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DRYING KINETICS OF OSMOTICALLY-TREATED TOMATOES

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ABSTRACT

The drying kinetics of three tomatoes varieties was studied at two levels of drying temperature ranges of (55 ± 1 and 65 ± 1 C°), without pre-treatment and pre-treatments salt, sucrose and calcium lactate, and three sizes of tomatoes parts. The kinetics of the osmotic dehydration of tomatoes in a stationary system using selected osmotic active substances was analyzed. Also, the ratio of the surface area and the volume was measured. Time evolution of measured parameters is cross analyzed and presented in diagrams. Moisture content, drying rates and relative moisture content are calculated and also presented in diagrams. Moisture content verse drying time data were collected. The resulted curves were plotted in diagrams and graphically compared with experimental data. In the experiments, optimum conditions for osmotic dehydration of tomato have been established, as a pretreatment before drying.

It was obvious that the initial osmotic dehydration shortens drying time depending on the kind of osmotic active substance used, the time of osmotic pre-concentration and final water content of the dried product. The results indicated that at the two temperature levels studied, the time required to dry tomatoes at high level (65˚C) was less ≅ 30% than low level (55˚C) at the same treatment. Also, the results showed that drying rates of pre-treatment samples were faster than raw control samples for most treatment combination, by (23%) at constant level temperature. Drying process took place in the falling rate period, and the maximum reduction of drying time was for smallest size of tomato pre-treatment with solution (salt + sucrose + calcium lactate) at high temperature (65 ± 1°˚C). The drying rate increased together with increasing the ratio between the surface area and the volume.

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INTRODUCTION

Drying of fruits and vegetables is one of the oldest methods of food preservation. Dried fruits are also considered a major source of income and foreign exchange in Greece, Iran, Turkey, Portugal, Egypt, and Serbia Republis. Drying prevents occurrence of undesirable changes due microbial activity. Although preservation is the primary reason for drying, it also lowers the product mass and volume which improves the efficiency of packaging, storing and transportation. Dry vegetables have come to occupy a peculiarly representative role in the whole field of food dehydration sharing in both its triumphs and its frequent disappointments. Perhaps it is because vegetables have come into prominence again and again during periods of crisis, and at each resurrection have managed to be conspicuous.**(Van Arsdel et al., 1973).**

Tomato (Lycopersicon esculentum Mill) is the world's most commercially produced vegetable **(Ensminger et al., 1994)**.

Tomato is consider among seven major vegetables in the world, (onion , garlic, cauliflower, green peas ,cabbage, tomato and green beans**. (Sarsavadia et al., 1999)**.

Tomato is a worldwide important agricultural commodity, being the second horticultural product cultivated area and the first in industrialized volume **(Camargo Filhoz and Mazei, 1996).** Egypt is considered the fifth in the world in production, producing about 8 % tomato of the total world production **(FAOSTAT, 2004).**

Helmy et al. (2003) mentioned that total cultivated area of tomatoes in Egypt is about 430207 feddans (180687 ha), produces about 6328725 tons. Total exporting tomatoes is about 29 % of the total production. During the last few years more than 36,000 green houses have been built, about 1/3 of them was used in tomato planting with production about 84,000 tons **(Ministry of Agricultural and Land Reclamation, 2002).** Dried tomato products are used as components for pizza, various vegetable, spicy dishes and the increasing interest in the antioxidant activity of lycopene. The most abundant carotenoid in tomatoes has been promoting several research activities on fresh tomato and tomato products **(Zanoni et al., 1999, Shi et al., 1999, Tavares et al., 1994).**

The higher industrial use of dried products has increased the level of requirements, particularly in terms of “functional properties". Also, there is increasing consumer demand for processed products that keep more of their original characteristics in such a way that preserving quality attributes of dehydrated food stuffs are becoming of crucial importance quantifying the mobility changes induced by glass transition may be the rout for the elucidation of the link between the process and product quality (**Telis and Sobral, 2002**).

Shi et al. (1999) carried out experiments to dry tomato in the different dehydration methods and two levels of namely temperature 55 and 95 ˚C to define the changes of lycopene content in tomato samples.

Heredia et al. (2006) said that dehydration of tomatoes is a process commonly used to preserve the product and extend shelf-life. High temperatures or long drying times in conventional air drying can cause serious damage to product flavor, color and nutrients, and reduce the dehydration capacity of the dried product. Comparison of kinetics and other related properties, the results showed that osmotic dehydration with ternary solutions formulated with salt, sucrose with the addition of calcium lactate were used in an osmotic treatment prior to microwave assisted to obtain tomato products that are shelf stable and have better quality than the traditional product.

Bruin (1987) said that osmotic concentration is a water removal process which is based on placing foods, such as pieces of fruit or vegetables, in a hypertonic solution. Because of the higher osmotic pressure of the solution a driving force for water removal arises between solution and food, while the natural cell acts as a “semi permeable’’ membrane **(Lerici et el., 1985, Farkas and Lazar (1969)** mentioned that a treatment prior to drying, freezing or freeze drying, direct osmosis appears particularly useful as a means of limiting energy consumption.

Goula and Adamopoulos (2005) conducted a detailed study on stability of lycopene during spray drying of tomato pulp and the effect of drying conditions on the lycopene content of tomato powder. Tomatoes and tomato products are the major source of lycopene and are considered to be an important contributor of carotenoids to the human diet. However, processing and storage of tomato products cause lycopene degradation as reviewed by **(Nguyen and Schwartz 1999)**. Lycopene loss increased with increasing air inlet temperature and in both drying and compressed air flow rate. The extent of loss found to be influenced not only by inlet and outlet air temperatures but also by factors such as droplet moisture content, oxygen, light exposure and particle size. These factors are dependent on processing conditions.

