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Banana Chips Production by Hot Air and Microwave Dehydration Methods: A Comparative Study

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Abstract: Banana slices belong to long Cavendish variety first pretreated with blanching and chemical treatments (T_1, T_2, T_3) followed by hot air drying at 60, 70 and 80°C and microwave drying at 300, 500 and 700 W microwave power intensity. Dried samples were evaluated for color, sugar content (sucrose), ascorbic acid, rehydration ratio, drying time and drying rate. Pretreatments caused increase in drying rate and decrease in drying time. Drying rate in microwave is tenfold of hot air drying therefore drying time in microwave drying about one tenth of hot air drying. Quality factors such as sugar content reduced at microwave drying method (average 6.64 mg/100) was more than hot air drying (average 10.36 mg/100). Also ascorbic acid retention in hot air drying was more than microwave drying.Rehydration ratio that indicated texture destruction during drying is highest at 60C in hot air drying and 500 W power intensity at microwave drying. Among various pretreatments, T_2 was the best to produce high quality banana chips and hot air drying at 60°C was the best drying method for produce banana chips.

Key words: Banana chips · Microwave drying · Hot air drying · Pretreatments · Quality parameters

INTRODUCTION

One of the oldest and developing methods of food preservation is drying process that provides an extension of shelf life besides the preservation of product quality for example nutritional value, flavor, aroma, color and structure. Fruits like banana have high sugar needs high temperature and long time to reach safe moisture during drying.This may caused losses in flavor, color, nutrients and decrease bulk density and rehydration capacity of final product. In hot air drying because heat conductivity of food is low, heat transmission to internal parts of food occurred slowly, so the drying time will be long. Food drying in a microwave field offers several advantages over more conventional methods of drying. The moisture content of food directly affects the amount of microwave absorption. In initial stage of drying, higher amount of water in a food increases dielectric loss factor. At later stage of drying where moisture content of food is low, the influence of specific heat on the heating process is more pronounced than that of dielectric loss factor. Therefore, due to low specific heat, foods with low moisture content also dry at acceptable rates in microwave [1].

Maskan (2000) studied on different drying methods includes hot air, microwave and combined hot air-microwave finish drying of banana slices[2]. The results showed that drying time at conventional hot air drying was longer than two other methods and drying rate increased with microwave power intensity.

Demiral and Turhan (2003) studied drying behavior of two species of bananas (Dwarf Cavendish and Gros Michel) by using different pretreatments such as : sodium bisulphate 1% and ascorbic and citric acid mixture 0.1% and an untreated sample as a control. results showed that pretreatments increased drying rate and drying temperature didn't effect on shrinkage[3].

Dandamrongrak *et al.* (2002) used several pretreatments such as : blanching, freezing, combined of both and cooling. Drying behavior of treated banana was studied in heat pump dryer. In research performed by Boudhiroua *et al.* (2002) rheological properties of banana slices were evaluated in hot air drying [12].

Chua *et al*. (2002) used heat pump dryer for banana drying in two stage hot air dryer [5]. They concluded higher air temperature at beginning of drying process and decreased gradually in later stages product color and drying time would be improved.In current research banana

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dried by two drying methods of hot air and microwave drying and influence of various factors such as pretreatments,air drying temperatures, slice thickness and power intensity on drying behavior of banana slice. Also, quality parameters of dried product such as color, rehydration ratio, sugar content and ascorbic acid were evaluated.

MATERIAL AND METHODS

Ripe bananas of long Cavendish variety were purchased from a local market and stored at 5-10°C during experiments. Bananas were peeled by hand and cut to 3, 5 and 10 mm thickness with a sharp knife on the polyethylene cut board. After preparation, the samples are randomly divided into 4 groups to perform pretreatments. Three pretreatments were applied to the banana slices before drying and an untreated sample (T_0) was used as a control. Pretreatments including 1% sodium bisulphite (T_1), combined blanching and 1% sodium bisulphite (T_2) and combined blanching and 1% ascorbic and citric acid (1:1) solution (T_3). The details of each pretreatment were described as follow:

- *Control T_0:* The samples were peeled and cut to 3, 5 and 10 mm thickness then placed into dryer directly without any pretreatment.
- *Pretreatment T_1:* The banana slices were peeled and cut to 3, 5 and 10 mm thickness, dipped into 1% sodium bisulphite solution for 2 min and then rinsed by distilled water for 30 s in order to remove the rest of sodium bisulphate from slice surface and finally blotted with tissue paper.
- *Pretreatment T_2:* The banana slices were blanched in boiling water for 3 min, immediately cooled by tap water for 3 min to remove excess heat and treated like to previous method.
- *Pretreatment T_3:* The banana slices were blanched like to previous method, dipped into 1% ascorbic and citric acid (1:1) solution for 1 min and finally blotted with tissue paper.

