Assessment of Osmotic Pre-Drying Treatment on Drying Rates of Fresh Tomato Fruits

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ABSTRACT: The aim of this work is to investigate the influence of osmotic pre-drying treatments on drying rates of tomato (*Lycopersiconesculentum*) at various drying temperatures. Fresh Roma tomato fruit samples were sliced to a thickness of 5 mm and the seeds were removed. Weight of 300 g was measured for each of the three replicates and immersed in a hypertonic solution of sucrose of different concentrations 40 and 60 ^{o}Brix each held for osmotic duration of 1 and 2 hours, drained for 10 min and then dried at 50, 60, and 70 ^{o}C in a mechanical dryer. Control samples were also weighed 300 g per replicate and dried at 50, 60, and 70 ^{o}C without pre-drying treatment. The initial moisture content of fresh tomato used was 94.5% (wb). Moisture loss of each sample was monitored and recorded hourly until the product has reached the desired final moisture content ($\leq$ 7%).The data collected were subjected to statistical analysis of variance (ANOVA) and Duncan New Multiple range tests (DNMRT) to ascertain the level of significance differences between the individual treatments and their interaction at $p \leq 0.05$.The results show that at all the drying temperatures used, the control tomato samples exhibited the fastest drying rate with an average of 35.2 g/hr, samples pre-treated at 40 ^{o}Brix has an average drying rate of 26.6 g/hr, while samples pre-treated at 60 ^{o}Brix has the slowest drying rate of 25.2 g/hr. It was also revealed that samples subjected to 1 hour osmotic time have faster drying rates than those treated for 2 hours osmotic time.

KEYWORDS: Tomato; Osmotic duration; Brix concentration; Drying temperature; Drying rate

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I. INTRODUCTION

One major problem with fresh tomato fruits is that these vital products deteriorate very fast after harvest leading to heavy postharvest losses. As reported by Olorunda and Aworh (1990) that in Africa, postharvest loss of tomato fruits after harvest was estimated to be between 20-50 percent. Morris *et al.*, (2004) identified various causes of postharvest losses namely: physical spoilage, physiological ageing of fruits, insect or rodent attack, and mechanical damage during transportation, microbial infection, chemical and enzymatic spoilage. In order to prolong the shelf-life of tomato fruit; the fresh products had to be processed. It has been revealed that fresh tomato fruits can be preserved by the application of different preservation techniques such as, freezing, application of heat, chemical method, physical method and drying (Morris *et al*., 2004). Drying of fresh tomato fruits is one method being used by many local processors of tomato fruit and the consumption of dried tomato fruit is becoming more popular in developing countries including Nigeria.

Drying as a means of preserving fruits involves the removal of moisture from produce so as to provide a product that can be safely stored (at moisture content less than 15%) for longer period (James and Kuipers, 2003). Drying is a simultaneous heat and mass transfer process (Haghi and Amanifard, 2008). It involves the removal of moisture present in fruits to a certain limit at which all metabolic activities are hindered, hence preventing the growth of micro-organisms. Drying of fruits helps in reducing its bulkiness and thereby reducing the costs of packaging, storing and transportation, since the weight and volume of the final product has been reduced compared to when it is still fresh (Neulicht and Shular,1995).

Drying of fruits and vegetables is one of the most time and energy consuming process in the modern food industry (Sunjka and Raghavan, 2004). In order to reduce the processing time to facilitate and accelerate the dehydration process, a number of obstacles must be overcome. The main problem in this food preservation technique is the outer skin which impedes water transport from the interior of the food product to its surface, slowing the drying process. There two main ways to reduce the effects of skin resistance and promote water transport, chemical and mechanical pre-treatments (Sunjka and Raghavan, 2004). Chemical pretreatment involves dipping of a product into a chemical solution of a specific concentration for a specific amount of time. Mechanical pre-treatment consists of skin abrasion, puncturing or cutting the product into smaller pieces.

One of the most useful pre-treatment for drying of fruits is osmotic dehydration. Several works had been done on some of these pre-treatments as they affect drying of fruits ~~(~~(Simal et al., 1997, Karathanos and Kostaropolos, 1995, Rahaman and Lamb, 1991). One energy-efficient drying technology is

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osmotic dehydration in combination with various methods of thermal drying (Abraham *et al*., 2004). It is therefore necessary to investigate some of these pre-drying treatments on the drying rate of fresh tomato fruit. Thus, the objective of this research work was to study the effects of osmotic pre-drying brix concentration, osmotic duration and drying temperatures on the drying rate of fresh tomato.

