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EFFECT OF OSMOTIC CONCENTRATION AND ULTRASOUND PRE-TREATMENT ON THE QUALITY OF DRIED BANANA SLICES

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ABSTRACT

The effect of osmotic concentration and ultrasound pre-treatments prior to air-drying on some quality parameters of dried banana slices was investigated. Banana slices were osmo-concentrated in acidified or sulfited sucrose solution (60˚Brix) for 1.5, 3h, (with and without ultrasound), 6 and 12h. All samples were air-dehydrated at 60˚C for 12h. Results showed that, the water loss, solid gain and weight reduction percents significantly increased with treatment time. The use of ultrasound combined with osmotic concentration significantly increased these parameters. Osmotic concentration and ultrasound pre-treatments maintained the color of the samples during air-drying, made them lighter and of good yellow color. The pre-treatments improved the taste and texture of the dried samples, and increased the overall acceptability as compared to the control sample. Osmotic concentration and ultrasound could be used to enhance food drying by improving not only mass transfer but also product quality.
Keywords: Osmotic concentration, ultrasound, banana, quality, dehydration, color, acceptability

INTRODUCTION

Bananas belong to the genus *Musa* of the monocot family *Musaceae*. Bananas are a typical fruit grown only in the frost free and hot regions of the world. In Egypt, the total area under bananas cultivation is 21.5 thousand hectares and the production in 2007 was 880 thousand tons, ranking with the first 15 producer countries (FAO, 2009).

Bananas are one of the most consumed fruits in the world. It has a high nutritive value and is a good source of energy due to its high content of starch and sugar, as well as being a source of vitamins A and C, potassium, calcium, phosphorus and magnesium (Gebhardt and Thomas, 2002). Bananas are one of the fruits that present the highest losses by decomposition after cropping due to be extremely perishable and not allowing the use of freezing for its conservation. Bananas can be dried in order to save the part of the production that will not be readily consumed, since drying, a classical method of food preservation, extends the shelf-life, lighter weight for transportation and less space for storage (Sousa *et al.,* 2003). Dried bananas can be directly consumed as snacks or become part of foodstuffs like cakes, pastries, candies and many others.

Over the last few decades wide prospects for osmotic dehydration, better defined as dewatering impregnation soaking in concentrate solutions (DIS) (Raoult-Wack and Guilbert, 1990), have arisen as a pre-treatment in combined techniques. These processes use a sequence of technological steps to achieve controlled changes of the original properties of the raw material.

Osmotic dehydration has been successfully used to reduce water activity of water-rich foods, such as fruits and vegetables to about 0.9, by immersing them in a concentrated solution of sugar or salt (Torreggiani, 1993 and Karathanos *et al.,* 1995). During osmotic dehydration, two important mass transfers are driven from concentration gradients: flow of water from the food matrix to the liquid and flow of solute from the liquid to the food matrix (Raoult-Wack *et al.,* 1994; Spiazzi and Mascheroni, 1997 and Ramallo and Mascheroni, 2005). A third mass transfer involves food solutes leached in the solution. Although leaching has been generally considered to be quantitatively negligible (Dixon and Jen, 1977), it can result in loss of the nutritional content of foods (Peiró-Mena *et al.,* 2006 and 2007). Mass transfer rates during osmotic dehydration depend on factors such as temperature, concentration of osmotic solution, size and geometry of the samples, sample to solution ratio and the level of agitation of the solution (Barat *et al.,* 2001; Tedjo *et al.,* 2002 and Corzo and Gomes, 2004).

Osmotic dehydration removes water from the fruit up to a certain level, which is still high for food preservation, so this process must be followed by another process in order to lower even more the fruit water content (Fernandes *et al.,* 2006). Osmotic concentration, prior to dehydration, has a protective effect on the structure of the dried material, making it more flexible and less dense (Kim and Toledo, 1987 and Blanda *et al.,* 2009). Also, it reduces loss of fresh fruit flavor, color; moreover increased sugar content and removal of some fruit acids makes osmotically concentrated products more acceptable (Monsalve-González *et al.,* 1993 and Panagiotou *et al.,* 1999).

Power ultrasound is a novel technology in the food industry and few studies have addressed the use of ultrasound (Fuente-Blanco *et al.,* 2006 and Zheng and Sun, 2006). Only few studies have addressed drying of fruits and most have used ultrasound to assist osmotic dehydration (Cárcel *et al.,* 2007; Fernandes and Rodrigues, 2007; Fernandes *et al.,* 2008 and 2009).

