Osmotic Dehydration of Banana Rings and Tomato Halves

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Abstract: Osmotic treatment process was carried out as a means of pre-drying treatment to improve the quality of the final product. This pretreatment was carried out on banana and tomato rings; to study osmotic dehydration kinetics, colour attributes and organoletpic evaluations. The data indicated highest weight reduction when using 100% sucrose as an osmotic agent in banana. The tomato showed their maximum values when 30% NaCl and sucrose: salt (1: 1.5) were used. The data during tomato osmotic dehydration indicated lower chroma (C^*) and redness values (a^*) during progress in osmotic dehydration times. An overall acceptability in these two materials were noticed. [Journal of American Science. 2010;6(9):383-390]. (ISSN: 1545-1003).

Keywords: Osmotic dehydration – Banana rings – Tomato halves – hypertonic solutions

1. Introduction

Osmotic dehydration is a water removal process, involving soaking foods, mostly fruits and vegetables, in a hypertonic solution such as concentrated sugar syrup. Two major simultaneous counter-current flows occur during osmotic dehydration; Water flows out of the food into the solution and a simultaneous transfer of solute from the solution into the food (Azoubel and Murr 2004). There is also a third flow of natural solutes such as sugars, organic acids, mineral, salts, leaking from the food into the solution. All these mass exchanges may have an effect on the organoleptic and/on nutritional quality of the dehydrated product.

Osmotic dehydration is one of the energy efficient means of removing moisture from a food product, as the water doesn't have to go through a phase change to be released from the product. It is stated that some of the advantages of direct osmosis in comparison with other drying processes include minimized heat damage to color and flavor, and less decolorization of fruit by enzymic oxidative browning (Krokida and Kouris 2003).

Banana is one of the most important consumed fruits in the world, being produced in almost all tropical countries. It has a high nutritive value and is a good source of energy, due to high levels of starch and sugar, as well as being a source of vitamins A and C, potassium, calcium, sodium and magnesium. From the biological point of views; bananas are one of the fruits that present the highest loss by decomposition after cropping due to be extremely perishable and not allowing the use of freezing for its conservation. (Sousa et al 2003).

Banana can be pretreated with different anti-browning agents (Essa and Moharram 2001) and dried in order to save the part of production that will not be readily consumed. Drying is considered to be a classical method of food preservation, which provides an extension of shelf life, lighter weight for transportation and less space for storage (Chua et al 2001). It should be noted that enzymatic browning reaction are occurred during their dehydration. This causes changes in colour, sugar loss and HMF formation, thereby affecting the quality of the final products (Ibarz et al 1999). If the fruits are properly pre-treated, enzymatic and non enzymatic browning can be controlled thereby good quality of the final product is enhanced (Jalali et al. 2008).

Tomato is also a popular vegetable with an exceptional health image as a primary source of vitamins and antioxidant components. It is consumed fresh in many forms, but it is not suitable for traditional preservation. High temperatures or long drying times in conventional air drying can cause serious damage to product flavour, colour and nutrients, and reduce the rehydration capacity. (Aboushita et al. 1997).

In general the combination of osmotic dehydration with conventional drying method has been proposed for fruits and vegetables by many authors to reduce drying time and introduce into the product solutes such as sucrose, salt or calcium (Ertekin and Sultanoglu 2000). In addition, osmotic dehydration is effective at relatively low temperature with minimal damage to colour and texture.

Therefore, this work was carried out to evaluate the efficiency of osmotic dehydration as a pre-treatment before conventional drying of banana rings and tomato halves. Mass transfer, colour attributes and organoleptic properties were also investigated in this research.

2. Material and Methods

2.1- Materials

The banana (Musa cavendishii var balady) and tomato (Lycopersicon esculentum L) were obtained from the local market, Giza, Egypt. The tips of the banana were first removed and its medium part, cut into slices of 1cm length with a knife. Tomatoes were sorted and sliced to an average thickness of 10mm, and each slice was longitudinally cut into haves.