II. MATERIALS AND METHODS

A. *Selection of Materials*

Roma variety tomato fruits that were ripe, fresh and firm were bought early in the morning from a farmer in a local farm in Ilorin metropolis. The tomatoes were selected in order to obtain fruits of uniform size, shape and ripening degree based on the external appearance of the skin and the soluble solids content of samples. Tomato fruits used had 94.5% initial moisture content (wet basis). The tomato fruits were washed and sliced into a uniform slice thickness of 5 mm as shown in Plate I. The seeds of the sliced tomato fruits were removed to prevent immediate spoilage of the fresh samples due to microbial action on the seeds (Sunjka and Raghavan 2004).

Plate I: 5mm sliced fresh tomato fruits.

B. *Brix Preparation and Pre-Drying Treatments*

Osmotic brix concentration of 40 °Brix was prepared from a sucrose solute of 453 g and 60 °Brix was prepared from a sucrose solute of 680 g both dissolved in 925 ml of distilled water at room temperature for duration of 10 min with rigorous stirring. The concentration was monitored on a Portable refractometer scale (Eijkelkamp, model #300002). The sample was divided into five (5) parts, a weighing balance shown in Plate IV was used to weigh each part of the sample to 300 g. Thereafter pre-drying treatment of the samples was done in different bowls, this is shown in Plate II. The first part was treated with 40 °Brix for 1 hour Osmotic duration; Second part with 40 °Brix for 2 hours osmotic duration; the third part was treated with 60 ^{0}Brix for 1 hour osmotic time; the fourth part with 60 °Brix for 2 hours osmotic time and the fifth part was left untreated as the control. The samples were dried on labelled trays at three different temperatures of 50, 60 and 70 ^{o}C respectively.

Plate II: Sliced tomato samples undergoing pre drying treatment in sugar osmotic solution.

Moisture content determination of fresh and dried tomato samples was done according to the AOAC (1990) with the aid of the equipment shown in Plate III.

Plate III: Moisture meter at work used in determining the initial and final moisture content of the samples.

C. *Moisture Loss Determination*

Moisture loss of the samples was monitored during drying by measuring the mass of the tomato samples at hourly intervals, with a top loading balance (Snowrex counting scale SRC 5001 manufactured by Saint Engineering Ltd., Saint House, London) shown in Plate IV. It has an accuracy of 1g (0.001 kg) and measuring up to 5000 g (5 kg) until the desired moisture content was achieved.

Plate IV: Monitoring the moisture loss of labelled tomato samples at every 1 hour interval of drying.

D. *Drying Procedure*

After treatment, the treated samples were drained for about 10 min before being arranged into the dryer shown in Plate V. The dryer used for the drying of the samples both treated and untreated (control) was designed and constructed by Omodara and Olaniyan (2012). The electric dryer is a thin layer, hot air cabinet dryer. It consists of a heating chamber with 1.8 kW heating element connected directly to a blower (backward-curved centrifugal fan of 0.5 hp (0.37 kW). The drying chamber and the whole unit were connected to the temperature regulator/thermostat (0 – 400°C, graduated in 10°C) which controls the temperature of the heater.

Drying process was stopped when the products have reached the targeted final moisture content of ≤7% (wb). The products were removed from the dryer spread on a net for 10 min to cool before being packaged.

Plate V. Labeled tomato samples arranged on the dryer trays.

E. *Drying Rate Determination*

The drying rate (g/hr) was calculated using the formula adopted from Adeboye (2012), presented in eqn (1).

$$R = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t} \qquad (1)$$

where:

dM = change in mass (g),
dt = change in time (hrs),
t = total time (h),
m_i = initial mass of tomato samples (g), and
m_f = final mass of tomato samples (g).

F. *Statistical Analysis*

The data obtained were subjected to analysis of variance (ANOVA) and Duncan New Multiple Range Tests (DNMRT) for pair wise comparison of the treatment factors and their interactions. Differences were determined as significant or non-significant at a significance level of 0.05 in all cases.

G. *Statistical Analysis*

A factorial experiment under a randomized complete block design (RCBD) resulting into 45 runs altogether was used. Each experiment was replicated thrice. In the design, there are three (3) treatment factors which are: Sample pre-drying brix concentration (P), osmotic duration (t) and drying temperature (T). Two (2) levels of sample pre-treatment (P) namely 40 °Brix and 60 °Brix, three (3) levels of drying temperature (T) which were 50,60 and 70 °C and two (2) levels of osmotic duration (t) 1 hour and 2 hours were used. Control samples also have three (3) levels of drying temperature (T) of 50, 60 and 70 °C and were replicated thrice.