Ultrasound waves can cause a rapid series of alternative compressions and expansions, in a similar way to a sponge when it is squeezed and released repeatedly (sponge effect). In addition, ultrasound produces cavitations which may be helpful to remove strongly attached moisture. Deformation of porous solid materials, such as fruits, caused by ultrasonic waves is responsible for the creation of microscopic channels that reduce the diffusion boundary layer and increase the convective mass transfer in the fruit (Tarleton and Wakeman, 1998 and Fuente-Blanco *et al.,* 2006). Ultrasound can be used to enhance mass transfer during osmoconcentration. At high concentrations of sugars, ultrasound accelerates the rate of water movement out of osmoconcentration.

The aim of this study is a trial to evaluate the effect of osmotic concentration and ultrasound prior to conventional air-drying on mass transfer and some quality parameters of banana slices, beside evaluation of some quality attributes and acceptance of the final dried banana slices.

MATERIALS AND METHODS

1. Materials

Three batches (each weighting 10 kilograms) of banana (*Musa* spp. Variety Maghrabi) fruits, at commercial ripeness degree, were purchased from a local market at Ismailia governorate, Egypt.

2. Methods

2.1. Preparation of samples and treatments

Banana fruits were peeled and with the help of a cutting device (SEB, trancheuse électrique, type 8566, Yugoslavia) banana slices were produced from each radial cylinder in order to obtain cylinders of same dimensions with 5 mm thickness. Two hundred grams of banana slices were minced and used for analysis.

The following treatments were done:

1- Three hundred grams of banana slices were soaked in citric acid solution (2%) and another 300 g were soaked in Na-metabisulfite solution (1000 ppm) for 10 min, and then removed from the solutions and rinsed with running tap water for 10 seconds.

2- Osmotic concentration and ultrasound treatments: they were achieved in two experiments; the first, the osmotic solution 60˚Brix contained citric acid (2%) and the second contained Na-metabisulfite (1000 ppm), to prevent enzymatic browning during treatment (Hussain *et al.,* 2004).

Each experiment was carried out at six different conditions. In the first four conditions, banana slices (300 g for each) were placed in glass flasks and immersed in the osmotic solution at room temperature (22±4˚C) for 1.5 ($O_{1.5}$), 3 (O_3), 6 (O_6), and 12 (O_{12}) hours. The ratio of osmotic solution to banana was 4:1 (W/W) in order to minimize changes in the sucrose concentration (Fernandes *et al.,* 2006). The flasks were placed on Orbit Shaker at 100 rpm (LAB-LINE Instruments, Inc., USA) for the above mentioned times to maximize contact surface between banana slices and solution. In the second two conditions, banana slices (300 g) immersed in osmotic solution (4:1) were subjected to ultrasound power for 1.5 ($O_{1.5}$+U) and 3 (O_3+U) hours in an ultrasound bath (Julabo USR3, JULABO Labortechnik, GHBH, Seedbach, Germany) without mechanical agitation. The ultrasound frequency was 35 KHz.

After each treatment, the banana slices were removed from the osmotic solution, quickly rinsed with running tap water for 10 seconds to remove adhering sucrose, and dried with blotting paper tissue to remove all excess water. A part of the treated samples was used for moisture content, pH and titratable acidity analysis. The other part was dried at 60˚C for 12 hours in a forced air-drying oven (WT-Binder, type F115, Germany). The dried slices were left to cool down and then packed in polyethylene bags until further analysis. A diagram of treatments is presented in Figure (1). The experiments were carried out in triplicates.

F1

2.2. Chemical analysis

Moisture content, pH value, titratable acidity (as citric acid) and total sugars either of fresh or dried treated samples were determined according to the AOAC (1990). The alcohol soluble color index (ASCI) was determined as described by Askar and Treptow (1993). The index is expressed as the absorbance at 420 nm per 100 g of sample.

2.3. Mass transfer and dehydration ratio determination

Water loss (WL), solid gain (SG) and weight reduction (WR) were calculated as described by Fernandes and Rodrigues (2007) using the following equations:

$$WL(\%) = \frac{w_i.X_i - w_f.X_f}{w_i} \times 100$$

$$SG(\%) = \frac{w_f.X_{sf} - w_i.X_{si}}{w_i} \times 100$$

$$WR(\%) = \frac{w_i - w_f}{w_i} \times 100$$

Where: w_i = initial fruit weight (g), w_f = final fruit weight (g), X_i = initial fruit moisture content (g water g^{-1}) and X_f = final fruit moisture content (g water g^{-1}), X_{si}= initial fruit soluble solid content (g solid g^{-1}) and X_{sf}= final fruit soluble solid content (g solid g^{-1}).

