed the percent change in thickness and diameter with moisture content for ripe untreated banana dried at 60°C. Differences in percent change in dimensions increased as moisture content decreased

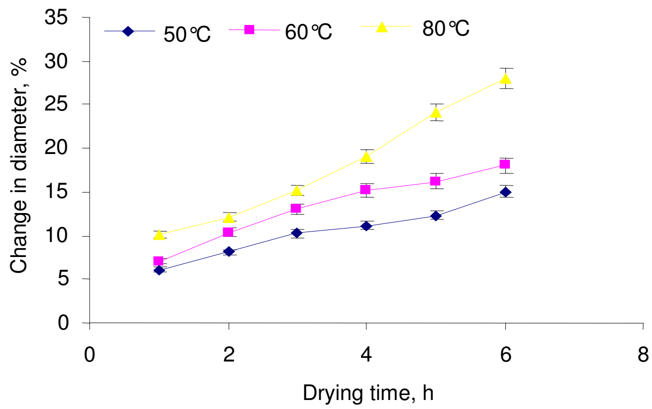

Figure 3a. Changes in diameter of ripe banana slices with drying temperature and time.

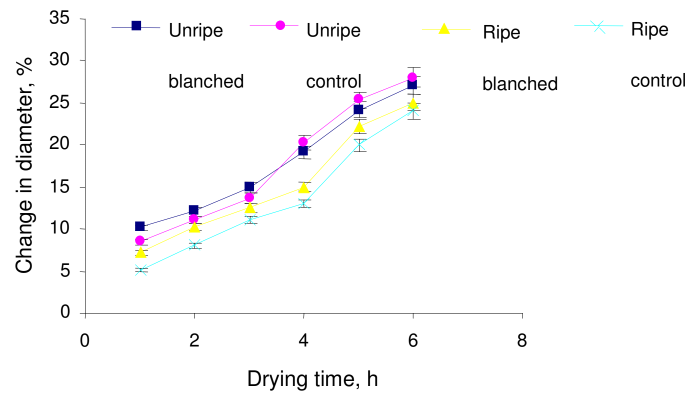

Figure 3b. Changes in product diameter of banana slices dried at 80℃.

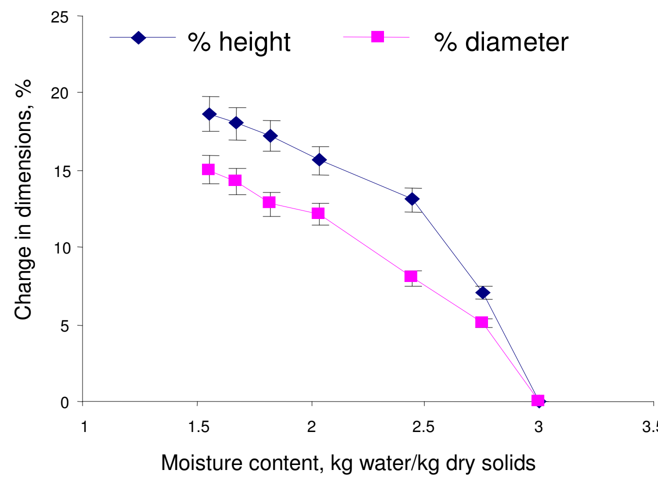

Figure 3c. Changes in product dimensions of ripe untreated banana samples dried at 60°C.

especially for samples dried at 60℃. There was no significant difference in percent change in dimensions in samples dried at 50 and 80℃ ($P > 0.05$). The change in dimensions was related to moisture content by a linear model of the type used by Wang and Brennan (1995). The regression constants and the correlation coefficients are presented in Table 1. The data gave a good fit ($0.879 < r^2 < 0.993$). Figures 4a and 4b show the relationship between percent change in volume with time and moisture content. Percent change in volume increased with time (Figure 4a) and the effect of drying became more distinct at longer drying times. Percent change was higher at the lower moisture content (Figure 4b). At high moisture content, drying at 60℃ had higher shrinkage but at about 1.8 kg water/kg dry solids moisture, samples dried at 80℃ exhibited greater shrinkage than samples dried at 50 or 60℃.