Sacilik et al. (2006) dried organic tomato by solar tunnel drying to the final moisture content 11.5% from 93% wet basis .The drying time was between 82 to 96 h and 106 to120 h for open sun drying .

Baker (1997) stated that the drying kinetics, considers the drying of a wet solid under fixed drying conditions. In the most general case, after an initial period of adjustment, the moisture content, X , decreases linearly with time, t, following the start of the evaporation . This is followed by a non-linear decrease in X with t until, after a very long time; the material reaches its equilibrium moisture content, $X*$ and drying stops. In terms of free moisture content, defined as $X_f = (X - X*)$ the drying rate drop to zero at $X_f = 0$.

Page (1949) modified the logarithmic model by adding an exponent parameter to the drying time (t). Three forms of this model were presented in the following form: $MC = Exp.(-K*t**N)$

Page's second model is a linear relation obtained by logarithmic.

Ln[-Ln(MR)] = Ln (K) +N*Ln (t) . The third tested model form of page is (the moisture content model) can be presented as follow: MC = (Mo – ME)* Exp (- K* t** N) + ME

Thin layer drying data is collected to determine the drying properties of agricultural products. To evaluate any drying process, the drying coefficient of agricultural product must be considered.

The following mathematical model suggested by **(Hall 1957)** was used to predict the drying coefficient (K) from the moisture content –time curve. The moisture ratio was calculated as follows:

$$MR = \frac{M_t - M_e}{M_0 - M_e} = \exp.(-K\theta)$$

And the drying constant has been calculated as follows:

$$K = -\frac{1}{\theta}\ln MR$$

Where: Mt = the moisture content dry basis, %, Mo = the initial moisture content dry basis at time zero, %,

MR = Moisture ratio, dimensionless, K = Drying coefficient (h), and $\theta =$ Time (h) .

Most of the thin layers drying models developed to predict the moisture and heat movement in thin layers and deep bed drying is based on **Hukills** equation **(Hukill 1947)**.

$$\frac{dM}{dT} = -K(M - M_E)$$

Which integrated in the following common from;

$$\frac{M - M_E}{M_o - M_E} = e^{-KT}$$

This equation modified by applying an exponent (n) to time (t) to fit better his thin layer drying data (**Page** equation)]

$$\frac{M_t - M_E}{M_o - M_E} = e^{-KT^n}$$

Where: M = moisture content at time T , % d.b. , M_o = initial moisture content % d.b. , M_E = equilibrium moisture content % d.b. ,T= drying time ,sec. K = drying coefficient, sec$^{-1,}$ and (n) is dimensionless constant.

OBJECTIVES

The main objectives of this study were to study the effects of temperature (55 $\pm$1 and 65± 1C°), pre-treatment and the size of sample on tomatoes drying rates, on drying time and properties of tomatoes.

MATERIALS AND METHODS

1- Materials:-

Three fresh and mature tomatoes varieties Chiquit (A), Stokdijk (B) and Hydropnic (C) product of Canada were obtained from local market (super store, Halifax, Nova scotia, Canada). The average vertical and horizontal diameters of these varieties were 7.75 and 4.63 cm, 6 and 7.45 cm and 6.37 and 7.24 cm respectively. The average volumes were (96.5, 186.67 and 202.84 cm^3). The average weights were (95.23, 194.14 and 203.29 g),. The initial moisture contents wet basis were (93.7, 91.9, 94.41 %), respectively.

2-Experimental protocol:-

The effect of drying temperature, pre-treatment and size of tomatoes, drying rates on drying time and properties of tomatoes were investigated in this study.

Before the drying experiments, the tomatoes samples were washed , cut into halves (½) , quarters (¼)and one eighth (⅛) and weighed with a Mettler PM 4600 digital balance of 0.01 g accuracy (Mettler instrument, Switzerland) The dimensions of tomatoes parts were measured with scale of 0.01mm accuracy to calculate the surface area. The initial moisture contents of tomatoes varieties were estimated by oven method at 70˚C for 6h. The samples were weighed each 2h until the weight was constant **(AOAC 2000).** The experiments were carried out on the department. of biological engineering, Dalhousie University, Canada. The first and the sixth experimental were run to dry the tomato parts non pre-treatment. The other experiments were run after tomatoes parts were immersed in a container containing the osmotic solution. The experiments were carried out with a brine solution as follows: (a) with solution 10 % salt. (b) with solution 25% sucrose (w/w) and 10% salt (Nacl) after it was agitation. (c) The third solution was contented salt and addition 2% calcium lactate (w/w)., to analyze the effect of this solute on sensorial properties, final composition and behavior in the subsequent drying process. (d) The fourth treatment for tomato parts was been with solution salt, sucrose, and calcium lactate to preserve the sensorial properties. All solutions were agitation for a period of three hours by shaker (Fisher Scientific, Thermix Stirrer Model 120M, made in U.S.A.). The range of agitation 100 or105 shakes per minute was kept constant for 3 hours and for all combinations.

