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Combined Hot Air-Microwave Drying Methods in Banana Chips Production

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Abstract: Bananas were sliced at three thickness (3, 5 and 10 mm) and treated by three pretreatments T_1, T_2, T_3 and T_0 as a control sample. Banana slice dried by combined hot air-microwave drying method. Drying parameters such as drying rate and rehydration ratio along with quality factors such as color, ascorbic acid and sugar content were evaluated. Pretreatments increased drying rate and decreased drying time. All pretreatments had significant effect on quality factors but pretreatment with 1% sodium bisulphite showed higher quality factors except ascorbic acid in comparison with other treatments.

Key words: Banana chips · Microwave assisted drying · Convection drying · Pretreatments · Ascorbic acid

INTRODUCTION

Banana is one of the important tropical fruits that are produced average of 45 million tons yearly in the world. The main part consumed as fresh and remaining used for processing and formulation. Banana have a high nutritional value and it is a good source of energy due to its high level of starch and sugar, as well as source of vitamin A and C, Potassium, calcium, sodium and magnesium.

From a biological point of view, bananas have high loss due to decay during handling and transportation and impose high expenses from economical point of view. One of the oldest and developing methods of food preservation is drying which provides an extension of shelf life besides protection product quality such as nutrient materials, flavor, aroma, color and structure. Fruits like banana that have more sugar need high drying temperature and long time to reach safe moisture content. During drying process some undesirable reactions were take place caused partial destruction of flavor, color, nutrients and decreased bulk density and rehydration capacity of dried product. In hot air drying method due to low heat conductivity of foods heat transfer to internal parts take slowly, so drying time will be longer. To solve this problem and prevent quality reduction in order to reach an effective heat transfer, microwave will be used for drying of foods. Microwave is a rapid method for food drying because energy transmission is different from conventional hot air drying method. In microwave drying method, heat transmission is bulkily, so moisture removal is quick. Also because concentrated energy of microwave fields, only 20-35% of the floor space is required as compared to conventional heating and drying facility. In other hand, it is not economical to dry food materials by microwave only because microwave drying is known to results poor quality product if not properly applied. Microwave energy produced heat internally in foods therefore its better applied to falling rate period where internal mass transfer is dominant.

Maskan (2000) studied on various drying methods such as hot air drying, microwave and combined drying of sliced banana [1]. The results showed that drying time in conventional hot air method was longer than two other methods. Also, it was observed in high microwave power the drying rate was increased and dried banana by combined method had light color and high rehydration ratio. Color change in microwave method depended on microwave power but in convectional hot air method was higher than two other methods. Moisture content of banana chips after rehydration didn't reach to their initial moisture content due to some texture destruction during drying. Demiral and Turhan (2003) studied drying behavior of two bananas species (Dwarf Cavendish and Gros Michel). They used different pretreatments such as: sodium bisulphate 1%, ascorbic - citric acid mixture 0.1% and an untreated sample as a control. The results showed that all pretreatments increased drying rate [2].

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Dandamrongrak *et al*.(2002) used pretreatments like blanching, freezing, combined of both and cooling. They studied drying behavior of treated bananas dried in a heat pump dryer. It distinguished that treatments increased drying rate [3]. Boudhiroua *et al*. (2002) studied rheological properties of banana slices were dried by hot air drying method [4]. Chua *et al*. (2002) used heat pump dryer for banana drying in two stage and found if higher temperature selected at beginning then decreased gradually, product color and drying time would be improved [5]. Some researchers focus on banana drying by freezing along with osmotic dehydration [6-9].

In present research banana dried by hot air drying followed by microwave drying and studied influence of pretreatments and different thicknesses banana slices on drying behavior of banana and influence of different drying parameters on color, rehydration, sugar and ascorbic acid contents of dried products.

