EFFECT OF DRYING METHODS ON THE QUALITY OF DRIED TOMATOES
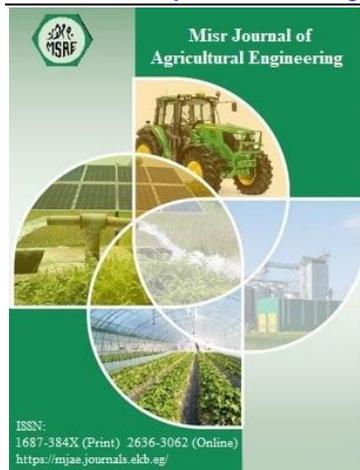
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Keywords:
Tomato, sun-drying, solar-drying, oven-drying, moisture content, drying rate

ABSTRACT

The aim of this study is to investigate the effect of different drying the fruits tomato under different drying systems (sun, solar and oven), different chemical treatments (Citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) on the quality of dried tomato fruits. The results indicate that the accumulated weight loss of fruit tomato for fruit treated by citric acid 2% lower than those the fruit without treatment. The accumulated weight loss of fruit tomato ranged from 2.00 to 94.73 % for all treatment. The highest values moisture content of fruits tomato were 870.08, 839.32, 819.15, 790.73 and 734.88 % d.b. for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm, respectively. The drying rate of fruits tomato ranged from 0.00 to 177.65, 0.00 to 71.03 and 0.001 to 163.36 $kg_{water}/kg_{dry\ base}.hr$ for sun drying, solar drying and oven drying systems. The highest value of drying rate of fruits tomato was 177.65 $kg_{water}/kg_{dry\ base}.hr$ was found for 7 mm fruit strips with citric acid 2% before drying for sun drying system. The sugar, ash and lycopene contents of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) belongs to family "Solanaceae" and is a worldwide important agricultural commodity. In terms of area, tomato is the second horticultural product cultivated and the first in industrialized volume**.** Tomato is a climacteric fruit, having a short shelf-life under ambient storage conditions (**Shahnawaz *et al.,* 2012**). The marketing of fresh tomato during the season is a great problem because of its short post-harvest life, which leads to high post-harvest losses (**Jayathunge *et al.,* 2012**). Short postharvest life and inadequate processing facilities result in heavy revenue loss. Therefore, it is advantageous to develop a preservation method for tomatoes. Tomatoes are processed in a range of products, such as concentrated juice and pulp, which needs high cost technology for good quality products. Therefore, development of low-cost processing methodologies to produce shelf-stable convenience products is the prime requirement of the present competitive

market. Drying is the most suitable method to fulfill the above requirements. Dried tomato products are used as important ingredients for pizza, various vegetables, spicy dishes, and the increasing interest in the antioxidant activity of lycopene as the most abundant carotenoid in tomatoes. Presence of lycopene promoted research activities on fresh tomatoes and tomato products (**Zanoni** *et al.,* **1999**). Drying is a form of preservation which is used in extending shelf life of produce, reducing risk of microbial spoilage due to reduction of water content to level where microbial growth no longer occurs. Drying tomatoes is a means of eliminating seasonal gluts and shortages, providing a technologically sound base for levelling out food surpluses and shortage within rural and urban area. Fresh tomatoes can be dried as halves, slices, quarters and powders. Once tomato is dried, it takes up a fraction of the space and can be used in all sorts of ways. It can be used in pizza toppings, snacks and other savory dishes (**Lewicki** *et al.,* **2002**). The quality of food can be seriously degraded if life is unprotected from rain, storm, windborne dirt, dust, and infestation by insects, rodents and other animals, so sometimes production becomes inedible. The drying process can be conducted by using several solar drying methods (**Sacilik** *et al.,* **2006 and Abd El-Haq** *et al.,* **2020**). Solar dryers can cost effectively because relatively unskilled village artisans can construct, operate and maintain the dryers at minimum cost and locally available materials can be used for the construction (**Mumba, 1995**). **Ekechukwu and Norton (1999)**, in reviewing the various designs of solar-energy drying systems, classified them with respect to their operating temperature ranges, heat supply modes and sources, operational modes and structural modes as well. Natural circulation and forced-convection solar dryers are the two main groups that were identified (**Vlachos** *et al.,* **2002**). The drying characteristics of tomato and their mathematical drying model are still being developed. Thin layer drying equations are used to estimate drying time of several products and also to generalize drying curves.

To keep the tomato quality, prolong shelf life and decrease losses, several methods of drying are required, therefore, the main aim of this work is to study the effect of drying methods, pre-treatments of fruit and shapes of fruit on the tomato quality and shelf life.

2. MATERIALS AND METHODS

The experiment was carried out at Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture Moshtohor, Benha University, Egypt (latitude 30° 21` N and 31° 13` E). During the period of June and July, 2018 season.

1.2. Materials:

The fresh tomato was brought from the Faculty of Agriculture Farm, Moshtohor, Benha University after harvesting for primary analysis.

1.2.1. Drying systems:

The tomato fruit were dried using different systems as follows:-
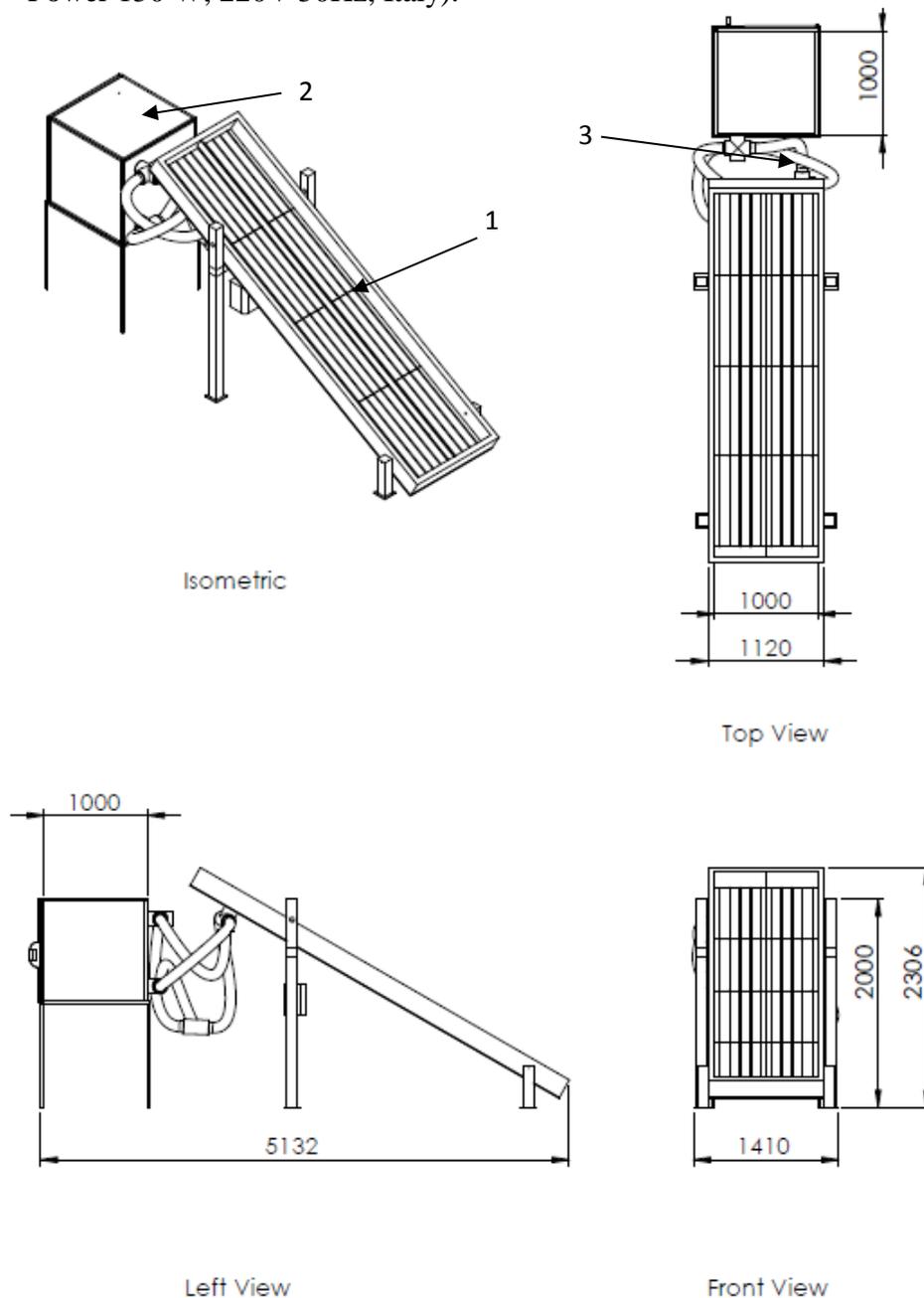
1. Sun-drying:

Tomato fruits were folded into a thin sheet of paper and placed on a flat plate in direct sunlight. Tray with a dimension of (0.8 m long, 0.6 m wide and 0.1 m high).