After pretreatments the samples were placed to drier for drying to safe moisture content 0.18 - 0.19 kg w/kgs according to following methods.

Hot Air Drying: Banana samples in three thicknesses and three pretreatments in addition to control samples were dried by a hot air convectional oven at three temperatures of 60, 70 and 80°C.Moisture loss was recorded each 30 min intervals during drying for determination of drying curves by removing samples from drier, cooling and weighting until safe moisture content was reached.

Microwave Drying: Banana slices with three thickness and three pretreatments in addition to control samples were dried in a microwave oven at three power intensity of 300, 500 and 700 W. Samples were removed each 30 s intervals from dryer,cooled, weighted and returned into dryer periodically until reached to the final safe moisture content. The samples were distributed into dryer symmetrically for uniform microwave energy distribution in oven. When samples reached to the final safe moisture content, cooled, packed in polyethylene bags and stored in cool and dark place before quality factors determination. These quality factors were determined in dried banana slice:

- Moisture content was determined initially and during drying by oven method [6].
- Banana color was measured by Loviband apparatus [7].
- Measurement of rehydration ratio [8].
- Determination of ascorbic acid by 2, 6 - Dichloroindophenol titration method [9].
- Measurement of sugar content (sucrose) by Lane - Eynon titration method [10].

Rehydraion Ratio: Dried banana chips first weighed then immersed in distilled water until constant weight then sample botteled by tissue paper to remove excess water and weighed again. Finally rehydration ratio was calculated as follows: RC= Wr/Wd

Statistical Analysis: Total 72 samples were obtained and quality control tests were performed in three replications. Randomized complete block design.were used for statistical analysis by STATGRAGH software. Duncan's multiple range test was used for comparison of averages.

RESULTS AND DISCUSSION

Drying Time: In hot air drying with increasing temperature drying time decreased. For example drying time until final moisture content at samples with 3 mm thickness and pretreatment T_2 that dried at 60, 70 and 80°C were 300, 240 and 180 min, respectively (Fig. 1).

In microwave drying method with increasing microwave power intensity drying time was decreased but in higher thickness due to bulk heating of microwave

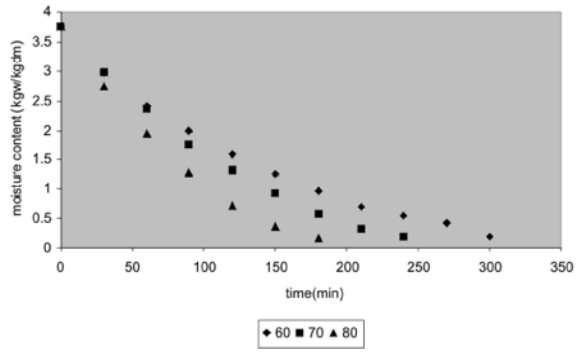

Fig. 1: Drying curves of banana slice with 3 mm thickness and pretreatment T2 at various temperatures

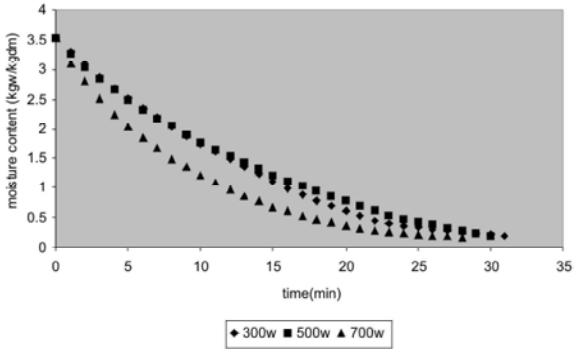

Fig. 2: Drying curves of banana slice with 3 mm thickness and pretreatment T1 at 300 , 500 , 700 W

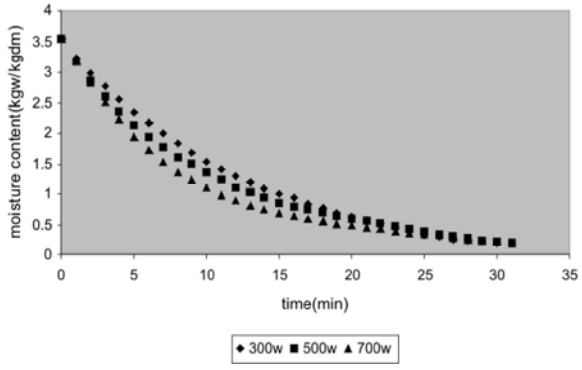

Fig. 3: Drying curves of banana slice of 5 mm thickness and pretreatment T1 at 300 , 500 , 700 W

energy this reduction isn't remarkable. For example drying time for reach to final moisture content in slice of 3 mm thickness and pretreatment T_1 that dried by 300, 500 and 700 W microwave power intensity were 33, 30 and 28 min, respectively (Fig. 2). Whereas drying time for reach to final moisture at slice of 5 mm thickness and pretreatment T_1 that dried by 300, 500 and 700 W microwave power intensity were 32 min (Fig. 3). Also ANOVA analysis