MATERIALS AND METHODS

Ripe bananas were purchased from a local market and stored at 5-10°C during experiments. Bananas were peeled by hand and cut with a sharp knife to 3, 5 and 10 mm thickness on polyethylene board. After preparation, the samples are randomly divided into 4 groups and three pretreatments were applied to sample 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 - citric acid (1:1) solution (T_3). The details of each pretreatment were described as below:

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

Moisture Content: Banana was peeled, cut to slices and crushed to banana puree.5 g banana puree placed in a clean and dry plate and dried until reach to constant weight in oven at 105°C [10]. When three consecutive weighting were constant, moisture content (wet basis) was calculated:

$$X_1 = (M_1\text{-}M_2) / M_1 \quad (1)$$

Initial moisture content of fresh banana was obtained 0.76 (3.25 in dry basis) and for blanched samples was determined 0.78 (3.76 in dry basis) due to some water absorption during blanching.

Combined Hot Air-Microwave Drying Method: Banana samples with three thicknesses and three pretreatments in addition to control samples first dried by hot air at 60°C temperature until reached to critical moisture content 1.25 kgw/kgs then dried by a microwave oven with 300 W power intensity until reached to final moisture content 0.18 -0.19 kgw/kgs. This power was selected because samples at higher microwave power intensity were burned. Moisture loss was recorded every 30 min period at hot air drying method and in 30 s intervals at microwave oven. Moisture content as function of drying time calculated by material balance:

$$M_1 (1\text{-}X_1) = M_2 (1\text{-}X_2) \quad (2)$$

Dried samples were collected, cooled and packaged in polyethylene bags and stored in dry, cool and dark place until quality factors measurements.

Vitamin C: Determination of vitamin C content performed by 2, 6 Dichloroindophenol titration method [11].

Rehydration Ratio: Dried banana chips first weighted then immersed in distilled water until constant weight (about 15 hours) then samples blotted by tissue paper to removed excess water and weighted again. Finally re hydration ratio was calculated:

$$RC = Wr / Wd \quad (3)$$

Sugar Content (Sucrose): sugar (sucrose) content determined by Lane – Eynon titration method [10].

Color Measurement: Banana chips color measured before and after drying by Loviband (model F) colorimeter. Three color index including redness (R), yellowness (Y) and blueness(B) were measured by

Loviband and total color index calculated by following equation. This index distinguish color changes during drying process.

$$\text{Total color index} = (R - Y)/(B - Y) \quad (4)$$

Fresh banana total color index was set as a reference for color changes during drying process.

Drying Time and Drying Rate Curves: The drying curve was sketched as dry basis moisture content of banana slice at each time versus drying time. Drying rate was calculated by dividing difference of two consecutive moisture content by drying time interval. Drying rate was sketched versus moisture content (dry basis).

Statistical Analysis: Randomized complete block design was used for statistical analysis. Average comparison were evaluated by Duncan's multiple range test.

RESULTS AND DISCUSSION

Drying Time: Figure 1 showed that treated samples had shorter drying time relative to control sample. In comparison between pretreatments, blanched banana slice had shortest drying time.

For example drying time for reach to final moisture content at samples for control T_0 and pretreatments T_1, T_2 and T_3 in 3 mm thickness were 250, 225, 124 and 124 min respectively. Samples treated with pretreatment T_1 showed 12% reduction in comparison with control sample. In other hand, banana chips that produced with pretreatments T_2 and T_3 showed 52% reduction relative to control sample and 45% reduction relative to samples those treated with T_1. During blanching pretreatment T_2 some destruction in banana texture maybe occurred so caused loss of more water during drying. Chemical treatments with sodium bisulphite results texture damaged but if retention time was selected more than 2 min caused serious texture destruction.

As shown in Figure 1 drying curve at microwave drying stage had sharp due to higher drying rate in microwave drying relative to hot air drying because heat produced inside of banana slice therefore heat transfer by microwave higher than convection and conduction heat transmission. ANOVA analyses showed that effect of pretreatments have significant difference in drying time as shown in Figure 2.