Dehydration ratio (DR) was calculated using the following equation:

$$DR = \frac{W_w}{W_d}$$

Where: W_w= weight of banana slices after pre-treatment and before dehydration and W_d = weight of dried banana slices.

2.4. Color attributes measurements

A Labscan Model LSXE (Hunter Associates Laboratory, Reston, VA, USA) was utilized to measure the color of the different treatments. From each treatment, 20 g of minced dried banana slices were placed in 50 mm diameter and 20 mm deep glass cup. Hunter color was measured as L^* (lightness), a^* (redness) and b^* (yellowness). Chroma (C^*) was calculatd as $C^*= (a^{*2} + b^{*2})^{0.5}$ and hue angle (h_{ab}) was calculated as $h_{ab}=\tan^{-1}(b^*/a^*)$ (Rørá and Einen, 2003). Whiteness index (WI) was expressed as:

$WI=100-[(100-L^*)^2+ a^{*2} +b^{*2}]^{0.5}$ (Bolin and Huxsoll, 1991)

2.5. Sensory evaluation

Sensory evaluation was carried out on a laboratory scale. As the aim of the work was to study the effects of osmotic concentration and ultrasound on the acceptance quality of dried banana slices, fresh samples were not analyzed.

The dried samples were introduced to panelists (staff members and office workers) in two groups; the first group included the samples treated with citric acid (2%) or acidified osmotic solution and the second group included those treated with Na-metabisulfite or sulfited osmotic solution. The taste, color, texture and overall acceptability of the samples were evaluated. A 10-point hedonic scale was used with scores ranging from "1" indicating extreme dislike to "10" indicating an extremely high acceptance level, with "5" indicating indifference.

3. Statistical analysis

The experimental data (15 treatments) were arranged in a complete randomized design with three replications. Analysis of variance (ANOVA) was performed using CoStat under windows program (CoStat program ver. 6.311, 2005). Duncan's multiple range test was used to established the multiple comparisons of the mean values at p=0.05.

RESULTS AND DISCUSSION

1. Effect of osmotic concentration and ultrasound treatments on some physical and chemical properties of the banana slices.

The effects of osmotic concentration and ultrasound on water loss, sugar gain and weight reduction percents are presented in Table (1). The results show that, water loss (WL) increased significantly with increasing processing time, from 13.69 and 13.20% after 1.5 h to 24.17 and 25.99% after 12 h for banana slices treated with solutions containing citric acid (2%) and Na-metabisulfite (1000 ppm), respectively. This result may be due to cell damage caused by the osmotic treatment (Wais *et al.,* 2004). The same trend was observed with solid gain (SG) percent, which increased from 6.04 and 6.88% after 1.5 h to 7.49 and 8.37% after 12 h of treatments, but there were no statistically significant differences till 6 h of treatments. These results are in agreement with those obtained by Rodrigues *et al.* (2003), El-Aouar *et al.* (2006) and Fernandes *et al.* (2009). Osmotic treatment promotes higher water loss than sugar gain since water removal and solids gain take place due to different mechanisms. Solids gain is largely a diffusion process while water removal is due to osmotic mechanism resulting from differences in water chemical potential between the cells of the banana slices and osmotic solutions (Fito *et al.,* 2001).

The most of water loss (about 70%) and solid gain (about 80%) took place after 3 h of the osmotic process. Fernandes *et al.* (2006) found that after 2 h of osmotic dehydration of banana slices, the diffusion of sucrose into the fruit stops and after this period only water is removed from the fruit. Harris *et al.* (1999) indicated that while equilibrium of water chemical potential in the product and solution is obtained after long time, no significant mass exchange took place after 4 - 5 h; the real end-point of osmotic treatment can be specified by observed changes in mass transfer data and the desired characteristics of the final product. Net weight reduction (WR) is a result of water loss and solid gain (Nieto *et al.,* 2004). Thus, in the early stages of the process, a significant weight reduction was observed either for samples treated with citric acid or those treated with sulfite. The weight reduction percent increased significantly from 7.65 and 6.32% after 1.5 h of the process to 16.68 and 17.63 after 12 h for samples treated with osmotic solution containing citric acid and metabisulfite, respectively.