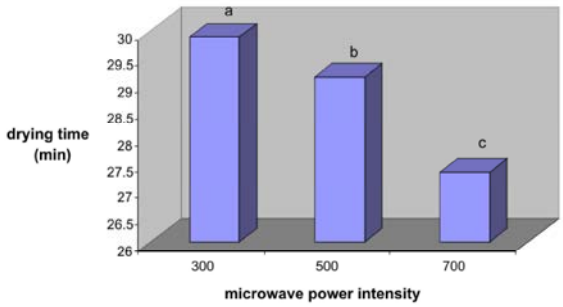

Fig. 4 : Influence of microwave power intensity on drying time

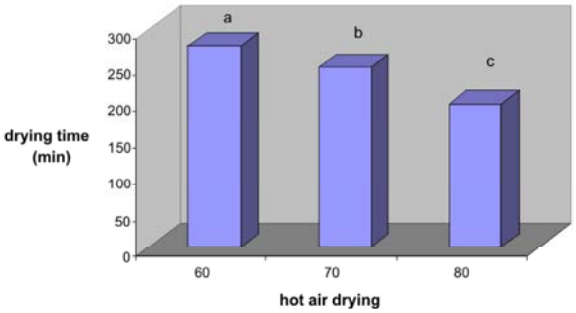

Fig. 5: Influence of hot air temperature on drying time

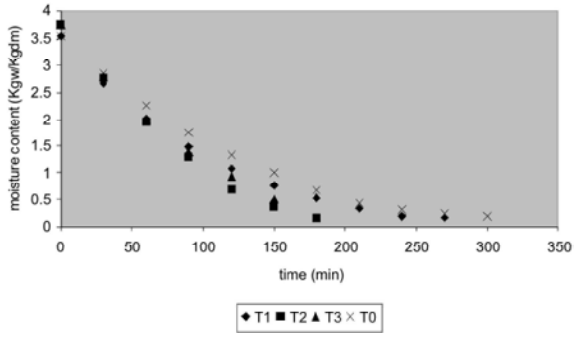

Fig. 6: Drying curves of banana slice of 3 mm thickness and pretreatments T_0,T_1, T_2, T_3 at 80°C

showed that temperature and microwave power intensity have significant effects on drying time as shown in Figures 4 and 5.

The results for both drying methods showed that pretreatments caused shorter drying time relative to control T_0.. However drying time for pretreatment T_1 is more than pretreatment T_2 but drying time for pretreatments T_2 and T_3 don't show significant difference. The reason may be due to effects of blanching and chemical treatment by sodium bisulphite damaged cell wall of banana slice caused moisture removal was enhanced. For example drying time in slice of 3 mm thickness, control

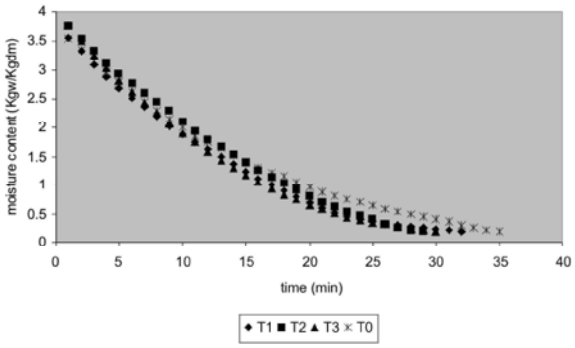

Fig. 7: Drying curves of banana slice of 3 mm thickness pretreated by T_0,T_1, T_2 and T_3 at 300 W

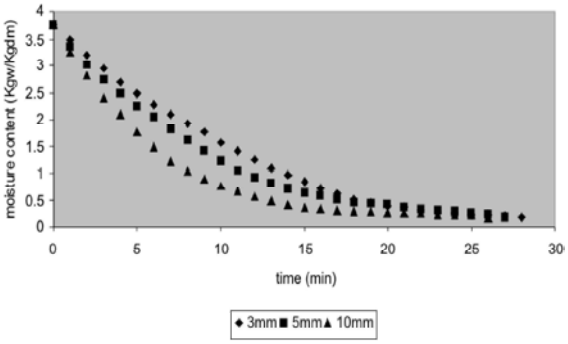

Fig. 9: Drying curves of banana slice with 3, 5 and 10 mm thickness and pretreatment T_2 at 300 W