The tomatoes samples were immersed by solution for 2 hours. There after the experiments were conducted in a forced draft oven (Fisher Scientific Isotemp oven model 630 F) when the drier reached to the required temperature. The moisture contents were calculated by recording the change in weight of samples 3 hours intervals. **Heredia et al. (2006)** used the same method to dry cherry tomatoes and **Bruin (1987)** used it to dry carrot. The optimum time for osmotic dehydration of carrot, as a pretreatment before convection drying, is 2-3h at temperature 30˚C and the best osmoactive substance are saccharose and starch syrup.

3- Statistical analysis:-

Simple, polynomial and multiple linear regressions were used to fit the best model for determining the moisture content of opinion. The actual drying time and the experimental moisture content were the input data for the best fitting. Many investigators used the linear regression such as **Zhong and Lima, (2002)** reported that the mean dimensionless moisture ratio (MR) was determined using the equation

$$MR = \frac{M(t) - M_e}{M_o - M_e},$$

where M(t) is moisture content at time t ={0,3,6,9,12,15,..} , M_e is the initial moisture content ,and M_e is the equilibrium (final) moisture content . The moisture ratio concept was developed by **Hukill (1947, 1954)** to determine moisture content during the drying of grain products. A separate nonlinear exponential decay model was fitted to each of the treatment combinations. The nonlinear model is $MR = a + be^{-ct}$ where a is the horizontal asymptote, b is the distance from the asymptote to the intercept of the vertical axis, and c is the slope or rate. For this investigation, the rate parameter, c, is the effect of the drying time for a specific treatment combination. The larger the value of c the faster a particular treatment combination reduced the MR .The model used is similar to that published drying models **(ASAE, 2000)** and was used to generate a best fit for the data. A nonlinear analysis of covariance was used to evaluate treatment combination differences **(Hinds and Milliken, 1987** and **Doymaz, (2007)**, calculated the drying rate of pumpkin slices during drying experiments by using the following equation:

$$\text{Drying rate} = \frac{M_{t+dt} - M_t}{dt}$$

where , M ,M_o, M_t and M_{t+dt} are the moisture content at any time , initial moisture content , equilibrium moisture content, moisture content at t and moisture content at t + dt (kg water /kg dry matter),respectively.

4-Color parameter measurements:-

Color measurements were performed in a Minolta Chroma Meter, model DP-30/ CR-300 diffuse illumination, 0˚ viewing angle; specular component included. Measuring area: Φ8mm. The coordinates of the color were measurement the L*,a*, and b* . a* and b* indicate two color axes , with a* the red-green axis and b* the yellow-blue. L* is measure of Brightness (whit- black). The chroma C* is described by the equation

$$C* = \sqrt{a*^2 + b*^2}$$

so that when chroma and value axes are compared as in figure shows the above color chart rotated 90° with value L* extended above the line drawn from the center through chroma C*. A Delta E*(ΔE*)

Value is then calculated to show the color differences with other samples (These are called color differentials). To compare the color difference (ΔE) between fresh and osmotic treated tomato must be estimated ΔL*, Δa*and Δb*. Color differences (ΔE) were estimated from the coordinates of the color by applying the following equation:

$$\Delta E = \pm\sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

RESULTS AND DISCUSSION

The "best" drying method for a food product is determined by quality requirements, raw material characteristics, and economic factors. The quality required in a finished product, and its necessary physical characteristics, are determined by its end use. The final moisture content of samples dried of tomatoes under different conditions ranged from 20% to 10 %(wet basis). The drying temperature has an important effect on drying of tomato cutteing samples. It is evident that pre-treatment had effect on moisture movement from the samples. Osmotic pre-concentration of tomatoes affects the course of convection drying of the material. Time osmotic dehydration and kind of osmotic active substance have a significant influence on the kinetic of osmotic-convection drying.

1-The effect of increasing the drying temperature on the process of drying tomatoes parts:-

The drying temperature has an important effect on drying rate of tomatoes parts. The effect of drying temperature and treatment on the drying time taken to reach the final moisture content of tomatoes are presented in Table (1). To compare the effect of increase drying temperature, the two levels of temperature were used (55 ± 1) and (65 ± 1) at the same experimental conditions. Ten groups of experiments were carried out at different two levels temperature of drying, different treatments and three types of cutting sizes .Graphical presentation of the data are shown in Figures (1 to 4). Each point represents an average of three replicates .When the moisture contents were plotted versus the time of drying as shown by the Figures, it was found that for each moisture content for the three cutting sizes of tomato under the same conditions. The results indicated that the increasing of the drying temperature decreased the final moisture content for all experiments.

Table (1) :Drying temperature , pre-treatment ,drying time and drying rate

Temper-ature °C	Treatments	Cutting size					
		(1/2)		(1/4)		(1/8)	
		Drying Time (h)	drying rate (%/h)	drying Time (h)	drying Rate (%/h)	drying Time (h)	Drying Rate (%/h)
55± 1	non pre-treatments	36	2.19	27	2.93	21	3.77
	Salt	27	2.89	22	3.55	17	4.59
	salt+ sucrose	30	2.59	23	3.38	16	4.86
	salt+calcium lactate	31.5	2.48	20	3.92	15	5.23
	salt+sucrose+calcium lactate	31	2.52	21.5	3.64	16.5	4.75
65 ± 1	non pre-treatments	24.5	3.21	17	4.63	14	5.63
	salt	19	4.07	15	5.16	11.5	6.73
	salt+ sucrose	22	3.51	14	5.52	11	7.04
	salt+calcium lactate	19	4.12	14	5.59	11	7.11
	salt+sucrose+calcium lactate	22	3.56	12	6.53	10	7.83