2.2- Methods:

2-2.1 Osmotic dehydration of banana and tomato:

Banana rings were subjected to the following osmotic treatments as follows:-

T_1 = 100% sucrose
T_2 = 50:50 glucose: sucrose.
T_3 = 30:70 glucose: sucrose

Tomato halves were also subjected to different NaCl concentrations or NaCl: sucrose combinations (1:1.5). The samples were ranked as follows:

T_4 : 5% NaCl
T_5 : 10% NaCl
T_6 : 20% NaCl
T_7 : 30% NaCl
T_8 : sucrose: salt 5%
T_9 : sucrose: salt 10%
T_{10} sucrose: salt 20%
T_{11} sucrose: salt 30%

The osmotic treatment processes were carried out under stirring (100 rpm) and at constant room temperature (RT). The ratio between solution and sample were 20:1 to avoid significant dilution of the medium and subsequent reduction of the osmotic driving force during the process. Samples were collected at intervals of 30 mins for 3 hrs of dehydration.

The samples were weighted and the total dry weight was determined at 105°C, for 24 hrs. The experiments were repeated three times.

The measured values were expressed as described by (Moura et al 2005, Kowalska and Lenart 2001) as:-

Water content in per g of dry matter of the dehydrated samples g/g d.m

Water loss and solids gain in $g.g^{-1}$ of the initial dry matter of the sample.

Rate of water loss and solid gain in $g.g^{-1}$ of the initial dry matter of the sample and per min (g/g i.am min).

2-2.2 Color measurements of fresh and osmosed dried banana and tomato.

Changes in colour assessment due to the osmotic dehydration were followed up using a tristimulus colour analyzer (Hunter Lab scan XE-Reston VA), as described using a standard white tile: (x=77.28, y=81.94, z=88.14), L^*=97.66, a^*=0.88, b^*=0.16. The colour was measured in terms of redness a^*, yellowness b^* and lightness L^*. Chroma $(C)^*$ and total colour difference (ΔE) were calculated using the following equations:

$$\Delta E = \sqrt{(L^*)^2 + (a^*)^2 + (b^*)^2} \quad \text{.................. (1)}$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad \text{.................................. (2)}$$

2-2.3- Organoleptic evaluation of the osmosed dried banana and tomatoes:

Colour, texture, taste and overall acceptability of both the osmosed dried banana and tomatoes were subjectively determined by trained panelists using a ten point scale, where (10=excellent, and 1= bad) as described by (Crandell et all 1990).

The results of sensory evaluation were analyzed statistically using the analysis of variance and least significant difference (LSD) as described by (Richard and Gouri 1987). Both the treatments and the samples were repeated triplicate.

3. Results and Discussions

3.1- Osmotic dehydration kinetics

Mass transfer in osmotic dehydration is a combination of simultaneous water loss and solid gains; (Hough et al 1993). For that reason, the experimental data of water loss and solids gain were analyzed and presented as an average of three replicates. Tables (1, 2) indicated the changes that occurred in weight reduction in both tomato and banana. It was clearly noticed that progress in immersion time caused an enhancement in weight reduction. The data also indicated that there was a direct proportional relationship between the percentage of NacL, and progress in weight reduction, the same was also noticed when different percentage of sucrose: salt 1:1.5% were used.

Regarding banana, the data showed highest weight reduction when using 100% sucrose as an osmotic agent. Table (2) also showed the changes in weight reduction, water loss and solid gains during applying different a, b, c Na cl% solutions. It seems that the higher the concentration of Na Cl, the higher the water loss. In contrast to tomato, Banana showed its maximum water loss, when sucrose: glucose solutions were applied at 30%. In solid gains, tables (2, 3); tomato showed its maximum. When 30% NacL and sucrose: salt 1:1.5 were applied. In banana maximum solid gains were achieved when using sucrose 100%.

The enhancement in weight reduction, water loss and solid gain might be due to the synergistic effect of both sucrose and salt to develop high osmotic potential; (Lanart and Flink 1984). It is also reported that solute molecular weight strongly affected both the rate and the equilibration value of solid gain (Panagiotou 1999). The addition of NaCl has been reported to attenuate the sweetness of the fruit and enhances water loss and solids gain (Taiwo et al 2003). The high capacity of NaCl to lower water activity has been reported to increase the driving force of the drying process, when NaCl is added to the osmotic solution (Lerci et al 1985). Due to the efficiency of this process in achieving a wide range of water loss/solid gain ratio, this process can be used for salting operations or for dehydration purposes; (Mayor et al 2006).