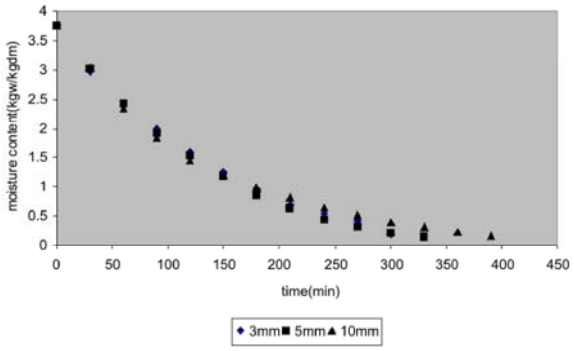

Fig. 8: Drying curves of banana slices with 3, 5 and 10 mm thickness and pretreatment T_2 at 60°C

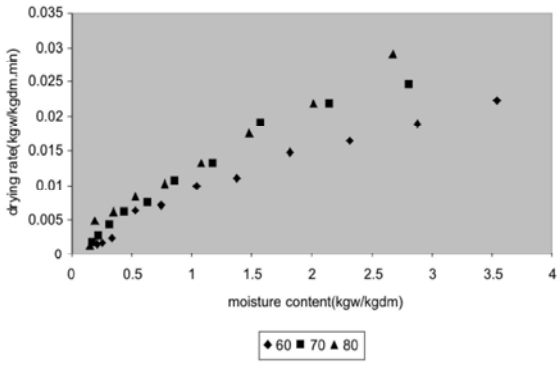

Fig. 10: Drying rate curves of banana slices with 3 mm thickness and pretreatment T_1 at 60, 70, 80 °C

T_0 and pretreatments T_1, T_2 and T_3 that dried at 80°C hot air temperature were 300, 270, 180 and 180 min, respectively (Fig. 6). Drying time at samples of 3 mm thickness, control T_0 and pretreatments T_1, T_2 and T_3 that dried at 300 W microwave power intensity were 35, 32, 29 and 30 min, respectively presented in figure 7. Also results of ANOVA analysis showed that pretreatments have a significant difference in drying time at both drying methods.

Results showed that in hot air drying with increasing of slice thickness drying time increased at all pretreatments. For example drying time at samples with 3, 5 and 10 mm thicknesses and pretreatment T_2 at 60°C were 300, 330 and 390min, respectively (Fig. 8).

But in microwave drying method at all power levels observed a steep slope in drying curve. The reason is absorption of microwave energy by dipoles specially water molecules followed by molecules oscillation at 2450 MHz frequency caused friction so heat evolved in bulk of banana slice finally caused moisture evaporation into banana slice and transmission of that out of banana slice. These incidents lead to porosity formation in banana structure.In contrast of hot air drying, in microwave drying with increasing banana slice thickness drying time becomes shorter [2]. For example drying time to achieved final moisture content at samples with 3, 5 and 10 mm thickness and pretreatment T_2 that dried at 300 W microwave power intensity were 28, 27 and 26 min,respectively which presented in Figure 9. These results showed that drying time of samples from about 300 min in hot air drying method decreased to 30 min in microwave drying method so observed 90 % reduction in drying time.

Drying Rate: The drying rate was calculated by dividing difference of two consecutive moisture content by time intervals and plotted against moisture content based on dry basis. Results of hot air drying experiments showed that with increasing of hot air temperature increased drying rate and at microwave drying method with increasing of microwave power intensity increased drying rate. The reasons are clear so increase of heat convection rate and more moisture evaporation from food material. For example average drying rates during drying of

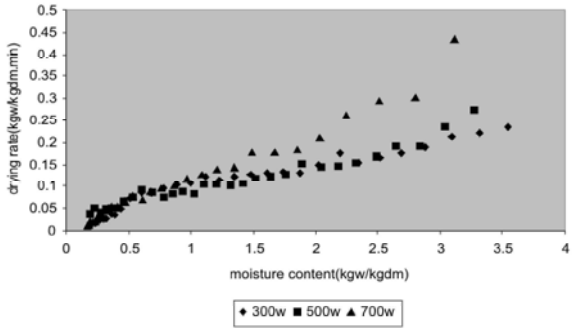

Fig. 11: Drying rate curves of banana slices with 3 mm thickness and pretreatment T_1 at 300, 500, 700 W