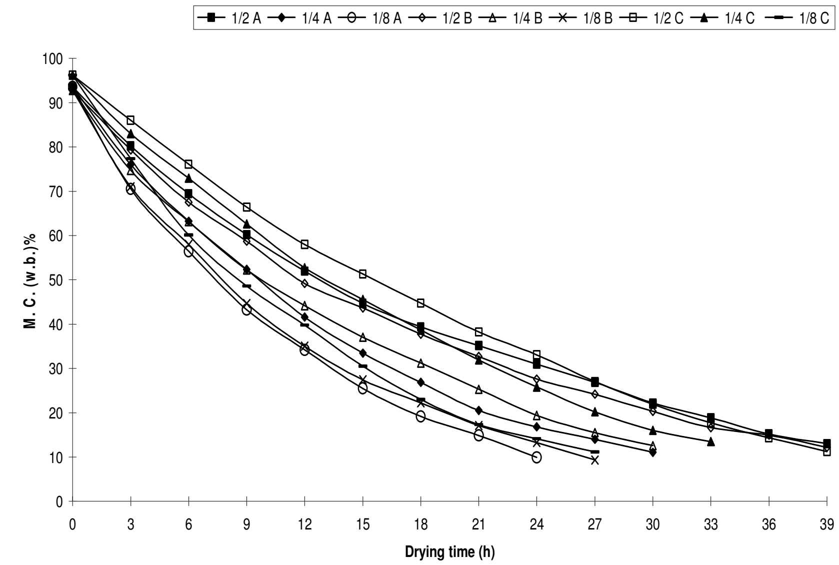

Fig. (1):Experimental moisture contents of tomato without treatment and drying time at temp. 55 C

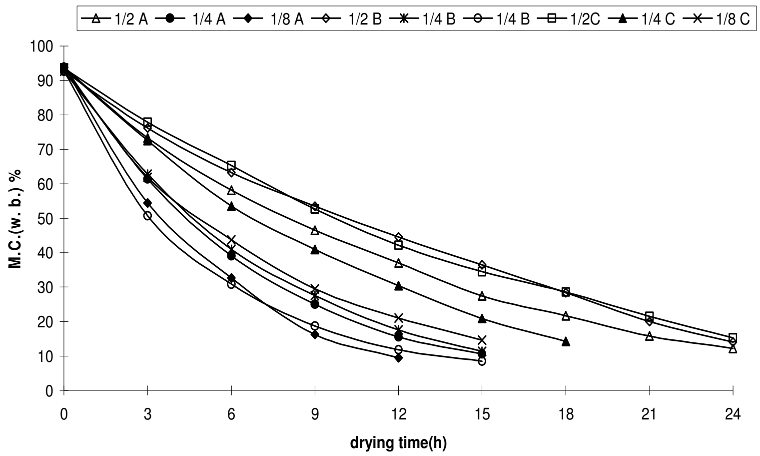

Fig.(2): Moisture contents of tomato with treatment (sugar+salt+calcium lactet) versus drying time at temp. 65 C

For example, at the non treatment of tomato, increasing the drying temperature from 55 to 65 C° decreased the moisture content from ≅ 35 % to 17 % after 21 hours for drying process. At the higher temperature of 65˚C, the drying time was less for control and pre- treatment samples. Similar observations have been reported for drying garlic slices **(Madamba et al., 1996)** ,onion slices **(Sarsavadia et al., 1999), (Abou El Hana, 1998)** and mangos slices **(Goyal et al., 2006).**

The relationship fits the experimental data on studying the effect of drying temperature on the reduction of moisture content by simple, polynomial and multiple linear regression analysis involving the drying time for the relationship for the following type was suggested. Osmotically dehydrated tomatoes appeared to be a promising though new processing technique to keep the fresh natural reddish color. Osmotic solution (sugar) remaining on the surface layer of tomato prevents oxygen from penetrating and oxidizing lycopene. A possible explanation of this result is that sugar enters the tomato matrix and strengthens the binding force on lycopene in the tomato matrix. Osmotic treatment could reduce lycopene losses in comparison with other dehydration methods. These results will be useful to develop the following model:

$Y = B_1 X^2 + B_2 X + A$ and $Y = A + B_1 X_1 + B_2 X_2$

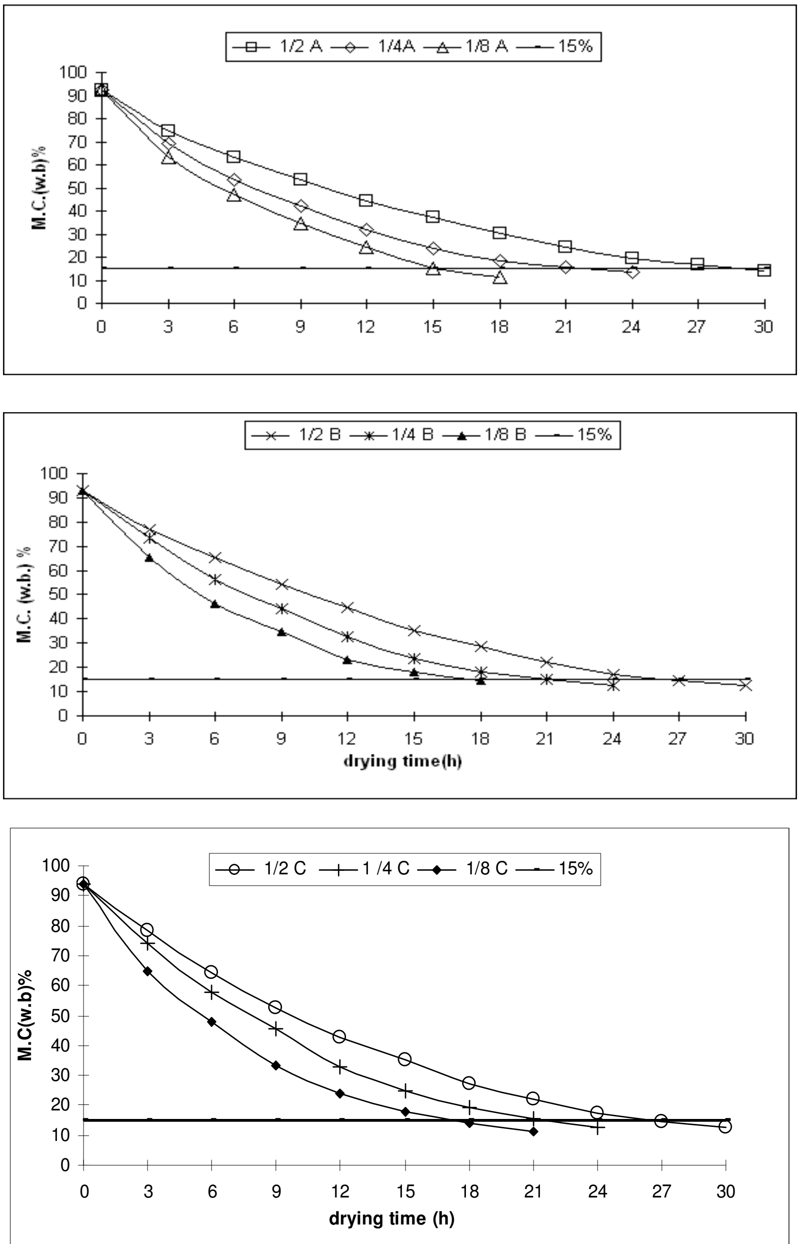

Fig.(3): Moisture content of tomatoes with treatment (salt) and drying time (h) at temperature 55 C

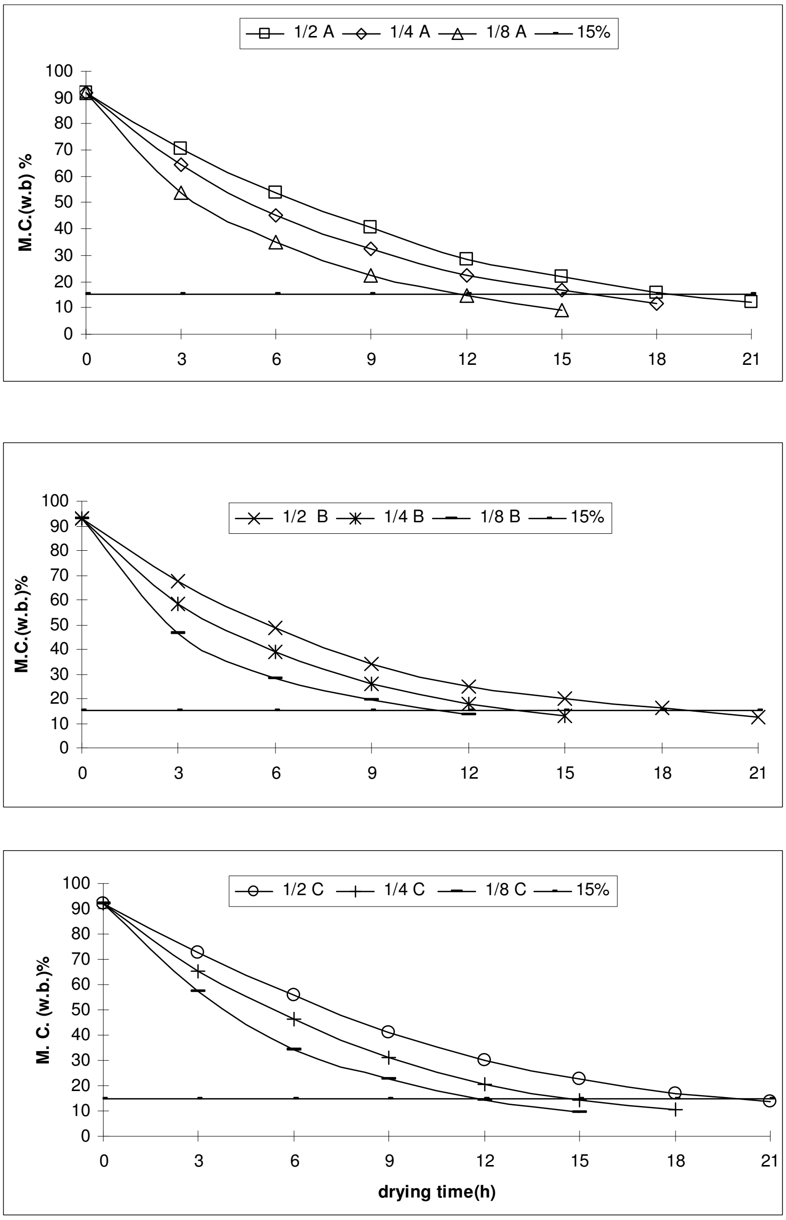

Fig. (4) Moisture content of tomatoes with treatments (salt) and drying time (h) at temperature 65 C

Where:

Y= MC = Moisture content wet basis, % ,

X =X_1 = θ = Drying time, (h)

X_2 = S = The size of tomato

A ,B_1 , B_2 = Constants under a given condition and the units used .