Rehydration capacity (RC)

The rehydration curves of dried banana slices are shown in Figures 5a and b. The temperature of drying did not influence the RC of banana significantly ($P > 0.05$) but the values were higher with temperature increase. For samples dried at 50 or 60℃, the slope of the curves ranged between 0.4 and 0.46 while for those dried at 80℃, the slope was between 0.51 and 0.55 which shows a marked difference in RC. This result agrees with the report of Maskan (2000) that drying conditions did not influence the RC of bananas ($P > 0.05$). Data in Figure 5b showed that neither blanching nor ripeness had any significant effect on the RC of the samples ($P > 0.05$) irrespective of the drying temperature which is similar to the report of Kaymak-Ertekin (2002) that the apparent diffusion coefficient for pretreated rehydrated green pepper were within the confidence intervals for the value of control samples. Rehydration rate at 100℃ was very rapid. By 15min between 66 and 71% of the total water reabsorbed had been sorbed by the dried samples. For samples dried at 50 or 60℃, the rate of rehydration had decreased by 45 min of soaking ($P < 0.05$). This is in agreement with the report of Taiwo et al. (2002a) on rehydrated apple slices. These authors reported that water uptake was higher at temperatures greater than 90℃, which promoted faster diffusion of water into the product through swelling and plasticizing of cell membranes.

Dry matter loss (DML)

The amount of DML increased with time (Figures 6a and b) and the initial drying temperature ($P < 0.05$). After 60 min of steeping, samples dried at 50℃ had lost between 19 - 25%, for those dried at 60℃, %DML ranged be-tween 22 - 29% and 30 - 37% for samples dried at 80℃

Table 1. Correlation parameters relating percent change in dimension to moisture content of banana samples under different conditions of drying.

Sample		Temp (°C)	Percent change in thickness =	r^2	Percent change in diameter =	r^2
Unripe	Control	80	-12.987x + 38.166	0.961	-15.046x + 44.424	0.930
		60	-12.213x + 39.937	0.879	-10.694x + 33.882	0.957
		50	-9.524x + 30.155	0.899	-8.049x + 26.756	0.887
	Blanched	80	-14.514x + 43.188	0.986	-14.680x + 44.545	0.958
		60	-12.580x + 41.484	0.885	-10.154x + 33.005	0.936
		50	-9.434x + 29.794	0.929	-9.238x + 29.699	0.914
Ripe	Control	80	-12.692x + 37.753	0.991	-14.192x + 42.350	0.993
		60	11.692x + 38.210	0.910	-9.689x + 30.763	0.964
		50	-9.939x + 29.935	0.991	-10.703x + 33.437	0.971
	Blanched	80	-13.957x + 41.259	0.981	-13.929x + 41.86	0.928
		60	-12.461x + 39.868	0.954	-9.736x + 31.199	0.958
		50	-10.607x + 32.312	0.981	-9.065x + 29.123	0.965

x – Moisture content, kg water/kg dry solids.

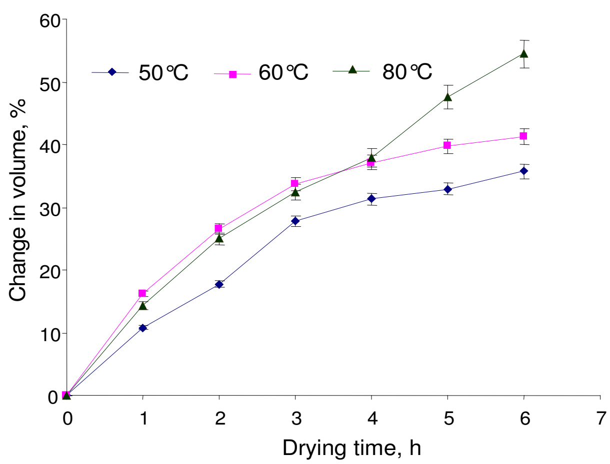

Figure 4a. Influence of drying temperature and time on change in volume of ripe untreated banana samples.