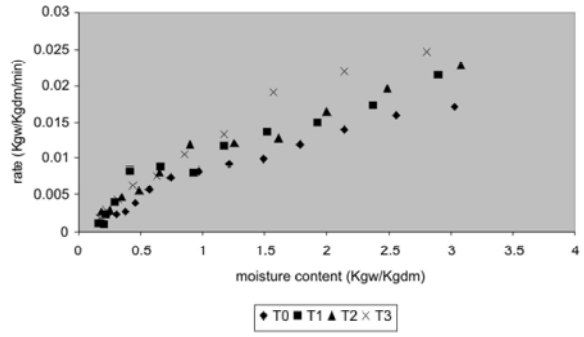

Fig. 12: Drying rate curves of banana slice with 5 mm thickness treated by T_0,T_1, T_2, T_3 at 70°C

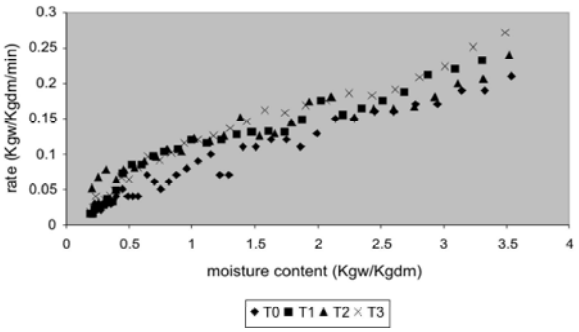

Fig. 13: Drying rate curves of banana slices with 3 mm thickness and pretreatments T_0,T_1, T_2, T_3 at 300 W

banana slice with 3 mm thickness and pretreatment T_1 at 60, 70 and 80°C air temperature were 0.009, 0.0107 and 0.012 ((kgw/kgs.min), respectively. This means drying rate at 80°C was 11% more than 70 °C temperature and 25% more than 60°C temperature (Figure 10).The mean drying rates during drying of banana slice with 3 mm thickness and pretreatment T_1 that dried at 300, 500 and 700 W microwave power intensity were 0.108, 0.111 and 0. 12 ((kgw/kgs.min),respectively. This means drying rate at 700 W was 7% more than 500 W and 10% more than 300 W (Fig. 11).

Comparison of drying rate at both drying methods showed that average drying rate during hot air drying was about 0.012 (kgw/kgs.min) and in microwave drying was 0.12 ((kgw/kgs.min) that tenfold of hot air drying rate. Also at hot air drying method, drying rate of treated samples was higher than untreated samples. For example average drying rate during drying of banana slice with 5 mm thickness by pretreatments T_0, T_1,T_2 and T_3 that dried at 70°Cair temperature were 0.007, 0.009, 0.0108 and 0.0112 (kgw/kgs.min),respectively. This showed that drying rate of banana slice in pretreatments T_1,T_2 and T_3 were 14 %, 30% and 36% more than untreated sample. This contributed to effects of blanching and chemical treatments on structure damage of banana slice result moisture removal was easier than control sample (Fig.12). Experimental results of microwave drying method showed that drying rate was changed at different pretreatments at constant microwave power intensity,also it didn't obeyed from special trend (Figs. 13 & 14).

Experiments results of hot air drying showed that drying rate at thinner banana slice (3mm) was higher than thicker (5, 10 mm) ones. Because increasing of thickness caused inside mass transfer resistance was increased that presented in Figure 15. In microwave drying method increasing of banana slice thicknesses increased drying rate due to bulk heating phenomenon in microwave method as shown in Figure 16.

Color: Visual observation of dried banana slice revealed effects of pretreatments, air temperature and microwave power intensity on color of samples. Fresh banana slices looked like white - yellowish and developed a yellow - brownish color during drying. Discoloration increased with increasing temperature due to Millard reaction that accelerated at higher temperatures. Also discoloration increased with increasing microwave power intensity, due to same reason. Under same conditions, treated samples exhibited less discoloration than untreated one. In addition pretreatment T_2 caused less discoloration than other pretreatments (Figs 17, 18 & 19). Available reports on the effects of pretreatment on dried banana color different from this research probably due to use of different varieties, pretreatment methods and different drying conditions. Garcia *et al.* (1998) reported ineffectiveness of sodium bisulphate on the color of dried bananas [11]. Boudhrioua *et al.* (2002) showed that pretreatments blanching and sodium pyrophosphate prevent discoloration of raw and ripe bananas dried at 60°C air temperature [12]. In another study

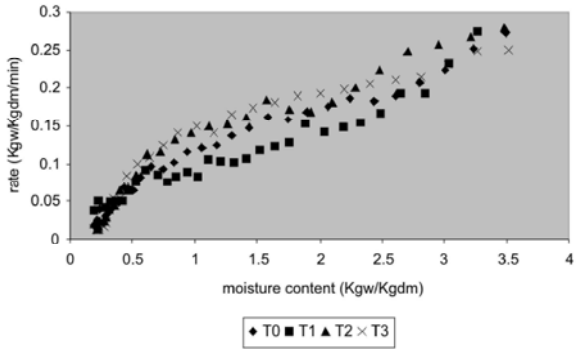

Fig. 14: Drying rate curves of banana slices with 3 mm thickness and pretreatments T_0,T_1, T_2, T_3 at 500 W