In banana the highest water loss, solids gains and weight reduction occurred at a range from 60 to 120 mins. It should be noted that solids gain is largely a differential 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). From this study, it seems that the type of osmotic solution has an influence on the osmotic dehydration. Increasing NaCl% has a positive effect on the rate of water loss. Also in banana, it seems that glucose: sucrose (30:70), were the best solutions that achieved a maximum mass transfer rate as seen in tables (1,2).

The rate of solid gains in banana treated by different sucrose levels and their combinations with glucose was approx 10 folds higher than tomato. (Chiralt and Talens 2005), relating these variations to product characteristics, and to tissue microstructure (cell packagining, permeability, and porosity). Another factor that can be considered also in this process of mass transfer is the epidermis resistance layer that found in tomato (Kross et al 2004). Loss of water and solids uptake near the surface at the beginning of osmotic dehydration might have been resulted in structural changes leading to compaction of these surface layers and increased mass transfer resistance for water and solids; (Singh et al 2007). The rate of water loss could be correlated with the rate of solid gains. In all the experiments, the data showed a highly significant correlation coefficients ($R^2 \geq 0.902$). With lower water content, the rate of water loss and the rate of solids gain decreased from the highest values at the initial water content to the lowest value at the final water content. (Kowalaska and Lenart 2001).

2- Colour:

The use of tristimulus colour measurements provided means of quantifying colour changes in fresh and osmosed dried banana and tomato. Lightness (L^*), Redness (a^*) and yellowness (b^*), in addition to chroma(c^*) and total colour difference (ΔE) were shown in tables (1, 2, 3).

In osmotically dried banana (Table 4), the colour values were characterized by lower L^* values, higher a^* and b^* values during further progress in osmotic dehydration time, these data were confirmed by the work of (Wais et al 2004). Higher a^* could be considered as a browning index (Riva et al 2005), that took place during osmotic dehydration treatments. The a^* values were relatively stable during banana osmotic dehydration time. The chroma values were enhanced progressively, during osmotic dehydration.

In osmotically dried tomato (Table 5,6) by using both NaCl% and NaCl- sucrose%, the data indicated lower chroma value (C^*) and (a^*) values during progress in osmotic dehydration time. It was noticed that the colour of osmotic solutions changed during osmotic dehydration, may be due to the leaching of pigments (lycopene compounds).

3.2- Organoleptic evaluation:-

Table (7) showed the sensory evaluation data of both osmotically dried banana rings and tomato slices. In banana, the sensory data for colour, texture, taste and overall acceptability revealed a non significant difference. The same was also observed in tomato treated by a combination of (sucrose: salt) solutions.

In tomato osmotically dried by different salt concentrations, a significant effect in colour, texture, and overall acceptability were indicated.Sucrose and NaCl concentrations showed a negative correlation with acceptability judgment of the osmotically processed products.At increasing concentration of the two molecules, the product sweetness and saltiness were enhanced; (Sacchatli et al 2001).It should be noted that, the increment of the level of sucrose showed a negative effect of product acceptability, that could explained by the non significant difference that found in Banana rings.

Table (1) Changes in water loss and solid gain g/g^{-1}dm of banana rings as a function of different osmotic solutions

Processing Conditions	WR Weight reduction	WL Waterloss	SG Solid gain	g.g^{-1} dm
T_1(100%) sucrose				
60 mins	1.5303	0.250	0.7384	
90 mins	1.5506	0.301	0.8659	
120 mins	**1.5799**	0.329	**1.0137*** **	
T_2 (50:50 glucose: sucrose)				
60 mins	1.414	0.3700	0.7566	
90 mins	1.487	0.3921	0.7880	
120 mins	1.540	0.398	0.8553	
T_3 (30:70 glucose: sucrose)				
60 mins	1.400	0.3082	0.7768	
90 mins	1.556	0.4247	0.8034	
120 mins	1.556	**0.4246**	0.8920	

Table (2) Changes in water loss and solid gain g/g^{-1}dm of tomato rings as a function of different NaCl%