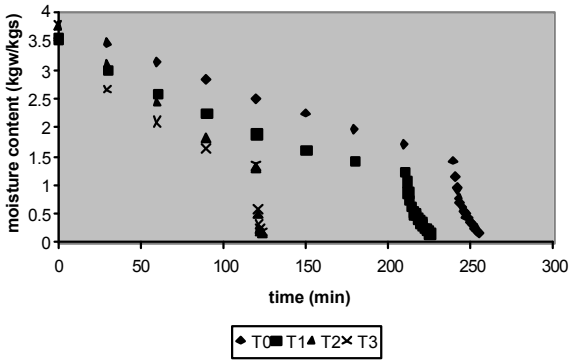

Fig. 1: Drying curve for banana slices with 3 mm thickness and pretreatments T_0, T_1, T_2, T_3

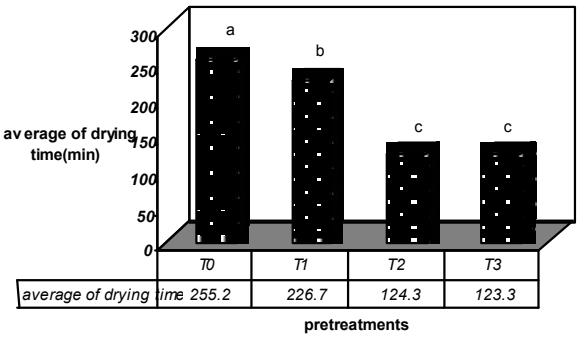

Fig. 2: Influence of various pretreatments on drying time

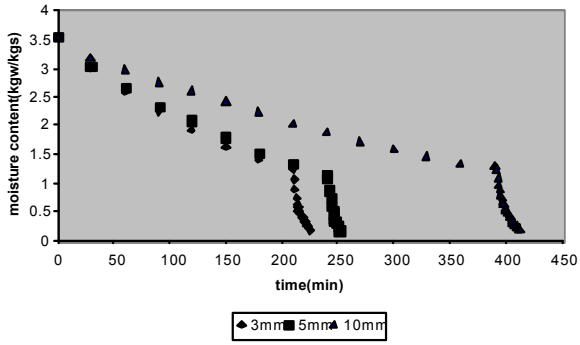

Fig. 3: Drying curve for banana slices with 3,5 and10 mm thickness and (T_1) pretreatment

The results showed that with increase of slice thickness drying time increased at all of pretreatments (Figures 3, 4 and 5). For example drying time in slices with 3,5 and 10 mm thickness and pretreatment T_1 were 225, 251 and 413 min, respectively. Furthermore results of ANOVA analysis showed that effect thicknesses have significant effect on drying time that presented in Figure 6.

Drying rate: Pretreatments increased drying rate and a sharp rise observed in microwave drying. The highest drying rate observed for T_2 followed by T_3, T_1 and control sample (T_0) as shown in Figure 7.

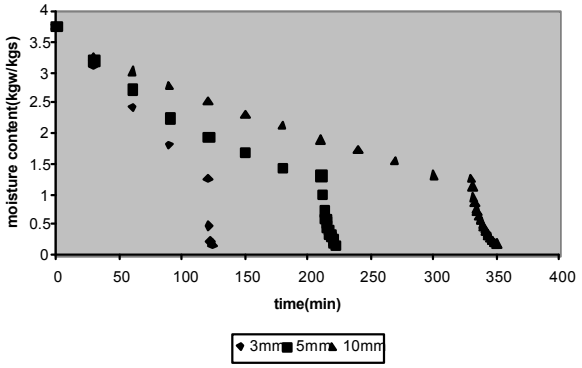

Fig. 4: Drying curve for banana slices with 3,5 and10 mm thickness and pretreatment T_2

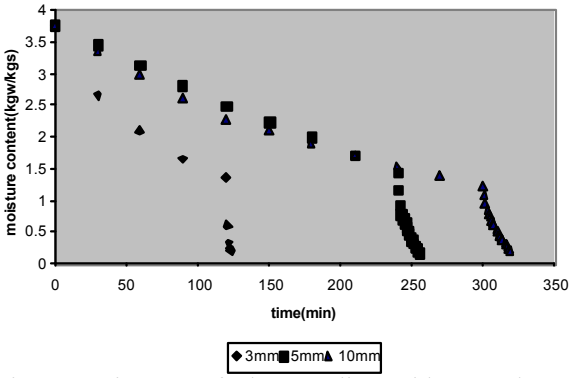

Fig. 5: Drying curve for banana slices with 3,5 and10 mm thickness and pretreatment T_3