Regarding the effect of combined ultrasonication with osmotic concentration on WL, SG and WR of banana slices, Table (1) shows that, the ultrasound treatment significantly increased the values of these parameters compared to the osmotic process only. The water loss and solid gain significantly increased from 17.74 and 7.11 % in the samples osmotically concentrated for 3 h to 33.59% and 9.41% in the samples osmotically concentrated with ultrasonication for 3 h in sulfited osmotic solution. These results confirm the observations of Fuente-Blanco *et al.* (2006), who found that the ultrasonic pre-treatment affected the fruit tissue making it easier for water to diffuse during drying, most probably due to the formation of microscopic channels in the tissue. The ratio of water loss to solid uptake is a good index of the efficiency of the process. The results in Table (1) show that the WL/SG ratio significantly increased during the osmotic concentration combined with ultrasound. This ratio may be used as a parameter for the efficiency index of the osmotic dehydration process (Lazarides *et al.,* 1997). Nowakunda *et al.* (2004) suggested that osmotic treatments led to optimal water loss without an excessive sugar gain being advantageous in terms of energy saving.

As expected the moisture content of osmotically concentrated banana slices decreased with time during the osmotic process. It decreased from 81.74% for the control sample to 62.86% after 12 h of the treatment, in sulfited osmotic solution. The main decrement occurred during the first 3 h after which no significant decrease occurred. The same were the results obtained in the case of banana slices treated with osmotic solution containing citric acid. Ultrasonic treatment caused non-significantly decrease in the moisture content of banana slices compared to the osmotic treatment only. These results are in agreement with those obtained by Cárcel *et al.* (2007), Derossi *et al.* (2008) and Kowalska *et al.* (2008).

Considering the pH values and titratable acidity (Table 1), it could be noticed that there was gradual and significant decrement in the pH values and gradual increment in titratable acidity with time in the case of banana slices treated with acidified osmotic solution. In the case of samples treated with sulfited osmotic solution, there were no significant changes in the pH values, compared to the control sample (4.65); however, there was gradual and non-significant decrement in the titratable acidity, from 0.259 to 0.211% after 12 h of treatment. These results are in agreement with those found by Peiró-Mena *et al*. (2007) and Blanda *et al.* (2009). Again the ultrasound treatments did not significantly affect the pH value or titratable acidity of the osmotically concentrated banana slices in the same time of treatment.

Regarding the dehydration ratio, Table (1) showed that the dehydration ratio, decreased with increasing the time of the osmotic process. This ratio significantly decreased from 5.06 to 2.45 and from 5.45 to 2.41 after 12 h in the sample osmotically concentrated with acidified and sulfited osmotic solutions, respectively. Using ultrasound with osmotic technique did not show significant effect on the dehydration ratio of the samples compared with the osmotic pre-technique only. No-significant differences were noted between the dehydration ratio of the samples treated with ultrasound for 3 h and that of the samples osmotically concentrated for 12 h. This suggested that the time of osmotic treatment can be reduced by combination with ultrasound treatment, as shown in Table (1).

2. Effect of osmotic concentration and ultrasound on some quality parameters of the dried banana slices

2.1. Moisture and total sugars contents

Table (2) show that the moisture content of resultant dried banana slices treated with osmotic solution and ultrasound for different times before dehydration was a round 14%. There were no-significant differences among all samples. This result is in agreement with that obtained by Stojanovic and Silva (2007).

Table (2): Effect of osmotic concentration and ultrasound on the moisture, total sugars contents and alcohol-soluble color index (ASCI) of the dried banana slices

Samples	Moisture content (%)	Total sugars content (%)*	ASCI (A˚ $100g^{-1}$)
Control sample	14.37^{a}	35.35^{d}	4.17^{a}
Sample soaked in citric acid	14.67^{a}	35.30^{d}	3.45^{bc}
Samples soaked in acidified osmotic solution for			
1.5h ($O_{1.5}$)	14.30^{a}	35.82^{d}	3.10^{cd}
3h (O_3)	14.23^{a}	36.13^{d}	2.88^{de}
6h (O_6)	14.80^{a}	40.90^{bc}	2.16^{g}
12h (O_{12})	13.40^{a}	42.15^{ab}	2.00^{g}
($O_{1.5}$ + U)	14.20^{a}	37.19^{cd}	2.37^{fg}
(O_3 + U)	14.20^{a}	38.91^{bcd}	2.09^{g}
Sample soaked in Na-metabisulfite	14.57^{a}	35.62^{d}	3.80^{ab}
Samples soaked in sulfited osmotic solution for			
1.5h ($O_{1.5}$)	14.03^{a}	36.90^{cd}	3.35^{c}
3h (O_3)	14.33^{a}	40.53^{bc}	2.32^{fg}
6h (O_6)	13.60^{a}	45.44^{a}	2.23^{g}
12h (O_{12})	14.00^{a}	45.84^{a}	2.17^{g}
($O_{1.5}$ + U)	14.07^{a}	40.52^{bc}	2.66^{ef}
(O_3 + U)	14.40^{a}	42.19^{ab}	2.04^{g}