III. RESULTS AND DISCUSSION

A. *Effect of Pre- drying Brix Concentration and Duration on Drying Rates*

The results of the effect of brix concentration and duration on the rate of drying are as shown in Tables 1 and 2. The results showed that the effects of brix concentration and duration on drying rate are highly significant ($p \leq 0.05$). It can be seen in Table 1 that samples with the slowest drying rate are those pre-treated at 60 °Brix with an average moisture removal of 25.2 g/hr while those pre-treated at 40 °Brix has an average drying rate of 26.6 g/hr. The control (untreated) samples have the fastest drying rates with an average moisture removal of 35.2 g/hr. These results are in agreement with earlier studies on osmotic pre-treatments on fruits (Simal *et al.,* 1997, Karathanos and Kostaropoulos, 1995, Rhaman and Lamb, 1991 Sunjka and Raghavan, 2004) which revealed higher moisture lost for the control (untreated) samples than for chemically treated samples. This may be due to sucrose concentration on the external and internal parts of the tomato slice which is capable of slowing down the drying process. Studies have also shown that syrup concentration in the range of 65 75 °Brix is not a critical parameter as far as moisture loss in fruits is concerned (Jalaki *et al*., 2008).

Table 1: Mean Values of Drying Rate (g/hr) of Tomato at different osmotic duration.

Brix conc.	Temp (°C)	Drying rate (g/hr) at Osmotic Time		
		0 hr	1 hr	2 hrs
40°Brix	50		35.67 ± 2.082	35.67 ± 2.082
	60		32.00 ± 3.000	32.00 ± 3.000
	70		38.00 ± 2.646	38.00 ± 2.646
60°Brix	50		36.00 ± 1.000	36.00 ± 1.000
	60		39.33 ± 2.517	39.33 ± 2.517
	70		45.67 ± 2.082	45.67 ± 2.082
Control	50	15.33 ± 0.577		
	60	16.33 ± 0.577		
	70	23.00 ± 2.646		

*Each value is the mean of triplicates ± standard deviation.

Table 2: ANOVA for the effects of sample pre-treatment, osmotic duration and drying temperature.

S. V.	D. F.	S. S.	M. S.	F	P>F
Pre-treatment (P)	1	53.78	53.78	9.680*	0.005
Osmotic Duration (D)	1	25.00	25.00	4.500*	0.044
Temperature (T)	2	304.9	152.4	27.44*	0.000
D × P	1	64.00	64.00	11.52*	0.002
D× T	2	38.00	19.00	3.420*	0.049
P × T	2	66.89	33.44	6.020*	0.008
D × P × T	2	24.67	12.33	2.220	0.130
Error	24	133.3	5.556		
Total	**35**	**710.556**			

*significantly different at $p \leq 0.05$

The results showed that the duration of samples in the brix solution significantly affect the drying rate. The results revealed that the samples treated for 1 hour osmotic duration generally have faster drying rates than those treated for 2 hours. It could be inferred here that those treated for 2 hours may have accumulated more sucrose than those treated for 1 hour. These results are however, different from those of Omoleyomi (2012) that osmotic dehydration time has no effect on drying rate.

B. Effect of Pre- drying Brix Concentration and Duration on Drying Rates

The results presented in Table 2 show that drying temperatures have significant effects ($p \leq 0.05$) on the rate of moisture removal from the tomato fruit samples. Drying rate increases with increase in the drying temperature for all the sample as it is seen in Table 1. This is in agreement with the results on the study of the drying rate of cocoa beans carried out by Ndukwu (2009) which revealed that the drying rate increases with drying temperature. The Duncan's New Multiple Range Test in Table 3 shows that the mean drying rate at the three drying temperatures were significantly different ($p \leq 0.05$) from one another.

Figures 1 - 3 show the plots of rates of moisture removal over the period of drying at 50°C, 60°C and 70°C respectively. It can be seen that the higher the drying temperature the shorter the drying time for all the samples to reach the desired final moisture content irrespective of the pre-treatments. These findings are in conformity with earlier studies Muhidin and Hensel (2012) on the influence of pre-treatment on the drying rates of chilli pepper. Generally, the rates of moisture removal from the samples were faster during the first hours of drying. The average rate of moisture lost during the first hour of drying at 50, 60 and 70°C were 43.5 g/hr, 48 g/h and 50 g/hr respectively. This could be attributed to unbound moisture present at the surface of the products which are easier to remove. This is similar with the findings of Agarry *et al.* (2005) on the effects of pre-treatment on drying rate of potato.