The predicted mathematical models which were obtained from the data as follows:

At drying temperature 55 ± 1 °C and the size was half (1/2)

$$MC = 0.5872\theta^2 - 13.651\theta + 105.72 \qquad R^2 = 0.9995$$

At drying temperature 65 ± 1 °C and the size was half (1/2)

$$MC = 0.7297\ \theta^2 - 17.153\theta + 108.31 \qquad R^2 = 0.9994$$

$$MC = 64.44 - 3.07\theta + 36.26S \qquad R^2 = 0.9029$$

non pre-treatment at temperature 65 ± 1°C

$$MC = 65.18 - 2.16\theta + 41.905 \qquad R^2 = 0.923$$

non pre-treatment at temperature 55 ± 1°C

With treatment salt, sugar and calcium and drying temperature 55 ± 1 °C

$$MC = 57.275 - 2.42\ \theta + 52.27S \qquad R^2 = 0.889$$

With treatment salt and sugar and drying temperature 55 ± 1 °C

$$MC = 57.924 - 2.339\theta + 43.38\ S \qquad R^2 = 0.879$$

$$MC = 107.67e^{-0.165\theta} \qquad R^2 = 0.985$$

at temperature55 ±1°C with pre-treatment and the size was half

$$MC = 124.92e^{-0..2544\theta}. \qquad R^2 = 0.9977$$

at temperature65 ±1°C the same treatment and the size was half.

It is clear that from the previous results, at the drying temperature 65 ± 1 C°, the total drying rate was greater than the low level drying 55 ± 1 C° by about 32 % at the same treatment and the size.

On the other hand,, by increasing the temperature, the total drying rate increased by 35 % at the half size and the treatment of salt for the same variety.

The value of the drying constant increased with increasing drying temperature, drying curve becomes steeper indicating faster drying of the product.

2- The effect of pre-treatments on moisture losses of drying process of tomato samples:-

The effect of the pre-treatments on moisture losses of drying curves of tomato dried at two levels of temperature are presented in Table (2) and Figures (5 and 6). The drying curves show that moisture ratio decreased continuously with drying time. In all cases, the value of R^2 was greater than 0.90, indicating a good fit.

3- The parameter color of tomato samples:-

The number of servings of lycopene rich food, such as tomato, tomato sauce and pizza, significantly correlated with allow risk for prostate cancer **(Giovannucci et al., 1995).** Deep red fresh tomato fruits are considered to contain high concentrations of lycopene. Processing conditions such as high temperature, long processing time, light, and oxygen have been shown to have effects on lycopene degradation. Degradation of lycopene not only affects the attractive color of the final products, but also their nutritive value. Losses of lycopene during the dehydration of tomatoes are commercial significance **(John Shi et al., 1999).**

Color evaluation of whole fresh tomatoes have traditionally been presented as Hunter L^*, a^* and b^* with the equation $C^* = \sqrt{a^{*2} + b^{*2}}$ and the overall color difference (ΔE) of the dried tomato products are presented in Table (3). Tomatoes with osmotic treatment had red color more than that non pre-treatment; the difference $\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$

Table(2): The effect of pre-treatments on moisture losses of tomato samples before drying process

Variety	Chiquit (A)			Stokdijk (B)			Hydropnic ©		
Size	1/2	1/4	1/8	1/2	1/4	1/8	1/2	1/4	1/8
Salt	2.98	4.33	9.04	3.68	6.81	7.44	4.09	7.57	10.23
	3.6	5.9	9.1	4.54	5.67	9.07	3.78	6.1	7.28
Salt +ca	3.59	8.45	10.47	3.78	7.36	10.29	5.75	9.18	10.24
	4.05	7.2	9.05	6.61	5.76	7.75	5.6	9.24	9.03
Salt+ sugar	3.97	9.06	12.45	3.59	9.69	10.37	6.27	11.7	13.45
	4.56	9.9	11.24	4.54	8.60	12.52	8.36	10.37	11.16
Salt+s+ca	5.96	8.77	12.6	4.67	8.8	12	4.18	7.3	11.53
	5.86	9.86	11.02	3.59	8.02	13.7	5.43	9.18	11.27
Average	4.32	7.93	10.62	4.37	7.58	10.39	5.43	8.83	10.52

Table (3) : Color values of fresh and dehydrated tomato samples

samples	color parameter				
fresh material	L*	a*	b*	c*	ΔE
A	45.98	25.61	27.97	37.92	
B	36.55	22.61	14.85	27.05	
C	36.69	18.13	19.705	26.77	
Dehydrated tomatoes					
Un-treatment					
A	35.697	24.047	19.33	30.82	13.52
B	31.19	18.68	12.48	22.46	15.257
C	28.44	18.96	11.98	22.42	19.01
osmotic dehydration					
A	39.026	25.17	25.115	35.55	6.64
B	32.73	22.46	14.65	26.81	3.828
C	32.26	19.65	15.56	25.06	6.267