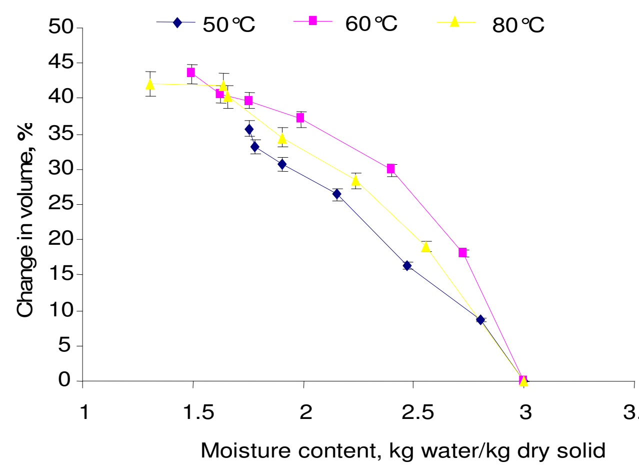

Figure 4b. Influence of moisture content and drying temperature on change in volume of ripe blanched banana samples .

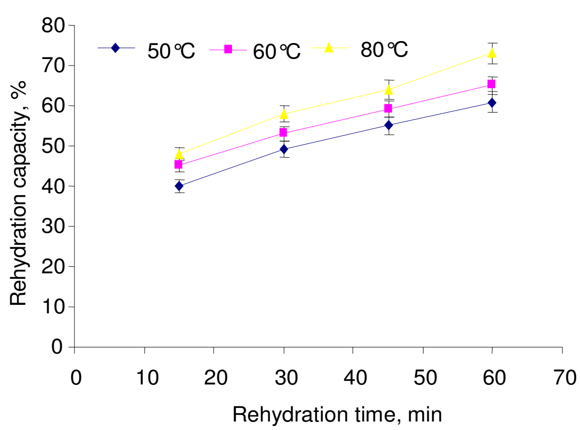

Figure 5a. Influence of drying temperature on rehydration capacity of unripe banana slices.

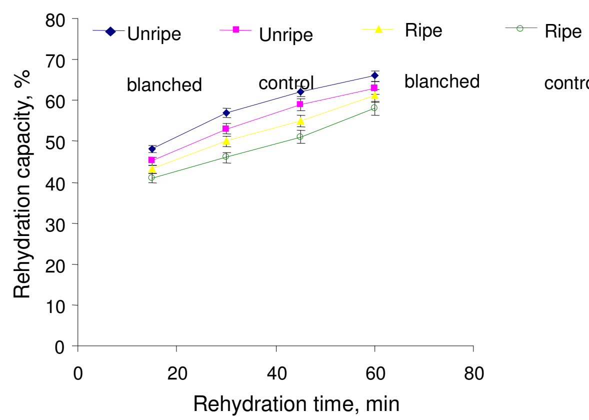

Figure 5b. Influence of blanching and ripeness on the rehydration capacity of banana Slices with rehydration time.

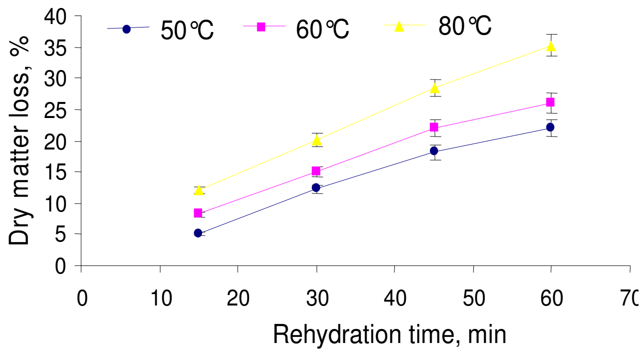

Figure 6a. Effect of drying temperature on dry mater loss with rehydration time of unripe banana slices.