2. Solar drying:

Fig. (1) illustrates the hybrid-solar drying system description. It shows the system which consists of solar collector, drying chamber, trays and blower.

The solar collector consists of three major components, namely: The glass cover has dimensions of 4.0 m long, 1.0 m width and 5.5 mm thickness. The cover is fixed on a wooden frame with a thickness of 10 cm. It is divided into two lanes, 50 cm wide each. The absorber plate is made from corrugated black aluminum plate. It insulated with a thermal glass wool with a 5.0 cm thickness. The drying chamber has a length of 1.0 m, width of 0.75 m and height of 1.0 m. It is made of galvanized steel (5 mm thickness). The inner surface of drying chamber is covered an insulated materials to reduce heat loss from the walls. The trays are made of stainless steel and have a length of 0.90 m, width of 0.65 m and height of 0.25 m. They have perforated bottom which allows heated air to pass through products. Two air blowers were used to force and re-circulate the drying air to the drying chamber (Model C.C.P. Parma – Flow Rate 6.6 m^3 h^{-1} – RPM 2800 – Power 150 W, 220V 50Hz, Italy).

1: solar collector   2: drying chamber   3: blower
Fig. (1): Isometric, top, left and front view for the solar dryer.

The dryer uses a chamber burner system in which heat is being produced. The burner incorporates switches with a sparking mechanism that ignites the gas when it is fed from the gas bottle.

3. Oven-drying:

Fruits tomato were spread evenly on baking sheets and placed in conventional laboratory oven (Fisher Scientific Isotemp Oven, Model 655F Cat. No. 13-245-655, Fisher Scientific, Toronto, Ontario, Canada).

1.3. Methods:

1.3.1. Treatments:

In this study, tomatoes were cut into halves, quarters, and strips with 3, 5 and 7 mm thickness. Samples were divided into 2 parts, one of them treated with citric acid 2% before drying and the other part left without chemical treatment. Table (1) shows the experimental design for drying tomato.

Table (3.4): The experimental design.

Variables	Levels	Variables Levels
Drying system	3	Sun drying
		Solar drying
		Oven drying
Pre-treatment	2	Citric acid 2%
		Without chemical
Tomato fruit size	5	Half
		Quarter
		3 mm
		5 mm
		7 mm

1.3.2. Measurements:

The mass was measured by electric digital balance (Model HG – 5000 – Range 0 - 5000 g ± 0.01 g, Japan) daily for sun drying methods and hourly for solar and oven drying methods. Temperature and relative humidity were recorded by using a HOBO Data Logger (Model HOBO U12 Temp/RH/Light – Range -20 to 70 °C and 5 to 95% RH, USA) every hour. Total content of macro elements were evaluated after being digested according to **Chapman and Partt (1961)**. Nitrogen was determined by Kjeldahl digestion apparatus (**Bremmer and Mulvaney, 1982**). Potassium, Calcium and magnesium were determined by Photofatometer (Model Jenway PFP7 – Range 0 - 160 mmol L^{-1}, USA) and phosphorus (P) was determined colorimetrically following the **Murphy and Riley (1962)** method.

1.3.3. Calculations:

- Moisture content:

Moisture content of the fresh and dried fruit tomato was determined using conventional laboratory oven kept at 105 °C until constant weight was reached (**ASAE, 1998**). Triplicate determinations were made and the moisture content calculated as the following equation:

$$MC = \frac{M_{wet} - M_{dry}}{M_{dry}} \times 100 \tag{1}$$

Where:

MC is the moisture content, % dry base (d.b.)

M_{wet} is the wet mass of samples, g

M_{dry} is the dry mass of samples, g

- **Drying rate:**

The drying rate (DR) of fruit tomato was calculated using the following equation:

$$DR = \frac{M_{t+dt} - M_t}{dt} \tag{2}$$

Where:

DR is the drying rate, ($kg_{water}/kg_{dry\ base}$.hr)

M_t is the moisture content at any time t, % d.b.

M_{t+dt} is the moisture content at t+dt, % d.b.

3. RESULTS AND DISCUSSION

3.2. Weight loss:

3.2.1. Sun drying system:

Fig. (3) shows the accumulated weight loss of fruit tomato that dried under sun drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the accumulated weight loss of fruit tomato increases with increasing drying period. It could be seen that the accumulated weight loss of tomato increased from 31.58 to 86.71 and 29.57 to 85.96 %, when the drying period increased from 1 to 10 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It increased from 32.84 to 86.81 and 30.67 to 85.35 %, when the drying period increased from 1 to 7 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It increased from 33.36 to 86.29 and 31.18 to 83.98 %, when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It increased from 36.34 to 86.01 and 32.42 to 84.56 %, when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It increased from 37.33 to 84.96 and 32.62 to 82.84 %, when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips 3 mm size.

The results also indicate that the accumulated weight loss of fruit tomato for fruit treated by citric acid 2% before drying lower than those the fruit without treatment. It could be seen that the accumulated weight loss of fruit tomato was 86.71 and 85.96, 86.81 and 85.35, 86.29 and 83.98, 86.01 and 84.56 and 84.96 and 82.84 % for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively, at the average temperature of 35.5 ± 3.7°C and relative humidity of 57.5 ± 2.0 %.

Regression analysis was carried out to obtain a relationship between the accumulated weight loss of tomato fruit dried on sun drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit
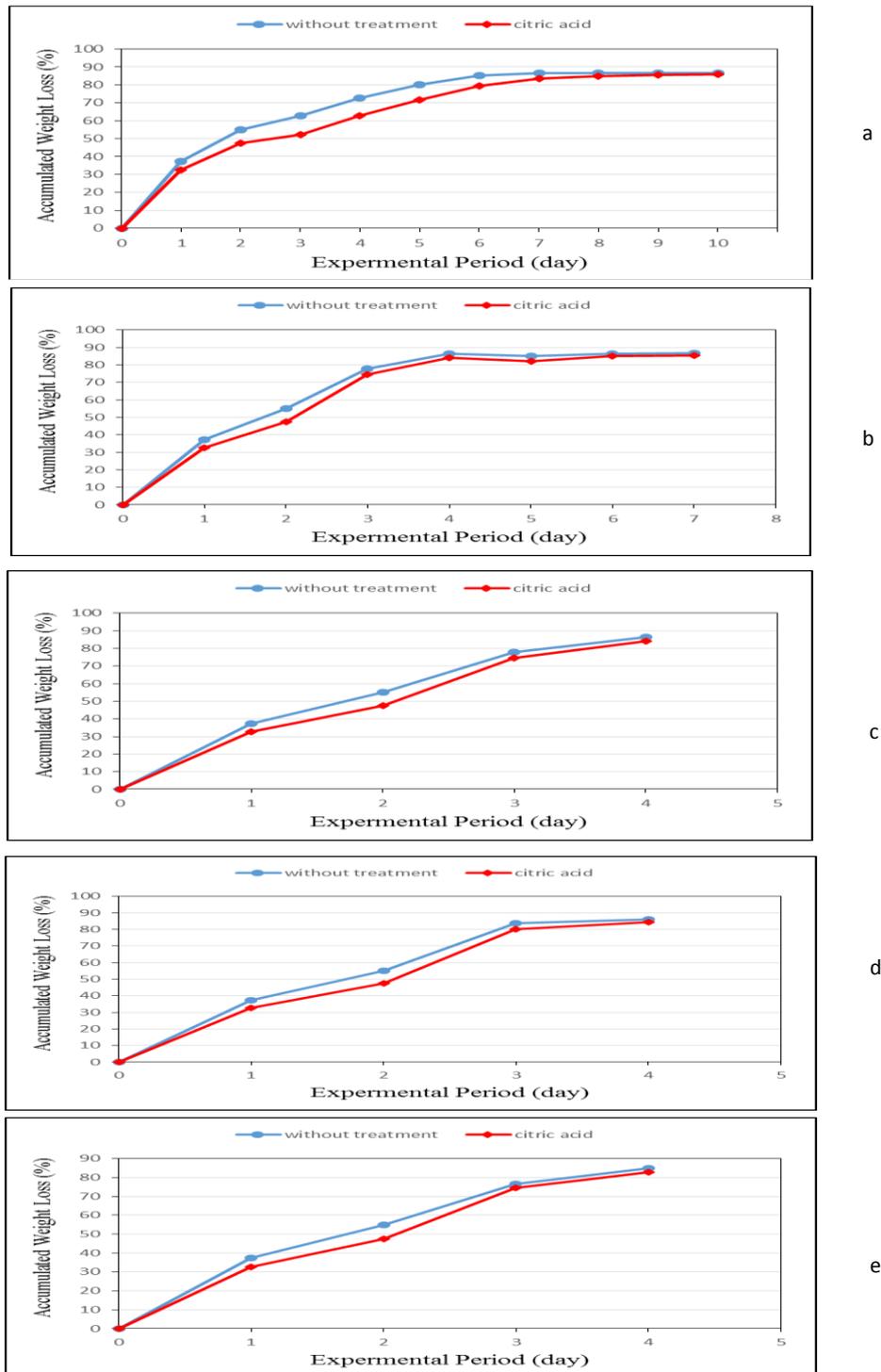
for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (2).

$$WL = a + b \ln t \qquad (4)$$

Where:

WL is the accumulated weight loss, %

t is the experimental period, day

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (3): The accumulated weight loss of fruit tomato at different sizes for sun drying system during experimental period.