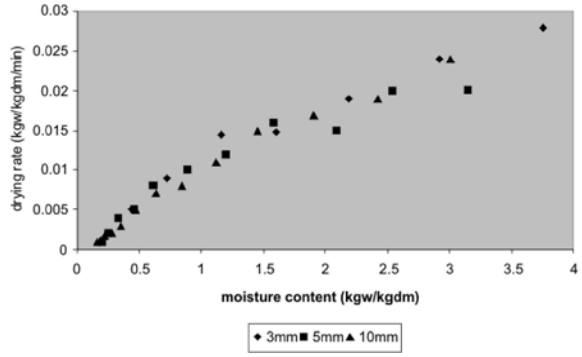

Fig. 15: Drying rate curves of banana slices with 3, 5 and 10 mm thickness and pretreatment T_3 at 70°C

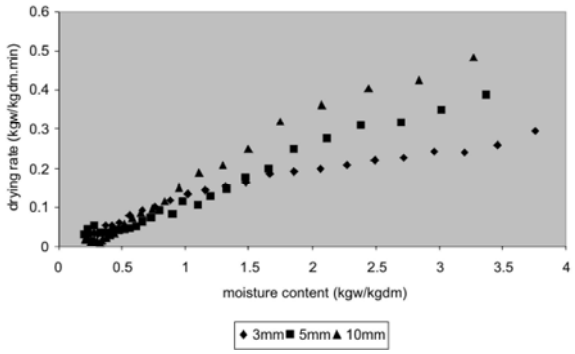

Fig. 16: Drying rate curves of banana slices with 3, 5 and 10 mm thickness and pretreatment T_2 at 700 W

Dandamrongrak *et al.* (2002) used from ascorbic - citric acid (1:1) solution as a chemical treatment to prevent discoloration of dried banana at temperature range of 40 - 70°C [4].

Sugar Content (Sucrose): The results of drying experiments showed that pretreatment, hot air temperature and microwave power intensity have significant effect on sugar content of dried banana. Sugar content of fresh

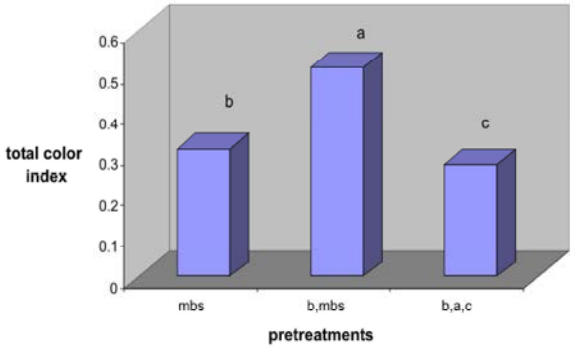

Fig. 17: Effect of pretreatment on color

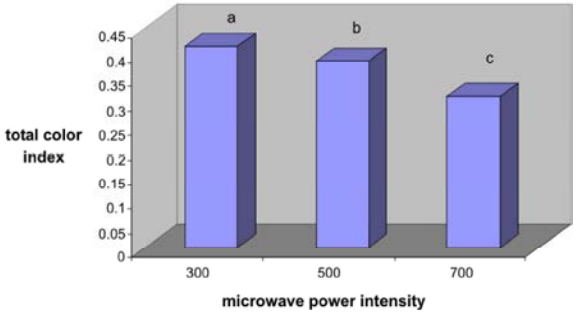

Fig. 18: Effect of microwave power intensity on color

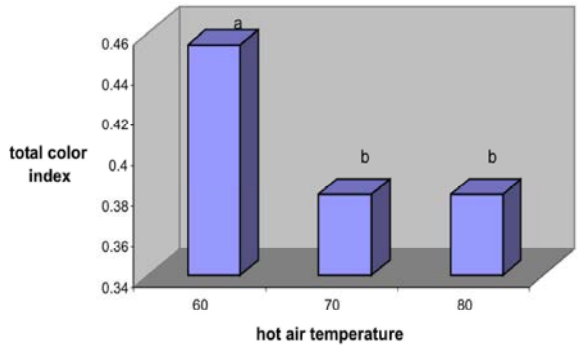

Fig. 19: Effect of drying temperature on color

banana was measured about 2.26 mg/100g. Figures 21 and 22 showed that in hot air drying with increasing of temperature sugar content was decreased and in microwave drying with increasing microwave power intensity, sugar content was decreased due to browning reactions accelerated in higher temperatures. Among three pretreatment methods, water blanching reduced the sugar content due to sugar leaching to boiling water (Fig. 20). Sugar content reduction at microwave drying method (average 6.64 mg/100g) was more than hot air drying (average 10.36 mg/100g) because higher heat transfer rate and sugar decomposition especially caramelization reaction in microwave drying method.