Means of triplicates
***calculated on dry weight basis** **A^{o}= absorbance**
O= osmotic concentration **U= ultrasound**
Means having the same letter within each column are not significantly different at $p\leq 0.05$

The total sugars content significantly increased with increasing the time of the osmotic process, from 35.30% (control) to 42.15% after 12 h of the treatment in the acidified osmotic solution. The same observation was found in the case of using the sulfited osmotic solution. The increase in the ultrasound treatment was higher than that in the osmotic concentration only.

2.2. Alcohol-soluble color index (ASCI)

The osmotic concentration decreased significantly the ASCI (Table 2), from 3.45 to 2.00 A˚ $100g^{-1}$ of the samples treated with acidified osmotic solution and from 3.80 to 2.17 A˚ $100g^{-1}$ of those treated with the sulfited osmotic solution for 12 h. There were no-significant differences between the samples treated with the acidified solution and those treated with the sulfited solution. This may be due to the effect of citric acid or metabisulfite on lowering the level of the non-enzymatic browning. This effect increased with increasing the exposure time. The ultrasound treatment reduced the ASCI comparing to the treatment with the osmotic concentration alone. In figures, the ASCI decreased from 3.10 and 2.88 A° $100g^{-1}$ after 1.5 and 3.0 hours of osmotic process to 2.37 and 2.09 A° $100g^{-1}$ after treatment with osmoconcentration combined with ultrasound for the same time, respectively.

2.3. Color attributes

Hunter color values (L^*, a^* and b^*) of banana slices after osmosis, ultrasonication and air-drying are given in Table (3). After drying, the banana slices L^*values were higher in the osmoconcentrated samples than in the control, in slices treated with citric acid and in metabisulfite samples. This increase in L^* values indicates a more lightening in color. The treatment with ultrasound combined with osmosis give a higher L^* value.

Table (3): Effect of osmotic concentration and ultrasound on "Hunter" color values of the dried banana slices

Samples	L^*	a^*	b^*	C^*	h_{ab}	WI
Control sample	35.85^{g}	9.34^{a}	15.78^{f}	18.33^{f}	59.38^{h}	33.28^{f}
Sample soaked in citric acid	41.35^{f}	8.23^{b}	19.01^{e}	20.72^{e}	66.59^{g}	37.97^{e}
Samples soaked in acidified osmotic solution for						
1.5h ($O_{1.5}$)	41.67^{ef}	7.50^{bcde}	19.99^{de}	21.11^{de}	69.76^{ef}	37.97^{e}
3h (O_3)	42.18^{def}	7.20^{cde}	20.34^{cde}	21.68^{de}	71.24^{de}	38.28^{e}
6h (O_6)	42.16^{def}	6.79^{efgh}	21.22^{abcd}	22.41^{abcd}	71.26^{de}	38.65^{e}
12h (O_{12})	44.26^{cdef}	6.78^{efgh}	22.21^{ab}	23.22^{a}	73.02^{bcd}	39.62^{de}
($O_{1.5}$ + U)	46.32^{abc}	7.89^{bc}	20.37^{cde}	21.84^{bcde}	68.83^{f}	42.05^{bc}
(O_3 + U)	46.71^{abc}	6.95^{defg}	20.72^{bcde}	21.85^{bcde}	71.45^{cde}	42.40^{bc}
Sample soaked in Na-metabisulfite	43.32^{cdef}	7.84^{bcd}	20.33^{cde}	21.23^{de}	68.85^{f}	39.47^{de}
Samples soaked in sulfited osmotic solution for						
1.5h ($O_{1.5}$)	45.25^{cd}	6.81^{efg}	20.27^{de}	21.73^{cde}	71.51^{cde}	41.09^{cd}
3h (O_3)	45.06^{cde}	6.78^{efgh}	20.36^{cde}	21.47^{de}	72.87^{cd}	41.01^{cd}
6h (O_6)	45.99^{bc}	6.13^{gh}	22.00^{abc}	23.02^{abc}	73.22^{bc}	41.29^{cd}
12h (O_{12})	48.76^{ab}	5.88^{h}	22.31^{ab}	23.07^{ab}	75.23^{a}	43.81^{ab}
($O_{1.5}$ + U)	46.64^{abc}	7.07^{cdef}	22.15^{ab}	23.25^{a}	72.30^{cd}	41.79^{c}
(O_3 + U)	49.70^{a}	6.18^{fgh}	22.76^{a}	23.58^{a}	74.81^{ab}	44.45^{a}