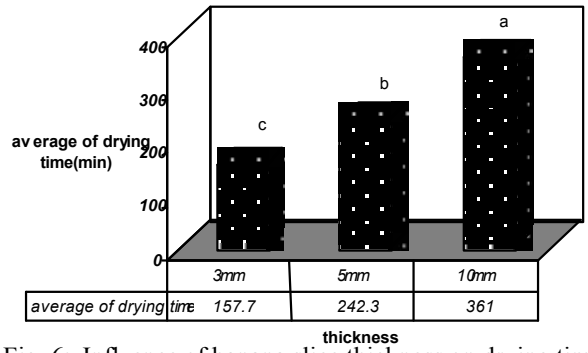

Fig. 6: Influence of banana slice thickness on drying time

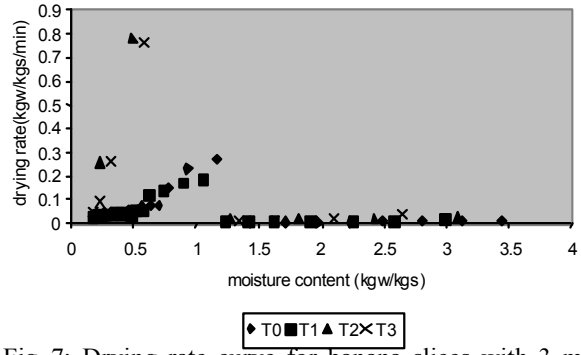

Fig. 7: Drying rate curve for banana slices with 3 mm thickness and pretreatments T_0, T_1, T_2, T_3

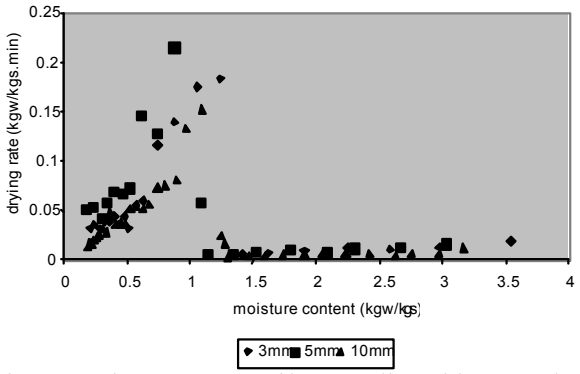

Fig. 8: Drying rate curve of banana slice with 3, 5 and 10 mm thickness and pretreatment T_1

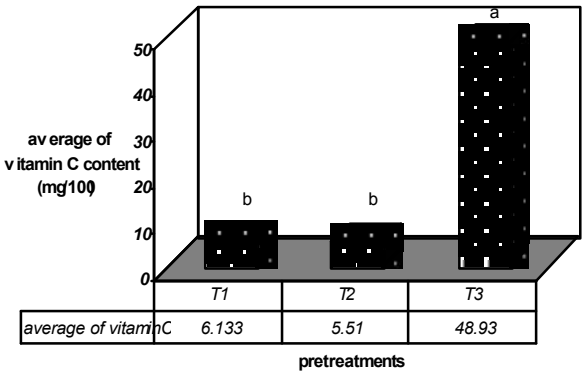

Fig. 9: Influence of pretreatments on vitamin C content

As observed from drying rate curves in Figure 7 in both drying methods (hot air and microwave), constant drying period don't observed and drying occurred only in falling rate period. Also shrinkage and case hardening due to rapid starch gelatinization caused a barrier to moisture transfer especially at later stages of drying. Also the results showed that with increasing slice thickness drying rate was decreased (Fig. 8). Although results of prior researches showed that for microwave drying method with increasing slice thickness, drying rate was increased [12, 13] but our results showed that in microwave drying stage, increasing of banana slice thickness decreased drying rate due to starch gelatinization in hot air drying stage.

Quality Factors

Vitamin C: The results showed that pretreatments had significant effect on vitamin C content of dried banana. It's value for fresh banana was obtained 6.26 mg/100g. Among three pretreatments T_3 had most vitamin C but T_2 had least due to dissolution of ascorbic acid in blanching water caused more loss of vitamin C as observed in Figure 9.