A, B, and C varieties of tomatoes

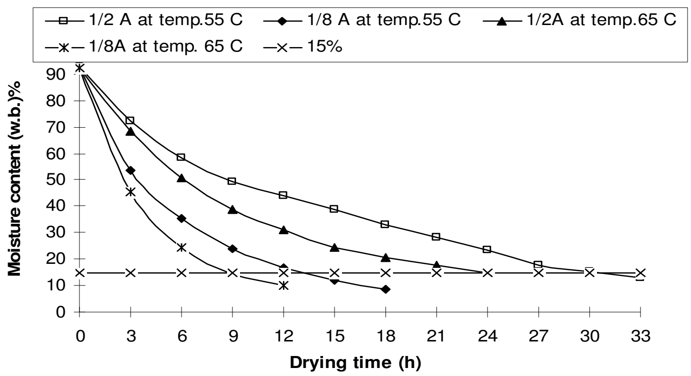

Fig. (5): tomatoes moisture content versus drying time at different two levels tepmerature (55 and 65 C)

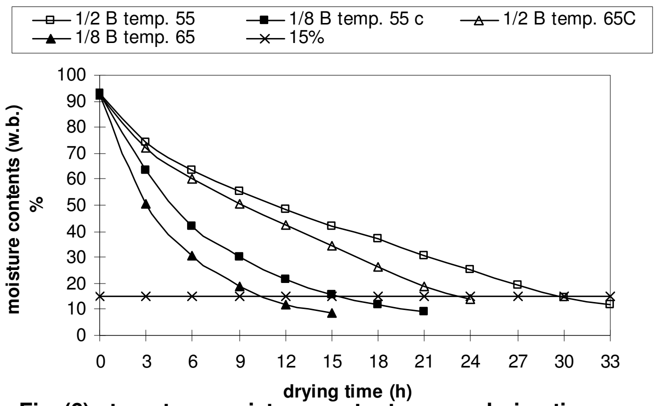

Fig. (6) : tomatoes moisture content versus drying time at different two levels temperature (55 and 65 C) at the same treatment (salt+sugar+calcium)

was less between somatically samples, which indicated there was more lycopene in samples. Osmotically-dehydrated tomatoes appeared to be a promising , though new processing technique to keep the fresh natural reddish color . During osmotic dehydration, lycopene content remained essential constant. A probable explanation is that the sugar solution keeps oxygen from the tomatoes and reduces the oxidation of lycopene in the tomato tissue matrix at low operating temperature dehydration techniques and improve product quality.

4- Drying behavior of tomato sizes :-

At the beginning of the drying process, depending on the sample size and the temperature at the constant of the other factors, moisture content loss from and solid gain by the tomato parts against drying time of osmotic and non pre-treatment can be observed from samples Figures (3 to 6). The moisture loss increased linearly with drying time increasing for all size parts at two drying temperature levels, at all concentration and non pre-treatment. Both, the moisture loss and solid gain were fastest for the small size (eighth) (⅛) then the drying time was shortest than two other sizes by (44% and 58%). To compare the trends of drying at the different of size pieces and the temperatures of drying, the experimental data of moisture content wet basis with the drying time (hours) are showed in Figure (1). The experimental data and predicted moisture content as a function of drying time are plotted in Figures (2 , 3 and 4) for three different size (1/8 , 1/4 and 1/2) respectively . Regression equations that could be used to predict the rate of moisture loss as function of time at the same conditions.

The predicted mathematical module was as follow:

At non pre-treatment and the drying temperature55±1°C

$MC = 65.18 - 2.16\theta + 41.90S$ R^2 =0.923

At pre-treatment salt at drying temperature 55 ± 1° C

$MC = 64.35 - 2.78\theta + 40.043S$ R^2 = 0.908

At pre-treatment salt and sugar at drying temperature 55 ± 1° C

$MC = 57.924 - 2.339\theta + 43.385S$ R^2= 0.879

At non pre-treatment at drying temperature 65 ± 1 ° C

$MC = 64.44 - 3.07\theta + 36.26S$ R^2 = 0.902

At pre-treatment salt

$MC = 56.002 - 3.27\theta + 45.68S$ R^2 = 0.828

The best relationship fits the experimental data between moisture content and drying time

$MC = 109.92e^{-0.147\theta}$ R^2 =0.996 At temperature 55± 1°C and **non pre-treatment at the half size**

$MC = 119.63e^{-0.2158\theta}$ R^2 =0.998 at temperature 55± 1°C and non pre-treatment the size was quarter

$MC = 125.09e^{-0.272\theta}$ R^2 =0.998 at temperature 55± 1°C and non pre-treatment the size was eighth Where M C = moisture content wet basis, %,

$\theta =$ Drying time (hours), and

S = the size of tomato piece

The results indicated that the (1/8) piece size of tomato dried faster, followed by (1/4) piece size and (1/2) half size of tomato comes last. The time required to dry the (1/4) piece size of tomato is more than the time required to (1/8) size by about 27.3 %. The drying time for (1/2) half size by about 48.7 %.

The over all rate moisture loss in (1/8) size of tomato was more than that in (1/4) size by about 27 % and more than that in the rate in (1/2) size by 47 %.

The total drying rate of tomato was affected by the species size .The drying rate decreased with increasing the pieces sizes.

CONCLUSION

The effect of drying temperature and pre-treatments on drying time of tomato cutter were investigated in this study. Based on the experimental results reported herein, following conclusions can be made:

1-Drying time decreased considerably with increasing drying temperature from 55 to 65 ˚C .The value of the drying constant increased with increasing drying temperature, drying curve becomes steeper indicating faster drying of the product.