Processing Conditions	WR Weight reduction	WL Waterloss	SG Solid gain	g.g^{-1} dm
T_4(5% NaCl)				
60 mins	1.131	0.125	0.0098	
90 mins	1.536	0.200	0.0387	
120 mins	1.814	0.258	0.1160	
T_5 (10% NaCl)				
60 mins	1.564	0.258	0.1302	
90 mins	1.584	0.262	0.1265	
120 mins	1.839	0.266	0.1280	
T_6 (20% NaCl)				
60 mins	1.588	0.264	0.1684	
90 mins	1.788	0.276	0.1724	
120 mins	1.957	0.325	0.1760	
T_7 (30% NaCl)				
60 mins	1.845	0.449	0.1730	
90 mins	1.849	0.477	0.2062	
120 mins	2.194	0.520	0.214	

Table (3) Changes in weight reduction and sugar gain of tomato rings as a function of sucrose: salt concentrations

Processing Conditions	WR Weight reduction	WL Water loss	SG Solid gain	$g.g^{-1}$ dm
T_8(sucrose: salt 1:1.5) 5%				
60 mins	1.480	0.145	0.1029	
90 mins	1.477	0.267	0.1037	
120 mins	1.696	0.291	0.1230	
T_9 (sucrose: salt 1:1.5) 10%				
60 mins	1.501	0.306	0.1701	
90 mins	1.818	0.313	0.1810	
120 mins	1.852	0.333	0.1820	
T_{10} (sucrose: salt 1:1.5) 20%				
60 mins	1.808	0.336	0.1839	
90 mins	1.850	0.339	0.2040	
120 mins	1.970	0.397	0.2275	
T_{11} (sucrose: salt 1:1.5) 30%				
60 mins	1.839	0.352	0.1730	
90 mins	1.880	0.354	0.2062	
120 mins	1.980	0.491	0.2140	

Table (4) Changes in the colour parameters during osmotic dehydration of banana rings using different osmotic solusions

Processing Conditions	L^*	a^*	b^*	C^* value	ΔE^*
Banana rings					
Control	70.07±0.345	7.31±0.09	34.612	35.375	78.494
T_1(100%) sucrose					
60 mins	62.83±1.298	7.45±0.192	36.48±0.775	37.2329	73.003
90 mins	61.66±0.650	8.31±0.200	37.17±0.614	38.0875	72.473
120 mins	53.20±3.53	8.98±1.259	38.80±7.226	39.8256	66.455
T_2 (50:50 glucose: sucrose)					
60 mins	62.88±1.290	7.986±0.360	32.48±2.38	33.447	71.222
90 mins	60.05±0.752	8.75±0.162	3466±8.818	35.747	69.885
120 mins	56.67±4.852	8.96±1.259	35.97±0.545	37.069	67.717
T_3 (30:70 glucose: sucrose)					
60 mins	62.88±1.290	8.34±0.049	31.56±0.817	32.643	70.378
90 mins	59.82±0.512	8.71±0.42	36.56±0.699	37.583	70.646
120 mins	56.55±1.88	8.87±0.014	37.89±3.21	38.314	68.646

Table (5) Changes in the colour parameters during osmotic dehydration of tomato rings using different NaCl%

Processing Conditions	L^*	a^*	b^*	ΔC^*	ΔE^*
Tomato Rings					
Control	29.60±1.220	40.79±1.209	24.54±0.454	47.60	56.055
T_4 (5% NaCl)					
60 mins	31.32±8.526	36.12±2.216	26.57±1.195	44.849	54.69
90 mins	39.95±2.584	33.51±0.185	24.98±1.818	41.796	57.81
120 mins	40.56±0.300	30.45±8.776	24.78±0.130	39.258	56.44
T_5 (10% NaCl)					
60 mins	33.67±4.180	36.07±0.854	24.91±2.459	43.835	56.51
90 mins	35.51±2.110	33.99±1.037	25.55±0.149	42.522	55.39
120 mins	37.71±1.344	31.55±0.149	28.40±2.196	42.449	56.78
T_6 (20% NaCl)					
60 mins	33.74±7.366	36.77±7.99	25.42±1.471	44.70	56.00
90 mins	38.72±1.062	35.25±0.470	25.32±0.172	43.40	58.16
120 mins	44.82±0.104	28.98±0.04	30.50±0.152	42.07	61.47
T_7 (30% NaCl)					
60 mins	30.54±6.195	37.73±0.06	26.80±1.171	46.28	55.44
90 mins	37.86±0.313	35.19±0.911	28.99±0.219	45.59	59.26
120 mins	46.36±0.017	34.832±2.569	29.42±1.792	45.59	65.02