Table (2): The constants a, b and coefficient of determination for accumulated weight loss at the different tomato fruit sizes and the different pre-treatment before drying.

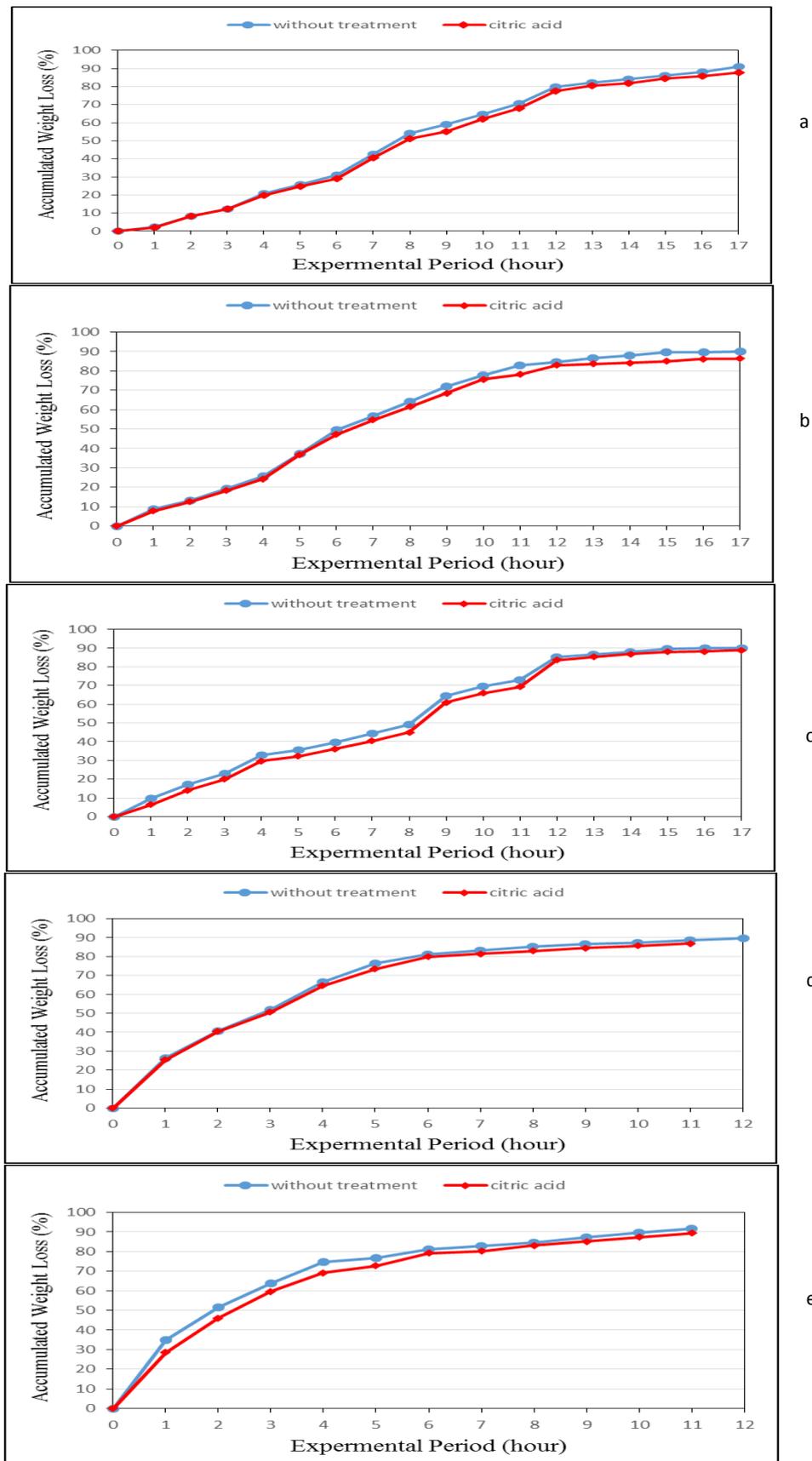| Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	A	b		a	b	
Half	-27.04	38.17	0.881	-26.44	36.98	0.876
Quarter	-20.36	38.54	0.926	-19.74	37.06	0.926
7 mm	-19.01	36.55	0.909	-21.74	36.59	0.891
5 mm	2.81	36.69	0.973	1.55	36.88	0.979
3 mm	9.14	35.49	0.964	5.18	35.95	0.979

3.2.2. Solar drying system:

Fig. (4) shows the accumulated weight loss of fruit tomato that dried under solar drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the accumulated weight loss of fruit tomato increases with increasing drying period. It could be seen that the accumulated weight loss of tomato increased from 2.24 to 91.15 and 2.00 to 87.62 %, when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It increased from 8.79 to 90.06 and 7.56 to 86.40 %, when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It increased from 9.89 to 90.08 and 6.39 to 88.83 %, when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It increased from 26.48 to 89.82 and 25.43 to 86.79 %, when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It increased from 34.79 to 91.69 and 28.45 to 89.44 %, when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the accumulated weight loss of fruit tomato for fruit treated by citric acid 2% before drying lower than those the fruit without treatment. It could be seen that the accumulated weight loss of fruit tomato was 91.15 and 87.62, 90.06 and 86.40, 90.08 and 88.83, 89.82 and 86.79 and 91.69 and 89.44 % for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively, at the average temperature of 51.0 ± 9.0°C and relative humidity of 40.0 ± 13.0 %.

Statistical analysis was carried out to obtain a relationship between the accumulated weight loss of tomato fruit dried on solar dryer as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (3).

$$WL = a + b \ln t \tag{5}$$

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (4): The accumulated weight loss of fruit tomato at different sizes for solar drying system during experimental period.

Table (3): The constants a, b and coefficient of determination for accumulated weight loss at the different tomato fruit sizes and the different pre-treatment before drying.
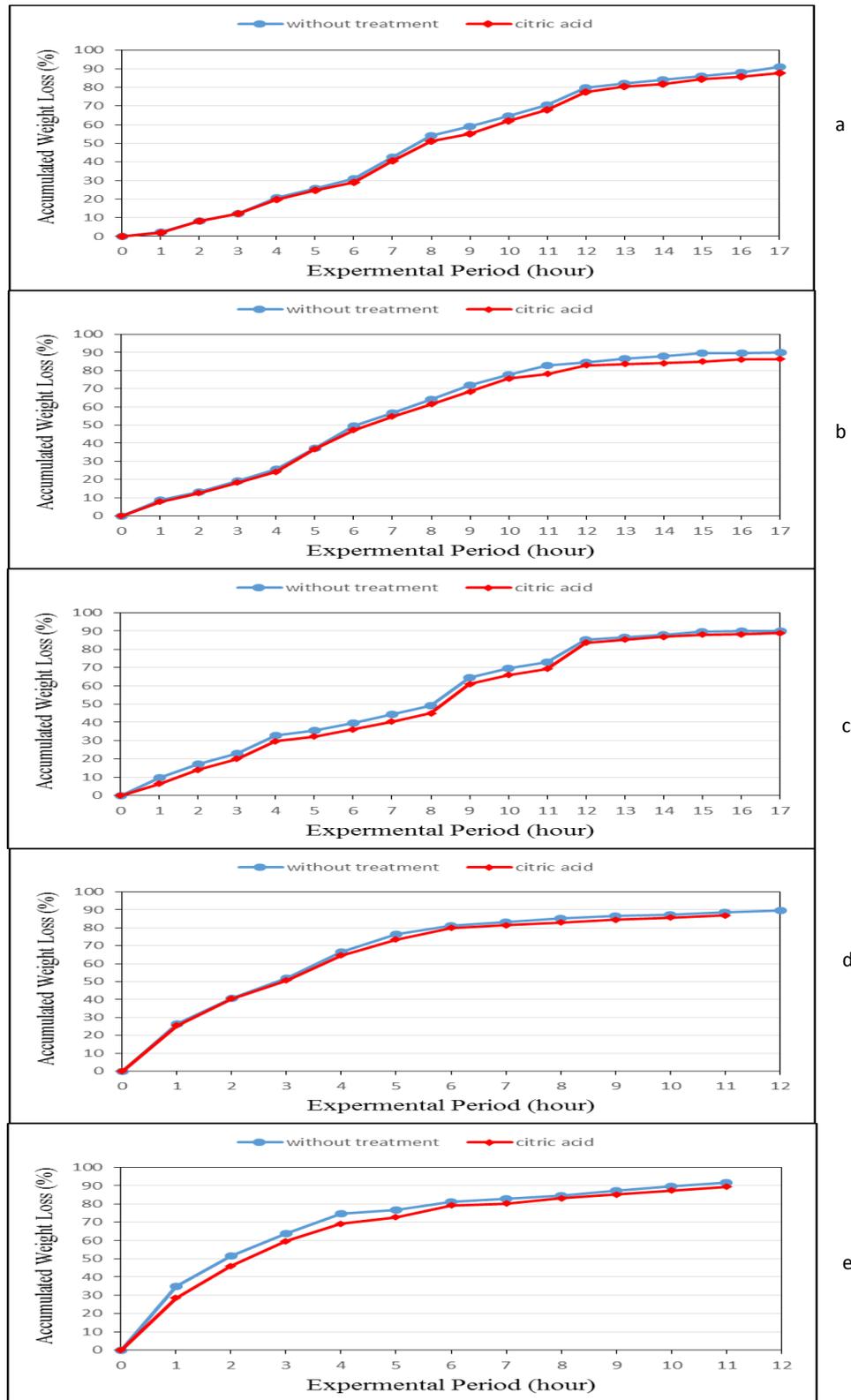
Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	A	b		a	b	
Half	7.76	37.04	0.955	3.26	37.00	0.986
Quarter	3.79	44.12	0.972	1.76	43.77	0.977
7 mm	-2.00	54.82	0.993	-3.04	52.72	0.979
5 mm	-1.20	55.78	0.982	-3.00	54.21	0.968
3 mm	-0.27	53.33	0.996	-2.31	51.99	0.981