2-Drying process took place in the falling rate period. Higher drying temperature and smallest size are greatly reducing moisture content of tomato. AS expected, the drying rate increased together with increasing the temperature and the ratio between the surfer’s area and the volume of tomato parts.

3- Optimum conditions for process had been established, as a pre-treatment before convection drying. Pre-treatments of tomatoes were decreased the drying time than control samples and will be useful to develop new drying techniques and improve product quality. .

4-Color analysis is important of food, especially quality criterion for the production and for the trade. From the results of color measurements, drying osmotically tomato in temperature of 65 ˚C was found to be goodness.

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الملخص العربى

تجفيف الطماطم المقطعة بعد معاملاتها انزيميا

نبيــهة حســن ابوالــهنا *

تعرف الطماطم علميا بأسم Lycopersicon esculentum وفي الإنجليزية باسم Tomato ومن الأسمائها الشائعة في الدول العربية البندورة أو الطماطم . وتعد الطماطم واحدة من أهم محاصيل الخضر من الوجهة الاقتصادية في معظم دول العالم . وقد بلغ الأنتاج العالمي من الطماطم حوالي 120 طن مترى في عام وقد احتلت مصر المركز الخامس في الإنتاج بين دول

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العالم إحصائية الفاو (2004). احتلت الطماطم المركز الثالث عشر (13) من حيث محتواها من فيتامين (ج) والمركز السادس عشر من حيث محتواها من فيتامين (أ) إلا أنها كانت الثالثة في الترتيب كمصدر لفيتامينى أ ،ج نظرا لكثرة ما يتناوله الفرد من الطماطم مقارنة بالخضر الآخرى ولهذا السبب احتلت الطماطم المركز الأول في الدراسة كمصدر لعشرة من المعادن والفيتامينات مجتمعة ولذلك كان الهدف الرئيسي لهذا العمل هو الأختيار لطريقة التجفيف الصحيحة لثلاث انواع من الطماطم تم شراءالطماطم التى اجريت عليها التجارب من الإنتاج المحلي لدولة كندا تم البحث فى معمل الهندسة الحيوية- بجامعة دلهاوزى حيث تم أختيار مستويين من درجة الحرارة55 ± 1 & 65 ± 1درجة مئوية و قبل عملية التجفيف تم غسل الطماطم جيدا وايجاد وزن الثمرة وحجمها وقياس القطر الطولي والقطر العرضى للثمرة ثم تقطيع الطماطم علي شكل نصف (2/1) تقطيع عرضي وربع (4/1) وثمن (8/1) وبعد عملية تقطيع الطماطم يأخذ قياس الأبعاد الطولية والقطرية لكل جزء وباستخدام معادلات هندسية أمكن ايجاد المساحة السطحية والحجم لكل جزء من الأجزاء المقطعة ثم تعامل الطماطم(انزميا) بمعاملات خاصة قبل عملية التجفيف لتقصير زمن التجفيف والمحافظة علي لون المادة المجففة لان تقصير زمن التجفيف أى تقليل الزمن التي تتعرض له المادة الغذائية للحرارة يصل بعملية التجفيف الي المثلي وكانت المعاملات أستخدام ملح بتركيز10% ثم تجارب آخرى بأستخدام ملح مع سكر وكان تركيزالسكر 25% وتجارب ملح مع كالسيوم لاكتيت بتركيز 2% ثم تجارب ملح مع سكر مع كالسيوم لاكتيت بنفس التركيزات السابقة و بعد عملية الإذابة باستخدام هزاز لمدة ساعتين وأجريت مجموعة من التجارب بدون معاملات للمقارنة أيجاد المحتوى الرطوبي كل فترة زمنية متساوية (3 ساعات) و ايجاد العلاقات البيانية للمحتوى الرطوبى للمادة الغذائية مع الزمن و أيجاد معدل التجفيف والمعادلات الرياضية باستخدام التحليل الإحصائي االانحدار البسيط والمتعدد الحدود والمركب .

أوضحت نتائج الدراسة مايلى :-

- أيجاد العلاقة الجدولية و البيانية بين زمن التجفيف والمحتوي الرطوبي للمادة المجففة للثلاث أنواع من الطماطم وللثلاث أحجام وجد ان عند نفس المعاملة ونفس الحجم للطماطم أي نفس الظروف للتجربة حدث انخفاض في زمن التجفيف بما يعادل 30% من وذلك عند المستوى الأعلى لدرجة الحرارة (65 ±1 °م) عن المستوى الأقل وهو(55 ± 1°م)
- وأوضحت النتائج زيادة ثابت التجفيف مع زيادة درجة الحرارة . والحصول علي معادلات رياضية تربط بين المتغيرات بعضها مع بعض وزيادة معدل التجفيف .
- وأوضحت النتائج المتحصل عليها أن زيادة النسبة بين المساحة السطحية للجزء وحجمه تعمل علي زيادة معدل التجفيف.

فكانت النسبة الأكبر للجزء الثمن(الاصغر) ثم يليه الربع والنصف وذلك موضح بالجدول داخل البحث.

- وأوضحت النتائج أن المعاملات المبدئية للمادة الغذائية قبل البدء في عملية التجفيف يقلل الزمن اللازم لإتمام عملية التجفيف مما له أهمية من الناحية الأقتصادية وتساعد علي الحصول علي منتج عالي الجودة .