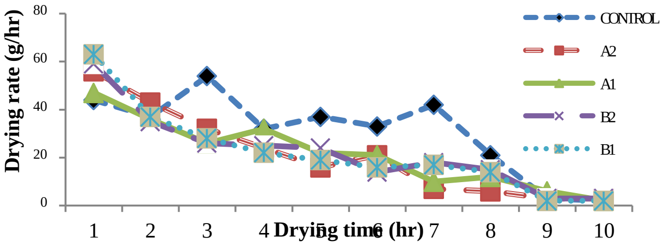

Figure 1: Drying rate vs time for different samples pre-treatments at 50 ^{0}C.

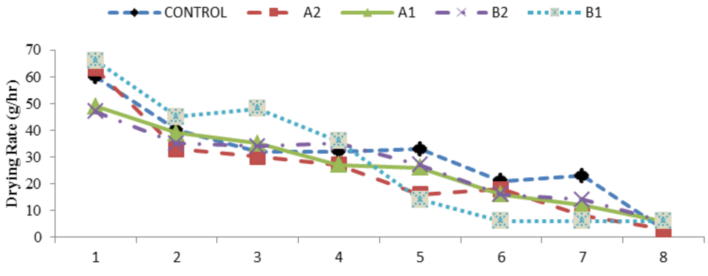

Figure 2: Drying rate vs time for different samples pre-treatments at 60 ^{0}C.

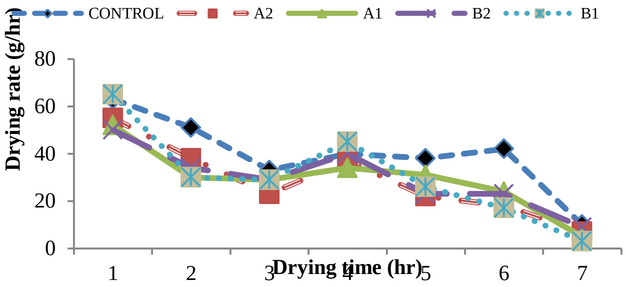

Figure 3: Drying rate vs time for different samples pre-treatments at 70 ^{0}C.

In other words, the rate of moisture removal from the samples of tomato differed significantly ($p \leq 0.05$) at different drying temperatures, with those dried at 70°C having the fastest drying rate shown in Table 3. It has been noted that dehydration velocities increases with the increase in temperature, but there is a limit to this increase so as to avoid browning and aroma loss (Jalaki *et al*., 2008). Abraham *et al.* (2004) also revealed that there was a very rapid decline in moisture of Jackfruit dried at 70°C compared to drying at 50°C. The results also indicated that samples of tomatoes subjected to osmotic brix treatments prior to drying required higher drying temperatures to enhance the rate of moisture removal compared to those untreated. The faster the drying rate, the better; to avoid the infestation by other spoilage organisms that could affect the final product. Osmotic pre-treatments of tomato fruit samples in sucrose would require drying at higher temperatures to attain the final moisture content of 7% (wb) which is adequate for storage.

Table 3: Duncan new multiple range test for the effect of temperature on drying rate.

Drying Temperature (°C)	Drying Rate (g/hr)
50	35.50^{a}
60	37.83^{b}
70	42.50^{c}

*Means with different letters are significantly different at $p \leq 0.05$.

IV. CONCLUSION

The effects of some pre-drying treatment on the rate of drying of tomato fruits had been carried out. From the results obtained and the analysis carried out, the following major conclusions can be drawn. Convective drying rate of tomato fruit increases with increase in drying temperature for both control and pre- drying treated samples. Pre-drying treatment is one important factor that affects the drying rate of tomato, the higher the degree of pre-drying brix concentration, the slower the convective rate of drying of the samples. Control samples have faster drying rates than pre-treated samples.

Samples subjected to 1 hour osmotic duration dry faster than those subjected for 2 hours. It was discovered that an osmotic duration of 2 hours in sugar solution at 60 ^{o}Brix, coupled with a drying temperature of 50 ^{o}C slows down the drying rate of tomato, hence it is recommended to tomato processing enterprise that whenever the need arise to subject tomato fruit to pre drying treatment, should adopt a pre drying treatment with low pre drying ^{o}Brix concentration, short osmotic duration and high drying temperature to achieve faster drying rate, which saves time, money, energy and does not give room for microbial infestation.

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