Means of triplicates
O= osmotic concentration **U= ultrasound**
Means having the same letter within each column are not significantly different at p≤ 0.05

The color parameter a^* decreased with increasing the osmosis time. The highest a^* value was attached to the control sample (9.34), and the lowest to the sample treated for 12 h with the sulfited osmotic solution (5.88). The ultrasound treatment decreased non-significantly the a^* values of the samples compared to those concentrated osmotically only for the same time. Sugar impregnation seemed to maintain lightness as it helps prevent oxygen contact with samples, and thereby prevent enzymatic browning. Generally, the color parameters L^* and a^* well correlated to darkening of the fruit tissue due to enzymatic browning (Mastrocola and Lerici, 1991). As browning increases, L^* values decrease and a^* values increase. This result is similar to that found by Mandala *et al*. (2005).

The yellowness (b^*) values increased as the osmosis treatment time increased (Table 3), from 19.01 to 22.21 and from 20.33 to 22.31 for the samples treated with the acidified and the sulfited osmotic solution, respectively. The ultrasound treatment non-significantly increased these. Changes in redness (a^*) and yellowness (b^*) of dried banana slices can be evaluated by chroma (C^*). A high chroma values represents more pure and intense color (Pomeranz and Meloan, 1971). Chroma values (Table, 3) gradually increased with increasing the osmosis time. The ultrasound treatment also increased the chroma value. The increase in yellowness and decrease in redness are and seem to be a result of matrix concentration and solids uptake. Forni *et al.* (1997) and Rodrigues *et al.* (2003) observed similar behavior for osmotically treated apricots and papaya, respectively.

Regarding the hue angle (h_{ab}) values, Table (3) show that the h_{ab} (0˚= red hue and 90˚= yellow hue) values significantly increased with increasing osmosis treatment time and by treatment with ultrasound. This indicated that the osmotic concentration and ultrasound maintained the pale yellowish color of banana during dehydration. Both treatments increased the whiteness index (WI) values, indicating the development of white surface discoloration. The higher WI values were for the samples treated with the ultrasound combined with the sulfited osmotic solution for 3 h (44.45). The samples treated with the sulfited osmotic solution, showed higher WI values than those for the samples treated with the acidified osmotic solution. The differences were statistically significant (Table 3).

2.4. Sensory evaluation

Osmotic concentration processes are normally designed with the aim of maximizing water removal meanwhile restraining solid uptake, to obtain a product with a taste and flavor almost like that of the fresh food (Ramallo and Massheroni, 2005). The physical and chemical changes that take place throughout the osmotic process reduce changes in macroscopic product properties, such as optical and mechanical properties (Torreggiani, 1995). These changes are directly related to the color, appearance and texture of the product (Talens *et al.,* 2002). Osmotic pretreatment prior to conventional dehydration improves texture characteristics of the dehydrated fruits and vegetables, decreases enzymatic browning and reduces structural collapses (Chiralt *et al.,* 2001).

The results in Table (4) show that the taste scores of the dried banana slices pre-treated with osmotic concentration only or plus ultrasound were higher than for the control samples. The taste score significantly increased from 5.00 for the control sample to 6.50 and 9.00 for the dried banana slices treated with acidified and sulfited osmotic solution for 12h, respectively. The taste acceptability gradually increased by increasing the treatment time except the samples treated with acidified osmotic solution for 12 h. This may be referred to increase the acidity of these samples, makes they more sour; according to the observations of the panelists.

The osmotic and ultrasound pretreatments improved the Hunter color parameters, hue angle and whiteness index (WI) of the dried banana slices;

the panel test confirmed these results i. e the color scores were higher for both treatment by enhanced the color scores.