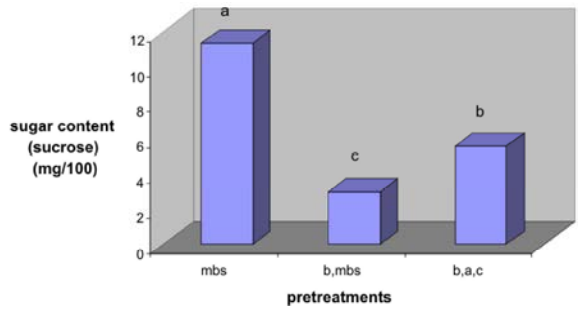

Fig. 20: Effect of pretreatments on sugar content

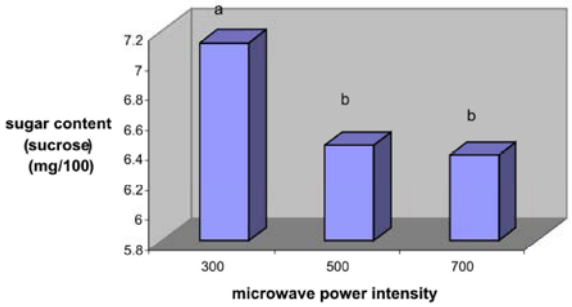

Fig. 21: Effect of power intensity on sugar content

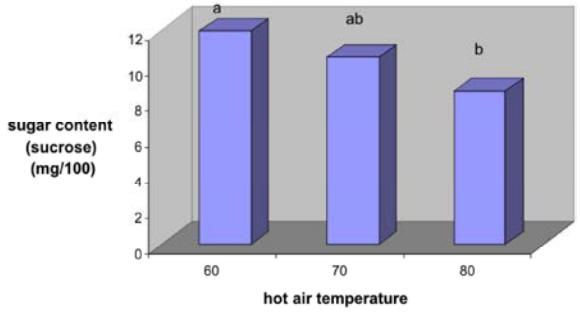

Fig. 22: Effect of drying temperature on sugar content

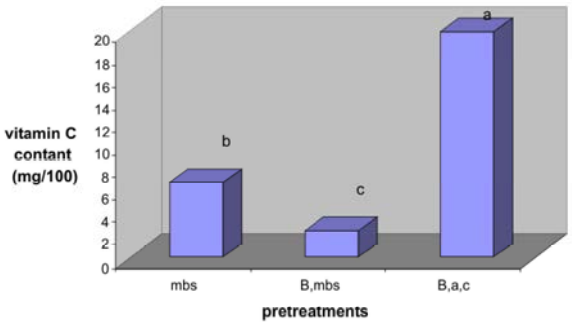

Fig. 23: Effect of pretreatments on ascorbic acid content

Ascorbic Acid: The results of experiments showed that pretreatments, hot air temperature and microwave power intensity have effect on the ascorbic acid content of dried banana. Ascorbic acid content of fresh banana was