3.2.3. Oven drying system:

Fig. (5) shows the accumulated weight loss of fruit tomato that dried under oven drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the accumulated weight loss of fruit tomato increases with increasing drying period. It could be seen that the accumulated weight loss of tomato increased from 12.57 to 94.79 and 11.01 to 93.40 %, when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It increased from 18.56 to 94.49 and 16.68 to 92.52 %, when the drying period increased from 1 to 8 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It increased from 54.09 to 93.45 and 46.20 to 90.41 %, when the drying period increased from 1 to 5 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It increased from 62.99 to 95.85 and 60.40 to 93.57 %, when the drying period increased from 1 to 4 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It increased from 83.32 to 94.73 and 80.37 to 91.65 %, when the drying period increased from 1 to 4 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the accumulated weight loss of fruit tomato for fruit treated by citric acid 2% before drying lower than those the fruit without treatment. It could be seen that the accumulated weight loss of fruit tomato was 94.79 and 93.40, 94.49 and 92.52, 93.45 and 90.41, 95.85 and 93.57 and 94.73 and 91.65 % for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively at temperature of 65°C.

The results also indicate that the shorter drying period (4 hours) was occurred under the oven drying system due to the higher temperature (65°C) and lower relative humidity (10 %). Meanwhile, the longer drying period (17 days) was occurred under the sun drying system due to the lower temperature (30.5 to 35.8°C) and higher relative humidity (51.92 to 61.44 %). The trend of these results agreed with those obtained by **Khater and Bahnasawy (2017)** and **Abd El-Haq et al. (2020)**.

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (5): The accumulated weight loss of fruit tomato at different sizes for oven drying system during experimental period.

Statistical analysis was carried out to obtain a relationship between the accumulated weight loss of tomato fruit dried on oven drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit

for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (4).

$$WL = a + b \ln t \qquad (6)$$

Table (4): The constants a, b and coefficient of determination for accumulated weight loss at the different tomato fruit sizes and the different pre-treatment before drying.

Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	a	b		a	b	
Half	-8.06	43.76	0.971	-8.15	43.40	0.969
Quarter	-5.00	50.56	0.966	-5.41	49.27	0.963
7 mm	7.11	60.94	0.937	4.16	57.94	0.967
5 mm	5.21	70.76	0.968	4.83	69.55	0.968
3 mm	17.74	57.52	0.896	17.11	55.81	0.898

3.3. Moisture content:

3.3.1. Sun drying system:

Fig. (6) shows the moisture content of fruit tomato that dried under sun drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the moisture content of fruit tomato decreases with increasing drying period for all drying systems. It could be seen that the moisture content of tomato decreased from 854.66 to 0.54 and 870.08 to 5.84 % d.b., when the drying period increased from 1 to 10 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It decreased from 735.31 to 0.81 and 754.54 to 0.88 % d.b., when the drying period increased from 1 to 7 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size.

The moisture content decreased from 701.22 to 3.34 and 718.32 to 7.74 % d.b., when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It decreased from 561.95 to 1.01 and 606.41 to 9.62 % d.b., when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It decreased from 551.34 to 0.64 and 567.41 to 0.54 % d.b., when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the moisture content of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the moisture content of fruit tomato was 854.66 and 870.08, 735.31 and 754.54, 701.22 and 718.32, 561.95 and 606.41 and 551.34 and 567.41 % d.b. for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively.
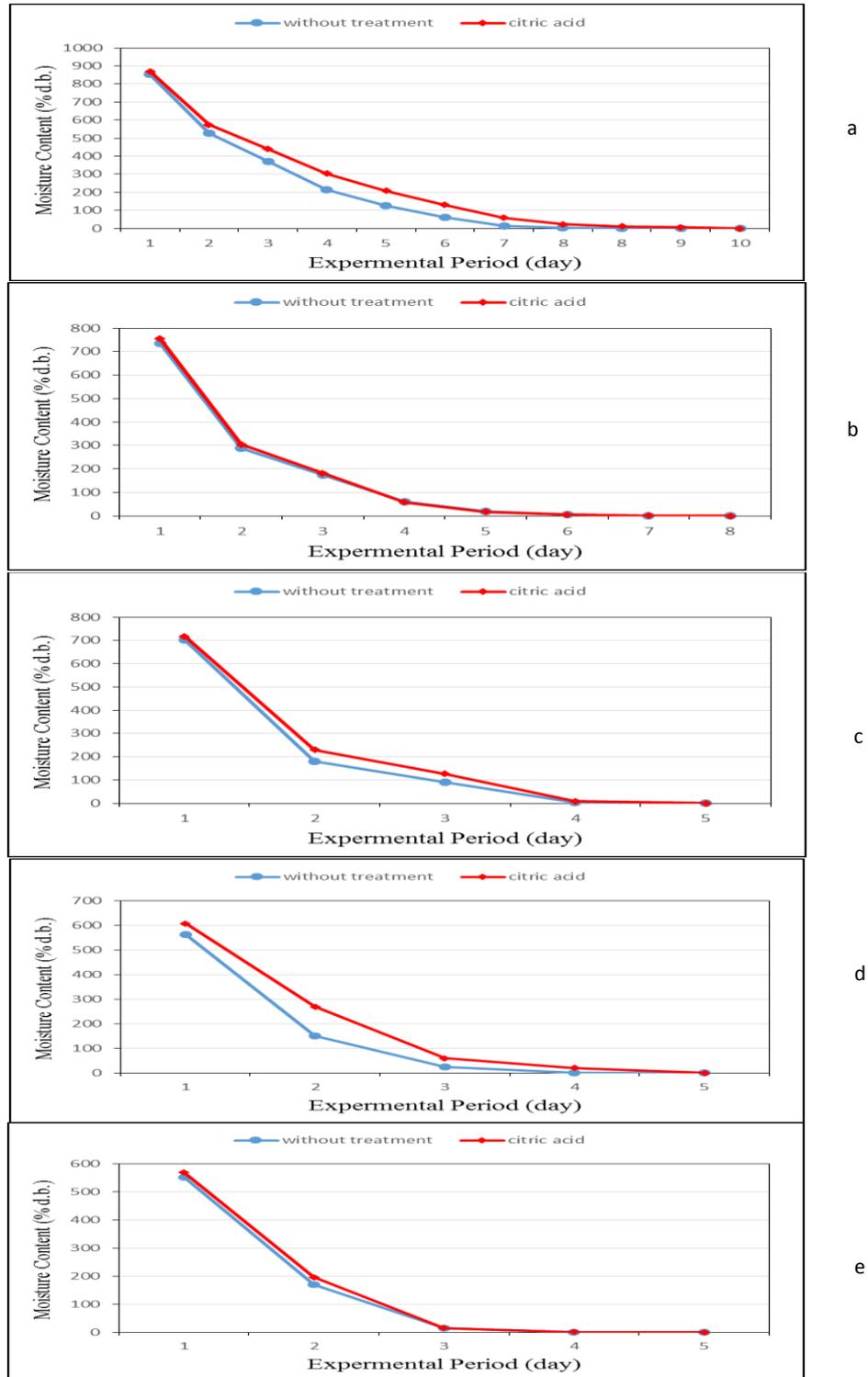
Statistical analysis was carried out to obtain a relationship between the moisture content of fruit tomato of tomato fruit dried on sun drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables.

The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (5).

$$MC = a + b \ln t \qquad (7)$$

Where:

MC is the moisture content. % d.b.

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (6): The moisture content of fruit tomato at different sizes for sun drying system during experimental period.

Table (5): The constants a, b and coefficient of determination for moisture content at the different tomato fruit sizes and the different pre-treatment before drying.