Table (6) Changes in the colour parameters during osmotic dehydration of tomato rings using different (sucrose: salt 1:1.5)

Processing Conditions	L^*	a^*	b^*	ΔC^*	$\Delta \varepsilon^*$
Tomato Rings					
Control	29.60±1.220	40.79±1.209	24.54±0.454	47.60	65.055
T_8 (sucrose: salt 1:1.5) 5%					
60 mins	42.23±3.402	31.50±0.056	29.85+0.711	42.05	59.592
90 mins	44.26+0.121	30.74±5.74	29.22±7.77	42.41	61.300
120 mins	47.23±3.799	24.24±4.56	29.66±0.189	38.26	60.780
T_9 (sucrose: salt 1:1.5) 10%					
60 mins	37.13±8.475	35.67±1.045	27.15±0.336	44.83	58.207
90 mins	37.97±3.352	34.52±0.605	22.21±1.22	43.95	58.08
120 mins	38.74±0.424	31.21±2.02	25.60±2.190	40.37	55.95
T_{10} (sucrose: salt 1:1.5) 20%					
60 mins	39.70±1.949	34.08±3.891	25.05±2.874	42.30	58.009
90 mins	34.53±8.96	29.51±2.83	27.66±1.440	40.45	59.42
120 mins	44.38±2.954	28.76±3.228	28.48±1.788	40.48	60.06
T_{11} (sucrose: salt 1:1.5) 30%					
60 mins	39.32±4.154	35.47±2.93	25.56±1.82	43.72	58.80
90 mins	43.89±1.239	30.70±4.45	25.91±0.386	40.17	59.50
120 mins	44.40±3.51	29.72±4.43	30.15±2.170	42.34	61.34

Table (7) Sensory evaluation data of osmotically dried Banana and Tomato rings for the parameters colour, texture, taste and overall acceptability.

	Banana			Tomato							
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
Colour	7.818 ± 0.873	7.78 ± 1.009	8.272 ± 0.786	7.55 ± 1.510	5.88 ± 1.76	4.77 ± 2.27	4.5 ± 2.314	7.00 ± 1.581	7.22 ± 1.20	7.66 ± 1.323	7.666 ± 1.414
		NS			**P = 0.01168**				**NS**		
Texture	7.36 ± 1.027	7.64 ± 0.809	810 ± 0.737	7.33 ± 1.414	6.33 ± 1.224	5.111 ± 2.21	4.56 ± 2.106	6.55 ± 1.809	6.888 ± 1.269	6.666 ± 1.224	6.898 ± 1.269
		NS			**P = 0.012**				**NS**		
Taste	7.72 ± 1.420	7.00 ± 1.00	6.45 ± 2.114	6.125 ± 2.295	5.75 ± 1.752	4.575 ± 2.326	4.188 ± 1.9628	6.75 ± 1.165	6.875 ± 0.834	6.75 ± 1.1649	6.25 ± 0.707
		NS			**NS**				**NS**		
Overall acceptability	7.6 ± 1.07	7.6 ± 0.842	8.2 ± 1.0317	7.625 ± 1.572	6.25 ± 1.832	4.75 ± 2.326	4.325 ± 2.326	7.50 ± 1.4142	7.5 ± 1.195	7.52 ± 1.309	7.5 ± 1.60
		NS			**P = 0.01442**				**NS**		

- T_1: 100% sucrose
- T_2: 50:50 glucose: sucrose
- T_3: 30:70 glucose: sucrose
- T_4: 5% NaCl
- T_5: 10% NaCl
- T_6: 20% NaCl
- T_7: 30% NaCl
- T_8: sucrose : salt 1 :1.5 (5%)
- T_9: sucrose : salt 1 :1.5 (10%)
- T_{10}: sucrose : salt 1 :1.5 (20%)
- T_{11}: sucrose : salt 1 :1.5 (30%)

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