Regarding the texture of dried samples, Table (4) showed that, osmotic concentration only or combined with ultrasound treatment improved the texture from the view of the consumer acceptance. The texture score gradually increased from 4.00 for the control sample to 6.87 and 8.17 for the samples pre-treated with acidified and sulfited osmotic solution for 12h, respectively. Wais *et al*. (2004) found that, the hardness of dried banana osmotically pre-treated decreased, while the cohesivity, elasticity, gumminess and masticability increased, i. e the products were softer and more elastic. The effects of osmosis combined with ultrasound treatment on the increment of texture scores may be referred to the increase in solid gain (Table 1) and lowering the adhesiveness of the products by the ultrasound treatment.

Table (4): Effect of osmotic concentration and ultrasound on the sensory properties of the dried banana slices

Samples	Taste	Color	Texture	Overall acceptability
Control sample	5.00^{f}	4.00^{f}	4.00^{e}	4.30^{f}
Sample soaked in citric acid	5.33^{ef}	5.00^{ef}	4.33^{e}	4.83^{ef}
Samples soaked in acidified osmotic solution for				
1.5h ($O_{1.5}$)	6.17^{def}	6.00^{de}	6.00^{d}	5.67^{def}
3h (O_3)	7.00^{bcde}	6.83^{bcde}	6.50^{cd}	6.78^{abcd}
6h (O_6)	7.50^{abcd}	6.83^{bcde}	6.83^{bcd}	7.00^{abcd}
12h (O_{12})	6.50^{cdef}	7.00^{abcd}	6.87^{bcd}	6.50^{cde}
($O_{1.5}$ + U)	7.50^{abcd}	7.17^{abcd}	6.83^{bcd}	7.50^{abcd}
(O_3 + U)	7.00^{bcde}	7.67^{abcd}	7.17^{abcd}	7.17^{abcd}
Sample soaked in Na-metabisulfite	6.83^{bcde}	6.33^{cde}	6.50^{cd}	6.67^{bcde}
Samples soaked in sulfited osmotic solution for				
1.5h ($O_{1.5}$)	7.33^{abcd}	6.33^{cde}	6.83^{bcd}	6.80^{abcd}
3h (O_3)	7.67^{abcd}	7.50^{abcd}	7.17^{abcd}	7.17^{abcd}
6h (O_6)	8.50^{ab}	8.33^{ab}	8.00^{abc}	7.92^{abc}
12h (O_{12})	9.00^{a}	8.67^{ab}	8.17^{ab}	8.67^{a}
($O_{1.5}$ + U)	8.00^{abc}	8.00^{abc}	8.00^{abc}	8.50^{ab}
(O_3 + U)	8.17^{abc}	8.83^{a}	8.50^{a}	8.50^{ab}

O= osmotic concentration **U= ultrasound**
Means having the same letter within each column are not significantly different at p≤ 0.05

The overall acceptability scores of the osmotically concentrated samples gradually increased by increasing process time. The samples pretreated with sulfited osmotic solution had higher acceptability scores than those pre-treated with acidified osmotic solution. In other words, the acid treatment is not suitable for dehydration of banana. As ultrasound treatment enhanced the taste, color and texture scores of dried banana, the overall acceptability of the samples increased. Ehabe *et al*. (2006) showed that consumers showed slight preference to osmo-dehydrated bananas than to only air-dried bananas.

Conclusion

The use of osmotic concentration and ultrasound in food processing is interesting treatments which are complementary to classical air-drying. During osmotic concentration a rapid increase in water loss and solid gain did occur within a short processing time. Ultrasound treatment increased the water loss and solid gain more than did in osmosis. The osmotic concentration and/or osmotic plus ultrasound pre-treatments enhanced the overall acceptability of the dried banana slices.

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تأثير المعاملة الأولية باستخدام الخاصية الاسموزية والموجات فوق الصوتية على جودة شرائح الموز المجففة

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تم دراسة تأثير المعاملات الاولية كالتركيز بالخاصية الاسموزية والموجات فوق الصوتية قبل عملية التجفيف على بعض خصائص الجودة لشرائح الموز المجففة.

عوملت شرائح الموز بالمحاليل السكرية مرتفعة التركيز (٦٠° بركس) سواء المحمضة أو المكبرتة لمدد ١,٥ ، ٣ (مع أو بدون استخدام المعاملة بالموجات فوق الصوتية) ، ٦ و ١٢ ساعة، ثم جففت جميع العينات بالهواء الساخن على درجة ٦٠°م لمدة ١٢ ساعة.