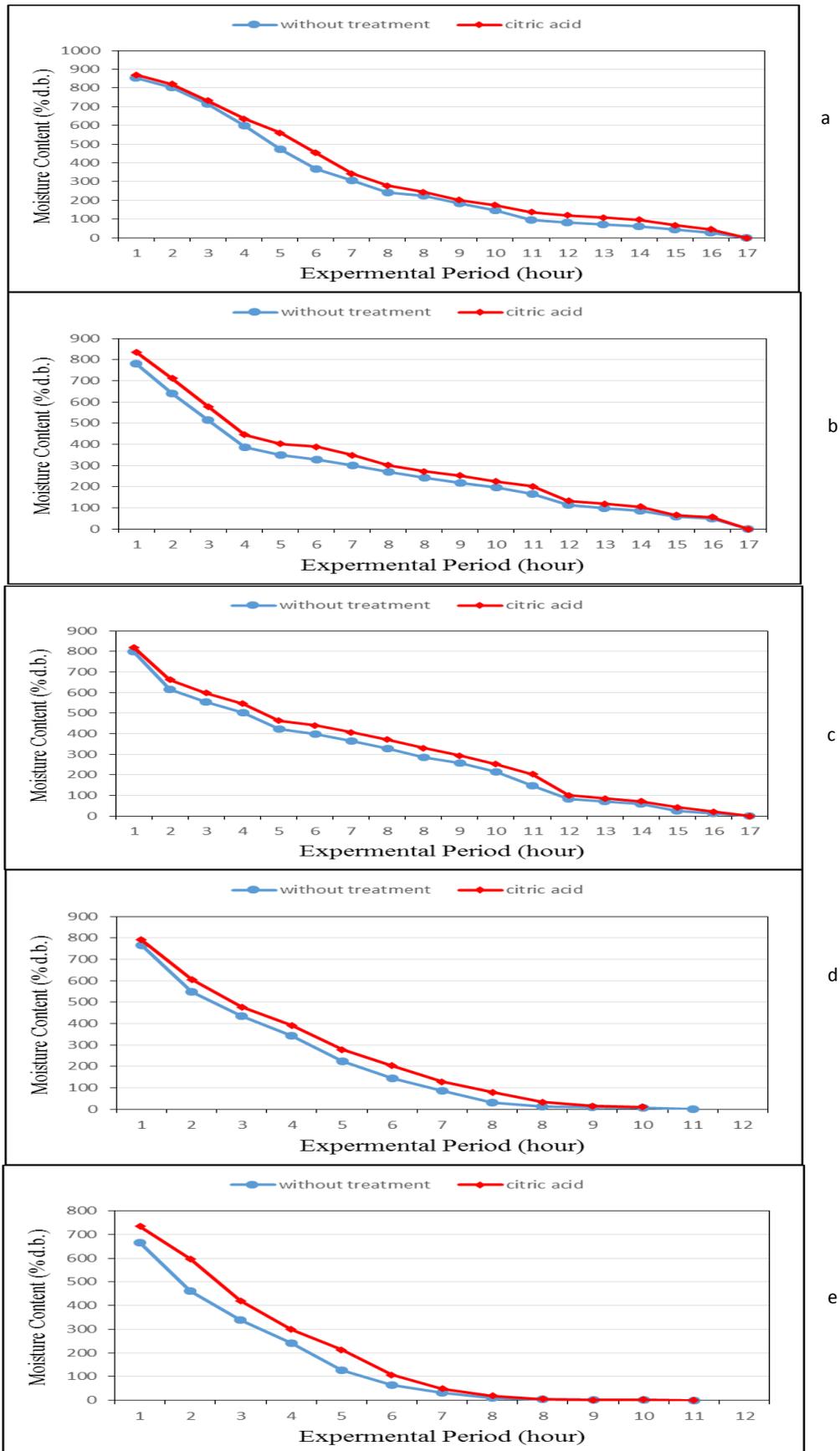| Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R²	Constants		R²
	A	B		a	b	
Half	799.33	-385.42	0.970	854.21	-391.75	0.992
Quarter	636.59	-371.91	0.920	656.40	-384.00	0.924
7 mm	643.36	-503.24	0.932	674.35	-508.48	0.959
5 mm	516.51	-418.29	0.935	589.60	-442.27	0.979
3 mm	514.23	-415.73	0.948	536.04	-429.63	0.958

3.3.2. Solar drying system:

Fig. (7) shows the moisture content of fruit tomato that dried under solar drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the moisture content of fruit tomato decreases with increasing drying period for all drying systems. It could be seen that the moisture content of tomato decreased from 853.55 to 26.79 and 869.96 to 45.44 % d.b., when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It decreased from 780.45 to 48.67 and 835.67 to 56.12 % d.b., when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It decreased from 799.19 to 13.08 and 918.15 to 21.09 % d.b., when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It decreased from 764.96 to 4.98 and 790.73 to 9.36 % d.b., when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It decreased from 664.24 to 1.35 and 734.88 to 1.62 % d.b., when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the moisture content of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the moisture content of fruit tomato was 853.55 and 869.96, 780.45 and 835.67, 799.19 and 819.15, 764.98 and 790.73 and 664.24 and 734.88 % d.b. for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively.

Statistical analysis was carried out to obtain a relationship between the moisture content of fruit tomato of tomato fruit dried on solar drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (6).

$$MC = a + b \ln t \tag{8}$$

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm
Fig. (7): The moisture content of fruit tomato at different sizes for sun drying
system during experimental period.

Table (6): The constants a, b and coefficient of determination for moisture content at the different tomato fruit sizes and the different pre-treatment before drying.

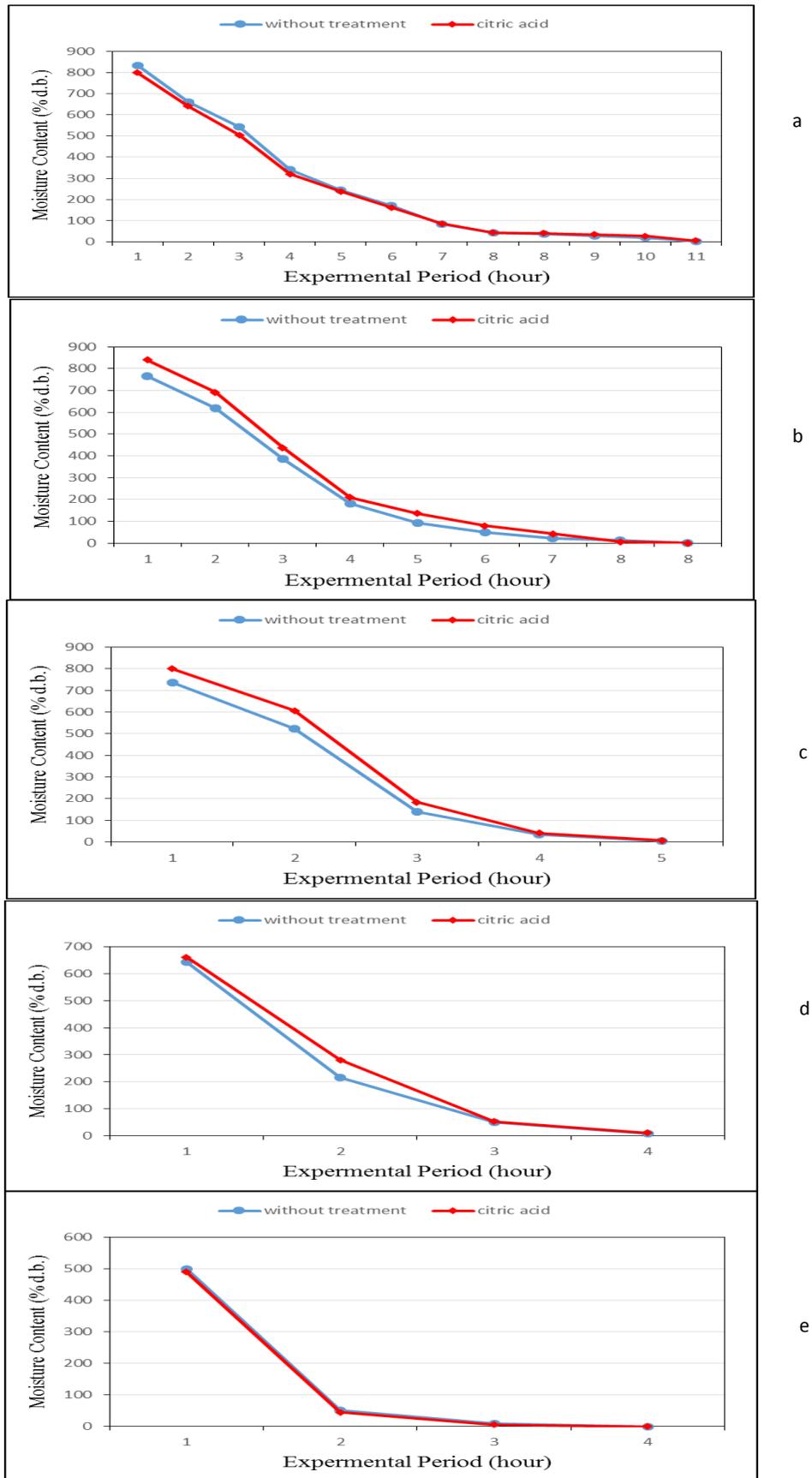| Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	a	b		a	B	
Half	987.58	-343.22	0.963	1019.42	-341.95	0.956
Quarter	790.21	-257.99	0.990	870.23	-279.46	0.988
7 mm	856.56	-281.34	0.962	902.24	-287.51	0.944
5 mm	770.82	-332.70	0.983	831.89	-351.00	0.989
3 mm	650.13	-297.55	0.974	771.13	-344.94	0.976

3.3.3. Oven drying system:

Fig. (8) shows the moisture content of fruit tomato that dried under oven drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the moisture content of fruit tomato decreases with increasing drying period for all drying systems. It could be seen that the moisture content of tomato decreased from 834.43 to 1.77 and 798.62 to 5.51 % d.b., when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It decreased from 765.32 to 12.51 and 839.32 to 6.15 % d.b., when the drying period increased from 1 to 8 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It decreased from 735.90 to 4.42 and 800.02 to 7.33 % d.b., when the drying period increased from 1 to 4 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It decreased from 643.22 to 8.55 and 661.44 to 11.50 % d.b., when the drying period increased from 1 to 4 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It decreased from 498.47 to 8.39 and 489.99 to 5.48 % d.b., when the drying period increased from 1 to 3 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size. These results were in agreement with those obtained by **Khater *et al.* (2019)**.