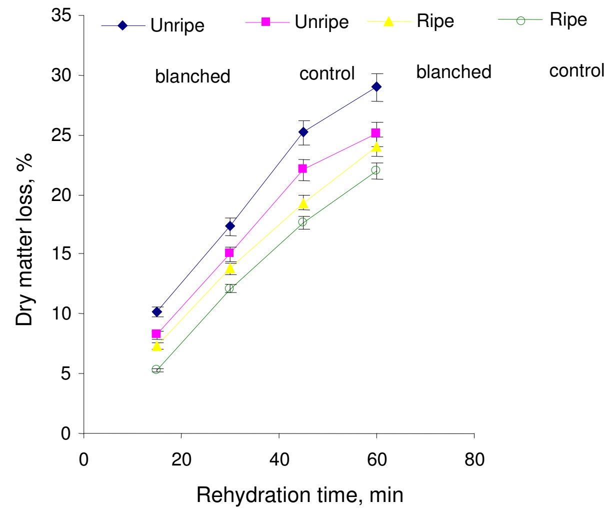

Figure 6b. Effect of blanching and ripeness on dry matter loss with rehydration time.

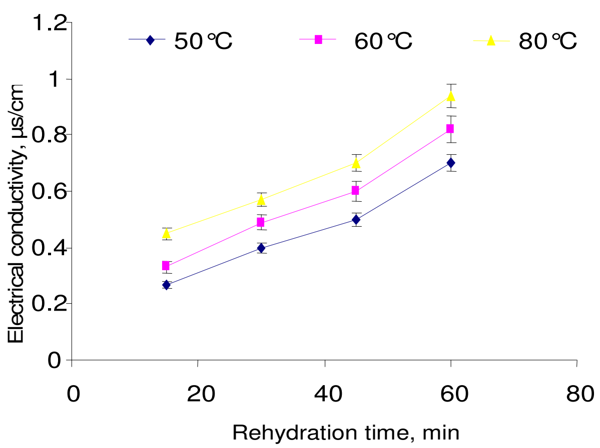

Figure 7a. Effect of drying temperature on electrical conductivity of immersion solution of unripe banana slices rehydrated with time.

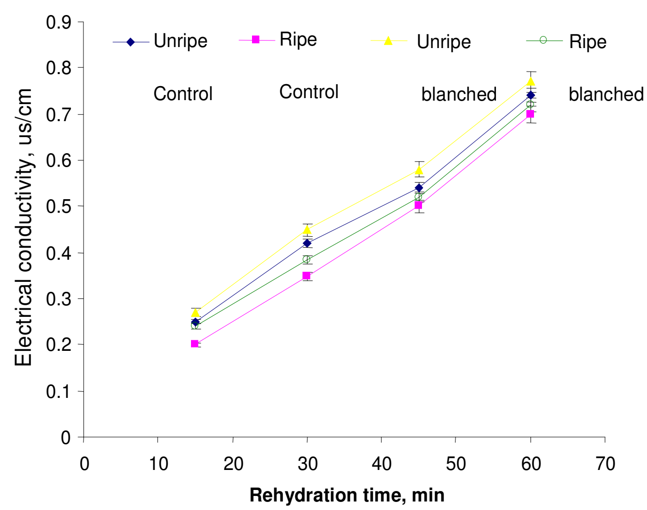

Figure 7b. Effect of blanching and ripeness on the electrical conductivity of immersion solution of dried banana slices with rehydration time.

80°C. The wide range in values is influenced by pretreatment and state of ripeness. Although the influence of blanching and state of ripeness for each drying temperature was not significant on %DML ($P > 0.05$), however, slightly higher DML values were obtained for blanched samples as well as for unripe samples. This agrees with the result of Mazza (1983) that loss of water soluble solids during rehydration was affected by the pre-drying treatment. Unlike RC that was very rapid initially, the rate of DML was gradual. In the first 15 min of soaking, the %DML ranged between 16 and 36% (depending on temperature of drying, etc.) while in the same time span 66 - 71% moisture had been absorbed. These values are similar to those reported for apples by Taiwo et al. (2002).