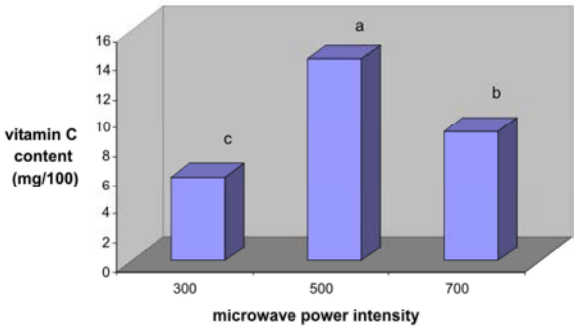

Fig. 24: Effect of microwave power intensity on ascorbic acid content

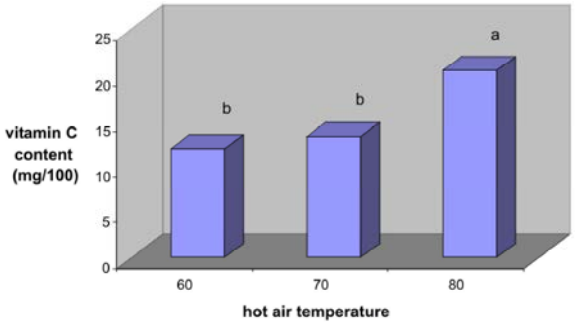

Fig. 25: Effect of drying temperature on ascorbic acid

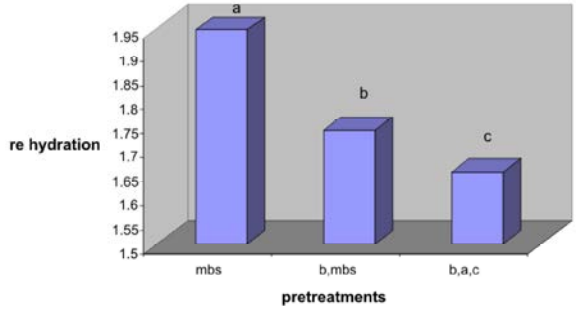

Fig. 26: Effect of pretreatments on rehydration ratio

obtained 6.26 mg/100g. Figure 25 showed that in hot air drying method use of higher temperature leads to less destruction of ascorbic acid because at lower temperature drying time is longer compared to shorter drying time at higher temperature. In microwave drying with increasing microwave power intensity bulk temperature of banana slice will increase too and due to higher temperature ascorbic acid destruction was more than hot air drying as shown in Figure 24. Among three pretreatment methods expected pretreatment T_3 have most of ascorbic acid retention and in next order pretreatment T_2 have more ascorbic acid content than pretreatment T_1 because some dissolution of ascorbic acid in water during blanching was occurred (Figure 23). Destruction of ascorbic acid in

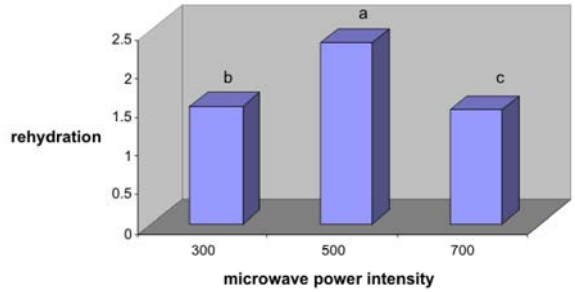

Fig. 27: Effect of microwave power intensity on rehydration ratio

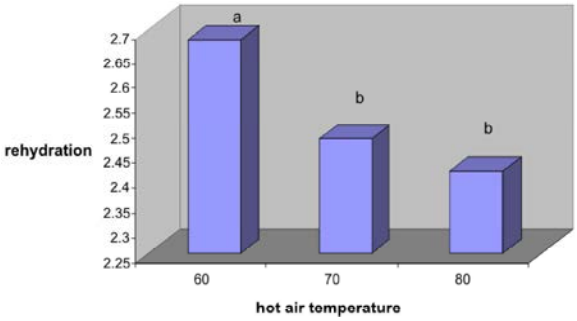

Fig. 28: Effect of drying temperature on rehydration ratio

microwave drying method (9.66 mg/100g) was more than hot air drying method (15.33 mg/100g) showed 37% reduction in microwave drying method.

Rehydration: The results of experiments showed that pretreatments, hot air temperature and microwave power intensity have effect on the rehydration ratio of dried banana slice. In hot air drying method the most rehydration ratio was obtained at 60°C but at microwave drying obtained at 500 W microwave power intensity. Among pretreatments, T_1 have the most rehydration ratio. None samples didn't obtain initial moisture content due to texture destruction and deformation during drying processes (Figs 26, 27 & 28). According to some researches color index and rehydration ratio at microwave drying method were 7.5% and 30% lower than hot air drying method [13,14].

CONCLUSIONS

Banana slices in thickness 3,5 and 10 mm first pretreated with blanching and chemical agents. Two different drying methods were used for drying of banana slice, one method is conventional drying with hot air at 60, 70 and 80°C temperatures and another method is novel technique application of microwave fields in drying of banana slices at microwave power intensity of 300,500 and 700W. Drying time from about 300 min in hot air drying method decreased to 30 min in microwave drying method so observed 90 % reduction in drying time. Also, average drying rate during hot air drying was about 0.012 (kgw/kgs.min) and in microwave drying was 0.12 (kgw/kgs.min) that tenfold of hot air drying rate. Among quality factors, sugar content reduction at microwave drying method (average 6.64 mg/100g) was more than hot air drying (average 10.36 mg/100g), also destruction of ascorbic acid in microwave drying method (9.66 mg/100g) was more than hot air drying method (15.33 mg/100g) showed 37% reduction in microwave drying method.

Nomenclature:

T_0 = Control sample
T_1 = 1% sodium bisulphite
T_2 = Blanching- 1% sodium bisulphite
T_3 = Blanching-1% ascorbic and citric acid (1:1)
RC = Rehydration capacity
Wr = Rehydration sample weight
Wd = Dried sample weight

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