The results also indicate that the moisture content of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the moisture content of fruit tomato was 834.43 and 798.62, 765.32 and 839.32, 735.90 and 800.02, 643.22 and 661.44 and 498.47 and 489.99 % d.b. for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively.

Statistical analysis was carried out to obtain a relationship between the moisture content of fruit tomato of tomato fruit dried on oven drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (7).

$$MC = a + b \ln t \tag{9}$$

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (8): The moisture content of fruit tomato at different sizes for sun drying system during experimental period.

Table (7): The constants a, b and coefficient of determination for moisture content at the different tomato fruit sizes and the different pre-treatment before drying.

Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	A	b		a	b	
Half	869.51	-371.31	0.973	827.37	-352.94	0.973
Quarter	805.19	-407.34	0.963	890.56	-441.88	0.967
7 mm	765.17	-498.70	0.951	848.53	-543.53	0.942
5 mm	605.15	-472.80	0.961	640.87	-489.81	0.978
3 mm	465.30	-467.53	0.916	546.52	-462.66	0.913

3.4. Drying rate:
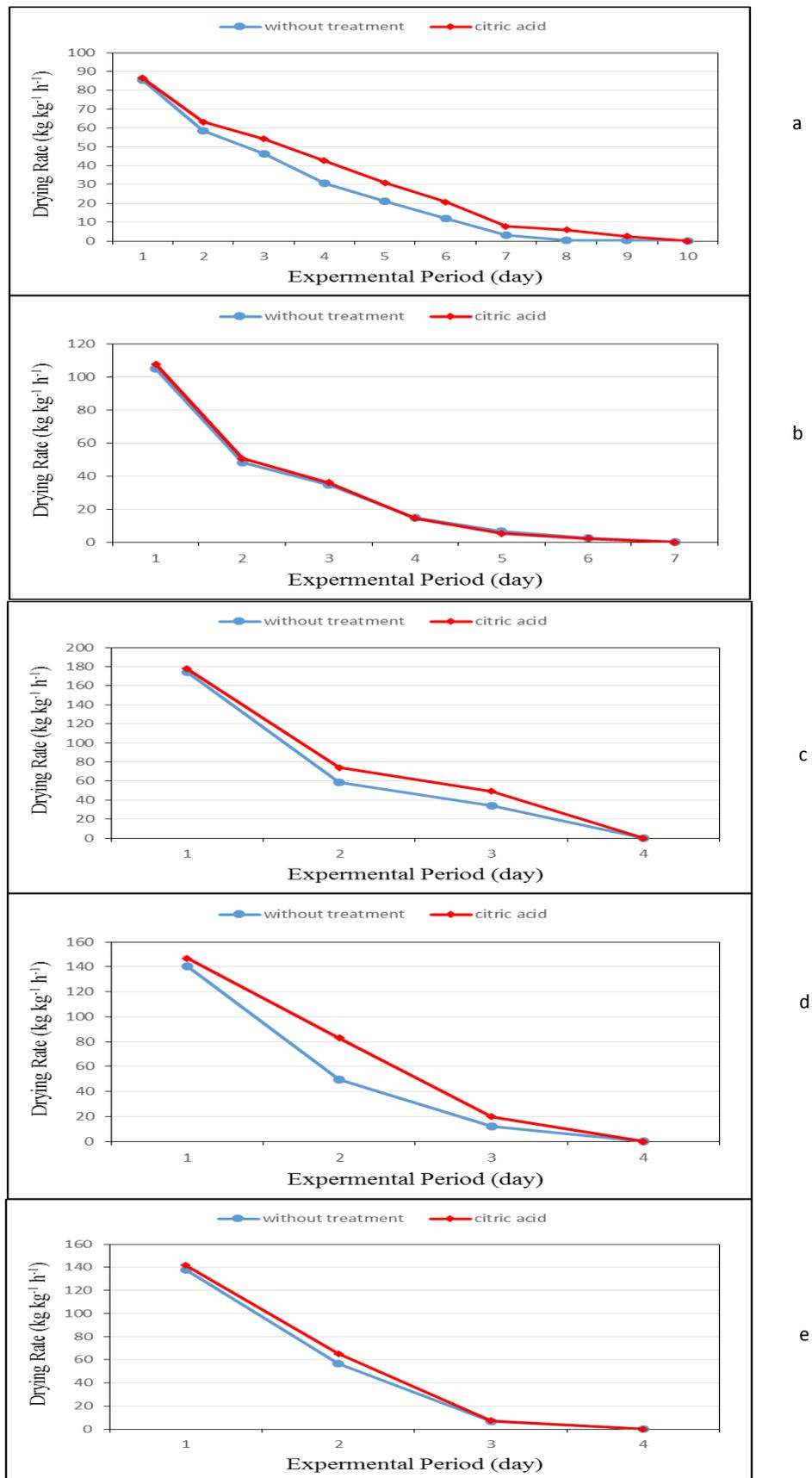
3.4.1. Sun drying system:

Fig. (9) shows the drying rate of fruit tomato that dried under sun drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the drying rate of fruit tomato decreases with increasing drying period for all drying systems. It could be seen that the drying rate of tomato decreased from 85.41 to 0.001 and 86.42 to 0.001 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 10 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It decreased from 104.93 to 0.001 and 107.67 to 0.001 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 7 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It decreased from 174.47 to 0.002 and 177.65 to 0.004 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size.

The drying rate decreased from 140.23 to 0.00 and 146.70 to 0.003 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It decreased from 137.67 to 0.002 and 141.72 to 0.004 $kg_{water}/kg_{dry\ base}$.hr., when the drying period increased from 1 to 4 days for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the drying rate of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the drying rate of fruit tomato was 85.41 and 86.42, 104.93 and 107.67, 174.47 and 177.65, 140.23 and 146.70 and 137.67 and 141.72 $kg_{water}/kg_{dry\ base}$.hr for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively.

Statistical analysis was carried out to obtain a relationship between the drying rate of fruit tomato of tomato fruit dried on sun drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (8).

$$DR = a + b \ln t \qquad (10)$$

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (9): The drying rate of fruit tomato at different sizes for sun drying system during experimental period.

Table (8): The constants a, b and coefficient of determination for drying rate at the different tomato fruit sizes and the different pre-treatment before drying.