أوضحت النتائج زيادة معنوية لنسب الفقد في الرطوبة والمواد الصلبة المكتسبة و النقص فى الوزن مع وقت المعاملة. كما أدى استخدام المعاملة بالموجات فوق الصوتية مع التركيز بالخاصية الاسموزية الى زيادة هذه المقاييس السابقة، كما حافظتا على لون العينات المجففة، اذ كانت براقة وذات لون أصفر جيد، حيث ازدادت قيم L^*, b^*, C^*, h_{ab} و WI، بينما انخفضت قيم a^* (الدالة على الاحمرار). كما أدى استخدام هاتين المعاملتين الى تحسين القوام والقابلية العامة لعينات شرائح الموز المجففة اذا ما قورنت بالعينات غير المعاملة.

لذا يمكن استخدام هذه المعاملات كمعاملات أولية واعدة لتحسين جودة المنتجات المجففة.

Table (1): Effect of osmotic concentration and ultrasound treatments on some physical and chemical properties of banana slices

Samples	Water loss (WL, %)	Solid gain (SG, %)	WL/SG ratio	Weight reduction (WR, %)	Moisture content (%)	pH value	Titratable acidity (%, as citric acid)	Dehydration ratio
Control sample	-	-	-	-	81.96^{a}	4.65^{a}	0.308^{bcde}	5.21^{a}
Sample soaked in citric acid	-	-	-	-	81.73^{ab}	4.62^{a}	0.440^{bcde}	5.06^{a}
Samples soaked in acidified osmotic solution for								
1.5h ($O_{1.5}$)	13.69^{j}	6.04^{f}	2.27^{bc}	7.65^{h}	73.37^{bc}	4.10^{ab}	0.552^{ab}	3.70^{b}
3h (O_{3})	17.15^{i}	6.24^{ef}	2.75^{bc}	10.91^{g}	70.39^{cde}	3.71^{bc}	0.507^{abc}	3.24^{bcde}
6h (O_{6})	22.12^{ef}	7.00^{cde}	3.16^{abc}	15.12^{de}	66.69^{cde}	3.69^{bc}	0.504^{abc}	2.89^{bcde}
12h (O_{12})	24.17^{cd}	7.49^{c}	3.23^{abc}	16.68^{cd}	63.51^{de}	3.19^{c}	0.701^{a}	2.45^{de}
($O_{1.5}$ + U)	22.70^{de}	6.38^{def}	3.56^{ab}	16.31^{cd}	71.12^{cde}	4.06^{ab}	0.417^{bcde}	3.26^{bcd}
(O_{3} + U)	35.61^{a}	8.48^{b}	4.20^{a}	27.14^{a}	64.29^{de}	3.84^{bc}	0.466^{abcd}	2.61^{cde}
Sample soaked in Na-metabisulfite	-	-	-	-	81.74^{ab}	4.64^{a}	0.259^{de}	5.45^{a}
Samples soaked in sulfited osmotic solution for								
1.5h ($O_{1.5}$)	13.20^{j}	6.88^{cde}	1.92^{c}	6.32^{h}	73.39^{abc}	4.62^{a}	0.253^{de}	3.55^{b}
3h (O_{3})	17.74^{hi}	7.11^{cd}	2.50^{bc}	10.63^{g}	70.39^{cde}	4.67^{a}	0.257^{de}	3.21^{bcde}
6h (O_{6})	19.25^{gh}	7.48^{c}	2.57^{bc}	11.77^{fg}	67.71^{cde}	4.62^{a}	0.247^{de}	3.00^{bcde}
12h (O_{12})	25.99^{c}	8.37^{b}	3.11^{abc}	17.63^{c}	62.86^{e}	4.67^{a}	0.211^{e}	2.41^{e}
($O_{1.5}$ + U)	20.35^{fg}	6.64^{def}	3.06^{abc}	13.71^{ef}	71.54^{cd}	4.64^{a}	0.297^{bcde}	3.38^{bc}
(O_{3} + U)	33.59^{b}	9.41^{a}	3.57^{ab}	24.18^{b}	64.39^{de}	4.66^{a}	0.273^{cde}	2.56^{cde}

Means of triplicates
O= osmotic concentration U= ultrasound
Means having the same letter within each column are not significantly different at $p \leq 0.05$