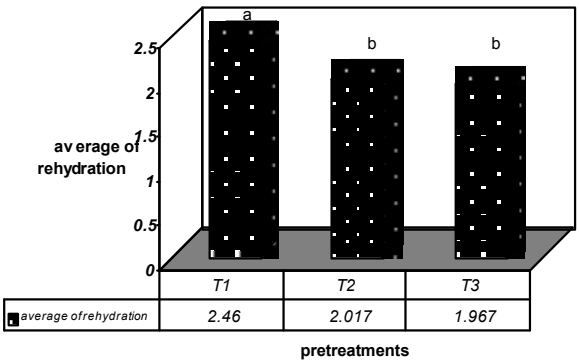

Fig. 10: Influence of pretreatments on rehydration ratio

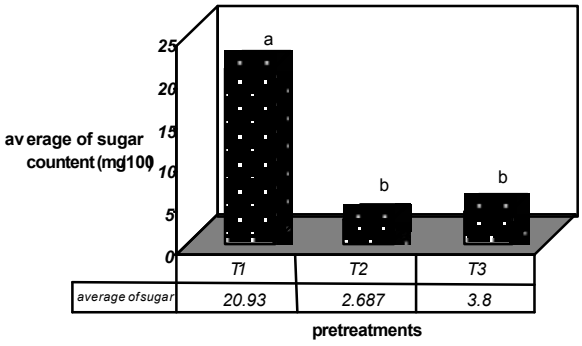

Fig. 11: Influence of pretreatments on sugar content

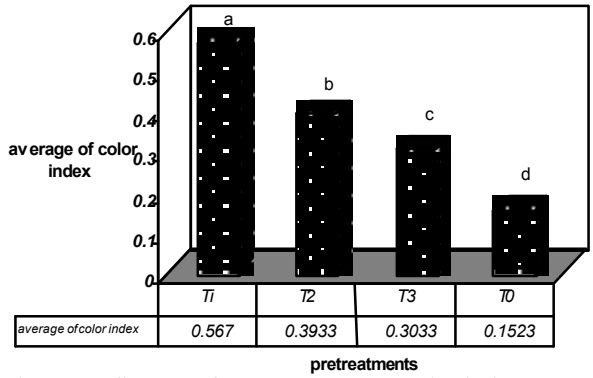

Fig. 12: Influence of pretreatments on color index

Rehydration Ratio: The results showed that pretreatments had significant effect on rehydration ratio of dried banana. Between pretreatments T_1 had the most rehydration ratio but none sample reached to initial moisture content (Fig. 10).

Sugar Content (Sucrose): The results showed that pretreatments had significant effect on the sugar content of dried banana. Sugar content of fresh banana was measured about 2.26 mg/100g. Among three pretreatments, blanching (T_2, T_3) reduced sugar content relative to other pretreatments due to dissolution of sugar in boiling water during blanching (Fig. 11).

Color: Visual observation of dried product revealed effect of pretreatments on banana slice color. Fresh Banana looking like white – yellowish but during drying process developed a yellow – brownish color in banana slice. Under the same condition, treated samples exhibited less discoloration relative to untreated samples. In addition pretreatment T_2 caused minimum discoloration in comparison of other pretreatments as shown in Figurer 12.

CONCLUSIONS

Banana slices dried with combined hot air-microwave finish drying by various pretreatments. Chemical factors such as total sugar and ascorbic acid and physical factors such as moisture content, color and rehydration ratio of dried sample were determined. Drying rate curve showed all treatment fall in falling rate period thus microwave was suitable for finish drying. All pretreatments had significant effect on quality factors but pretreatment with 1% sodium bisulphite showed higher quality factors except ascorbic acid in comparison to other pretreatments.

Nomenclature:

B	Blueness	-
M_1	Initial weight of banana slice	g
M_2	Final weight of banana slice	g
R	Redness	-
RC	Rehydration capacity	
T_0	Control sample	-
T_1	1% sodium bisulphate	
T_2	Blanching- 1% sodium bisulphate	
T_3	Blanching-1% ascorbic and citric acid Wr	
	Final weight after rehydration	g
Wd	Dried sample weight	g
X_1	Initial moisture content (dry basis)	
X_2	Moisture content at each time (dry basis)	
Y	Yellowness	-

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