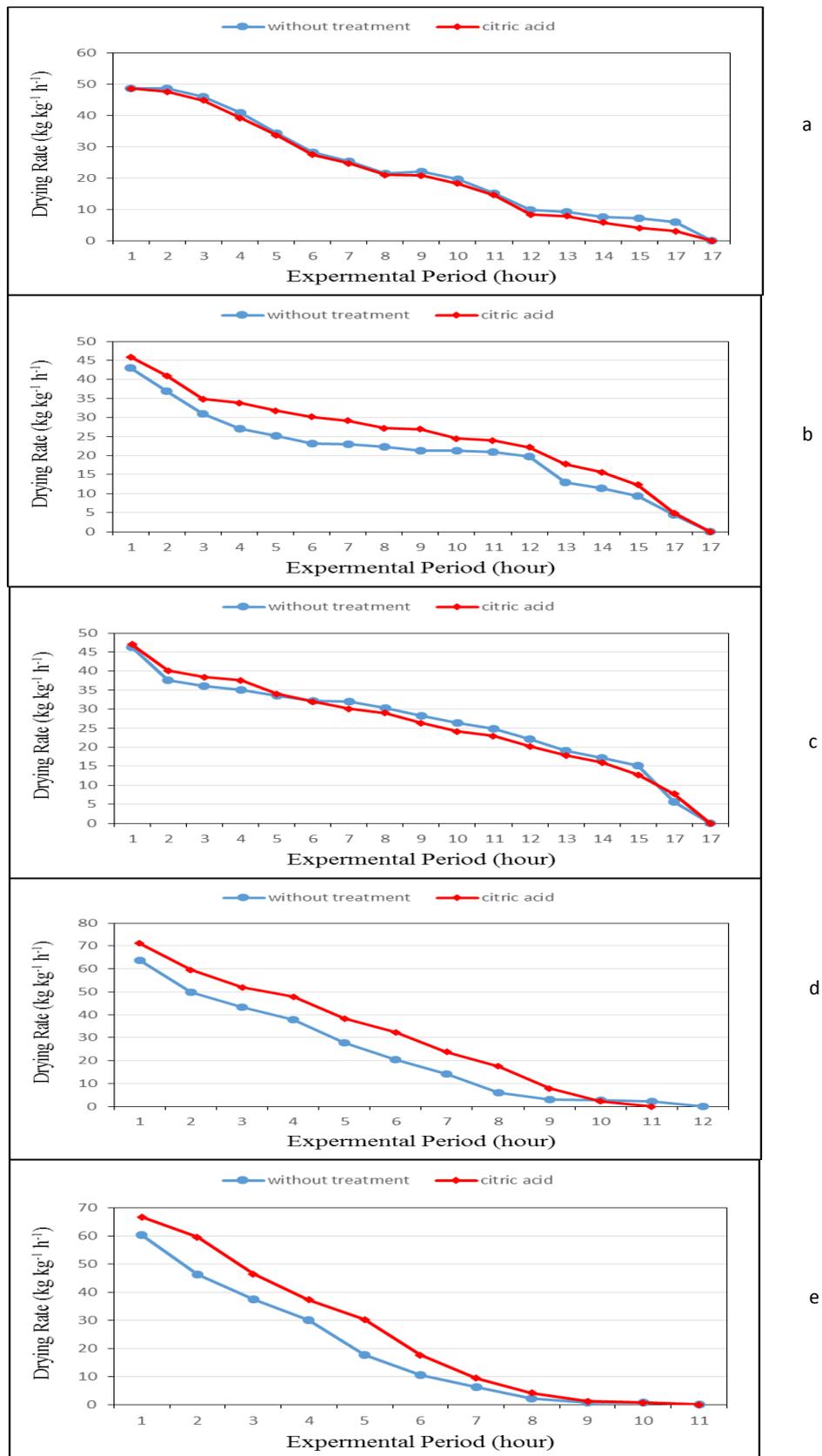| Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	a	b		a	b	
Half	85.89	-39.79	0.988	91.54	-39.82	0.978
Quarter	95.47	-53.61	0.961	98.52	-55.55	0.962
7 mm	165.06	-123.81	0.966	173.19	-123.30	0.979
5 mm	133.04	-104.00	0.971	149.48	-109.72	0.986
3 mm	133.06	-104.36	0.974	139.25	-107.95	0.977

3.4.2. Solar drying system:

Fig. (10) shows the drying rate of fruit tomato that dried under solar drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the drying rate of fruit tomato decreases with increasing drying period for all drying systems. It could be seen that the drying rate of tomato decreased from 48.63 to 0.00 and 48.70 to 0.001 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It decreased from 43.05 to 0.002 and 45.86 to 0.004 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It decreased from 46.24 to 0.002 and 46.94 to 0.00 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 17 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It decreased from 63.71 to 2.25 and 71.03 to 0.001 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It decreased from 60.10 to 0.002 and 66.66 to 0.004 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the drying rate of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the drying rate of fruit tomato was 4863 and 48.70, 43.05 and 45.86, 46.24 and 46.94, 63.71 and 71.03 and 60.10 and 66.66 $kg_{water}/kg_{dry\ base}$.hr for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively.

Statistical analysis was carried out to obtain a relationship between the drying rate of fruit tomato of tomato fruit dried on solar drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (9).

$$DR = a + b \ln t \tag{11}$$

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (10): The drying rate of fruit tomato at different sizes for sun drying system during experimental period.

Table (9): The constants a, b and coefficient of determination for drying rate at the different tomato fruit sizes and the different pre-treatment before drying.

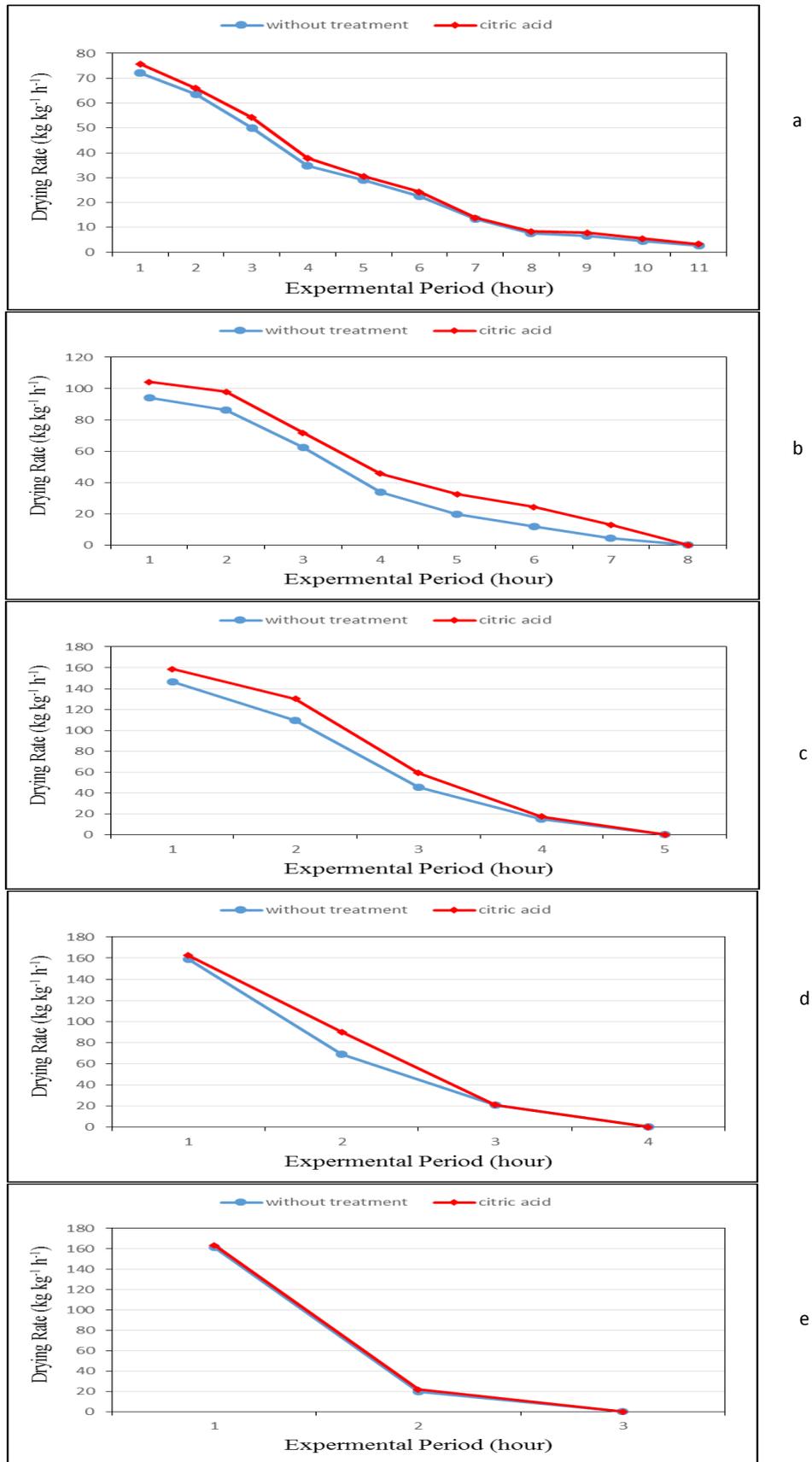| Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	a	b		a	b	
Half	60.67	-19.15	0.914	60.31	-19.59	0.920
Quarter	45.99	-12.81	0.867	51.58	013.59	0.813
7 mm	51.45	-12.93	0.798	53.62	-14.21	0.835
5 mm	69.59	-28.19	0.966	81.11	-30.85	0.922
3 mm	63.75	-27.98	0.975	76.21	-32.31	0.953

3.4.3. Oven drying system:

Fig. (11) shows the drying rate of fruit tomato that dried under oven drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) during experimental period. The results indicate that the drying rate of fruit tomato decreases with increasing drying period for all drying systems. It could be seen that the drying rate of tomato decreased from 72.10 to 2.80 and 75.70 to 3.25 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 11 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for half fruit tomato size. It decreased from 94.10 to 0.002 and 104.15 to 0.004 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 8 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for quarter fruit tomato size. It decreased from 146.30 to 0.003 and 158.54 to 0.003 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 4 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 7 mm size. It decreased from 158.70 to 0.001 and 162.48 to 0.002 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 4 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 5 mm size. It decreased from 161.50 to 0.002 and 163.36 to 0.004 $kg_{water}/kg_{dry\ base}$.hr, when the drying period increased from 1 to 3 hours for the tomato treated with citric acid 2% before drying and without treatment, respectively, for fruit strips of 3 mm size.