Electrical conductivity (EC)

Data on EC of the rehydrating medium is shown in Figures 7a and b. The EC of the steeping liquid increased with the soaking time and drying temperature. By 1 h of soaking, maximum values of 0.7 - 0.94 µs/cm were obtained depending on the initial drying temperature. The higher the EC values the greater the amount of electrolytes released into the rehydrating medium. The impact of blanching and state of ripeness on electrolyte release was not significant ($P > 0.05$) but the values were slightly higher for blanched and unripe samples than for ripe or control bananas. During thermal processing, changes occur in the polymeric properties of food fibres with resulting changes in EC. It has been reported that blanching promotes leakage of intercellular ions from the sample tissue (Halden et al., 1990; Taiwo et al., 2002b)

Table 2. Chemical composition of banana slices dried at 60℃.

Constituent	Ripe samples		Unripe samples	
	Blanched	Control	Blanched	Control
Moisture %	4.82* ± 0.30	5.18 ± 0.25	4.77 ± 0.32	5.02 ± 0.42
Ash %	7.53 ± 0.9	7.74 ± 0.12	8.14 ± 0.13	8.22 ± 0.11
Fat %	0.28 ± 0.02	0.32 ± 0.03	0.21 ± 0.05	0.34 ± 0.04
Protein%	1.05 ± 0.06	1.12 ± 0.03	1.07 ± 0.5	1.07 ± 0.6
Ascorbic acid (mg)	9.92 ± 0.62	10.05 ± 0.57	8.22 ± 0.81	8.32 ± 0.55

- Average of three readings ± standard deviation.

This result suggests that blanching at 60℃ for 10 min achieved minimal disintegration of cellular constituents. Higher EC values for unripe samples is contrary to expectation because soluble solids are largely sugars and as the fruit matures, its concentration of juice solids (which are mostly sugars) changes (Agunbiade et al., 2006). Sucrose comprised more than 70% of the total sugars in ripe bananas and plantains and about half of the total sugars in overripe fruits (Marriot et al., 1980). It is expected that ripe samples containing more sugar would exhibit higher electrolyte leakage resulting in higher EC values. During ripening, the flesh becomes softer owing to interconversion of pectic substances and the breakdown of starch to sugar (Ihekonroye and Ngoddy, 1985).

Nutritional components

Table 2 gives information on the chemical composition of the dried samples. The ash content of the unripe samples was higher than for ripe samples. The Ascorbic Acid (AA) content of ripe banana was higher than the unripe while blanched samples had reduced AA values. It is probable that vitamin C being water-soluble would have leached into water during blanching thus contributing to reduced AA values for blanched samples. Taiwo et al. (2001) also reported reduced AA content in apple slices blanched prior to drying. Hot air drying has been reported to cause a reduction in AA content of fruits (Taiwo et al., 2001; Forster et al., 2003) and this is confirmed in this work as the dried products had retention values of 20 - 29.6% of The initial amount which are in the range of values reported for guava by Sanjinez-Argandona et al. (2005).

Conclusion

This study examined the influence of blanching, ripeness and drying temperature on the physico-chemical characteristics of rehydrated banana slices. Increasing drying temperatures (50 - 80℃) facilitated greater moisture loss, greater product shrinkage, higher rehydration capacity, increased dry matter loss and higher electrolyte leaching. Greater shrinkage was observed along the axes (thickness) than along the diameter or radial shrinkage. Although the impact of blanching was not significant ($P > 0.05$) on most product attributes (shrinkage, dry matter loss, moisture loss, electrical conductivity and rehydration capacity) studied (due to the mild conditions used) it still improved mass and solid transfer through the samples. The influence of the state of ripeness was dependent on the drying temperature and was negligible.

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