The results also indicate that the drying rate of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the drying rate of fruit tomato was 72.10 and 75.70, 94.10 and 104.15, 146.30 and 158.54, 158.70 and 162.48 and 161.50 and 163.36 $kg_{water}/kg_{dry\ base}$.hr for the untreated tomatoes and for the treated with citric acid 2% for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively.

Statistical analysis was carried out to obtain a relationship between the drying rate of fruit tomato of tomato fruit dried on oven drying system as dependent variable and different pre-treatment before drying, tomato fruit sizes and experimental period as independent variables. The best fit for this relationship is presented in the following equation. The constants of these equations and coefficient of determination are listed in table (10).

$$DR = a + b \ln t \qquad (12)$$

a: half fruit, b: quarter fruit, c: strips 7 mm, d: strips 5 mm e: strips 3 mm

Fig. (11): The drying rate of fruit tomato at different sizes for sun drying system during experimental period.

Table (10): The constants a, b and coefficient of determination for drying rate at the different tomato fruit sizes and the different pre-treatment before drying.

Tomato fruit size	Without treatment			Citric acid 2% treatment		
	Constants		R^2	Constants		R^2
	a	b		a	b	
Half	79.62	-32.53	0.972	83.72	-33.93	0.969
Quarter	107.03	-51.29	0.941	119.41	-53.39	0.936
7 mm	155.91	-96.81	0.962	174.00	-105.51	0.937
5 mm	155.04	-116.94	0.992	164.97	-121.69	0.987
3 mm	154.24	-154.87	0.939	151.72	-153.16	0.933

3.5. Sugar, ash and lycopene contents:

Table (11) shows sugar, ash and lycopene contents of fruit tomato that dried under oven drying system at different chemical treatments (citric acid 2% and without treatment) and different fruit tomato sizes (half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm) at the end of experimental period. The results indicate that the sugar, ash and lycopene contents of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment. It could be seen that the sugar content ranged from 2.07 to 2.42 and 2.27 to 2.74 % for the untreated tomatoes and for the treated with citric acid 2%, respectively, for all treatment size. The ash content ranged from 2.33 to 2.68 and 2.34 to 2.74 %, respectively, for the untreated tomatoes and for the treated with citric acid 2% for all treatment size and the lycopene content ranged from 3.21 to 3.80 and 3.36 to 3.99 mg/100 g, respectively, for the untreated tomatoes and for the treated with citric acid 2% for all treatment size. The results also indicate that the sugar, ash and lycopene contents of fruit tomato for fruit dried in solar drying system higher than those the fruits dried in sun and oven drying systems.

Table (11) shows sugar, ash and lycopene contents of dried tomato.

Tomato size	Chemical treatment	Sugar, %			Ash, %			Lycopene, mg/ 100g		
		Sun	Solar	Oven	Sun	Solar	Oven	Sun	Solar	Oven
Half	W	2.34	2.41	2.09	2.61	2.60	2.35	3.63	3.78	3.21
	C	2.57	2.72	2.28	2.65	2.67	2.34	3.89	3.97	3.36
Quarter	W	2.31	2.29	2.09	2.62	2.67	2.34	3.62	3.75	3.28
	C	2.50	2.67	2.27	2.62	2.74	2.35	3.77	3.99	3.36
7 mm	W	2.35	2.40	2.07	2.59	2.68	2.35	3.59	3.78	3.30
	C	2.51	2.73	2.29	2.64	2.65	2.35	3.85	3.95	3.37
5 mm	W	2.36	2.42	2.11	2.60	2.61	2.39	3.63	3.80	3.30
	C	2.58	2.74	2.28	2.66	2.73	2.41	3.91	3.99	3.37
3 mm	W	2.36	2.40	2.10	2.62	2.65	2.33	3.62	3.79	3.31
	C	2.57	2.72	2.31	2.67	2.74	2.42	3.89	3.98	3.36

W is the untreated tomatoes   C is the fruit treated by citric acid 2% before drying

4. CONCLUSION

Tomatoes were treated before drying, cut into different size, dried successively three systems of drying (sun, solar and oven drying). Weight loss, moisture content and drying rate were evaluated during the drying period. It is concluded that the accumulated weight loss of fruit tomato for fruit treated with citric acid 2% before drying was lower than those the fruit without

treatment. The accumulated weight loss of fruit tomato ranged from 2.00 to 94.73 % for all treatment. The highest values moisture content of fruits tomato were 870.08, 839.32, 819.15, 790.73 and 734.88 % d.b. for half fruit, quarter fruit, fruit strips of 7 mm, fruit strips of 5 mm and fruit strips of 3 mm sizes, respectively. The drying rate of fruits tomato ranged from 0.00 to 177.65, 0.00 to 71.03 and 0.001 to 163.36 $kg_{water}/kg_{dry\ base}$.hr for sun drying, solar drying and oven drying systems. The highest value of drying rate of fruits tomato was 177.65 $kg_{water}/kg_{dry\ base}$.hr was found for 7 mm fruit strips with citric acid 2% before drying for sun drying system. The sugar, ash and lycopene contents of fruit tomato for fruit treated by citric acid 2% before drying higher than those the fruit without treatment.

5. <u>REFERENCES</u>

Abd El-Haq O.M., Khater E.G., Bahnasawy A.H. and El-Ghobashy H.M.T. (2020). Effect of Distillation Methods on Essential Oil Yield and Composition of Basil Dried by Different Drying Systems. Annals of Agric. Sci., Moshtohor, 52 (2): 247-260.

Abd El-Haq O.M., Khater E.G., Bahnasawy A.H. and El-Ghobashy H.M.T. (2020). Effect of Drying Systems on the Parameters and Quality of Dried Basil. Annals of Agric. Sci., Moshtohor, 52 (2): 261-272.

ASAE Standards (1998). ASAE S353 DEC97. Moisture measurement-meat and products. Adopted and published by ASAE 1998, St. Josebh, MI: ASAE. 45th Edition P552.

Bremmer, J. M. and Mulvaney C.S. (1982). Nitrogen-total. In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, second ed., Agronomy series No. 9 ASA, SSSA, Madison, WI, pp. 595–624.

Chapman, H.D. and Partt F.P. (1961). Methods of Analysis of Soils, Plant and Water. California University, pp. 150–200.

Ekechukwu, O.V., and Norton B. (1999). Review of solar-energy drying systems II: an overview of solar drying technology. *Energy Conversion and Management,* 40(6): 615-655.

Jayathunge, K.G., Kapilarathne R.A., Thilakarathne B.M., Fernando M.D., Palipane K.B. and Prasanna P.H. (2012). Development of a methodology for production of dehydrated tomato powder and study the acceptability of the product. Journal of Agricultural Technology, 8(2): 765-773.

Khater, E.G., Bahnasawy A.H. (2017). Basil Drying Performance and Quality under Different Drying Systems. 2nd International Sino-Egyptian Congress on Agriculture, Veterinary Sciences and Engineering (2nd ISEC-AVE), 7 – 10 October, 2017, Egypt.

Khater, E.G., Bahnasawy A.H., Hamouda R.M. (2019). Dehydration of chamomile flowers under different drying conditions. Journal of Food Processing and Technology, 10 (7), 1-7.

Liwicki, P.P., Vule H., Pmaranska-Lazuka E. (2002). Effect of pre-treatment on convective drying of tomatoes. Journal of food Engineering, 54, 141 – 146.
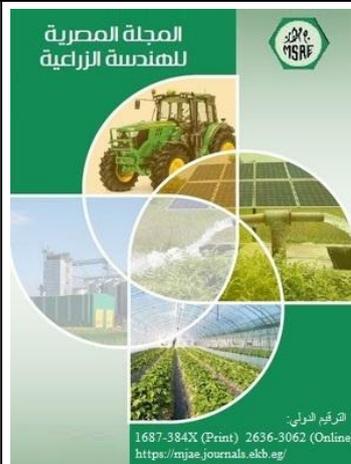
Mumba, J. (1995). Development of a photovoltaic powered forced circulation grain dryer for use in the tropics. *Renewable Energy,* 6(7): 855-862.

Murphy, J. and Riley J.P. (1962). A modified single solution method for determination of phosphate in natural waters. Anal. Chem. Acta, 27: 31–36.

Sacilik, K., Keskin R., and Elicin A.K. (2006). Mathematical modelling of solar tunnel drying of thin layer organic tomato. *Journal of Food Engineering,* 73(3): 231-238.

Shahnawaz, M., Sheikh S.A., Soomro A.H., Panhwar A.A., and Khaskheli S.G. (2012). Quality characteristics of tomatoes (*Lycopersicon esculentum*) stored in various wrapping materials, African Journal of Food Science and Technology, 3(5): 123-128.

Vlachos, N.A., Karapantsios T.D., Balouktsis A.I., and Chassapis D. (2002). Design and testing of a new solar tray dryer. *Drying Technology,* 20(6): 1243-1271.

Zanoni, B., Peri C., Nani R. and Lavelli V. (1999). Oxidative heat damage of tomato halves as affected by drying. Food Research International, 31(5):395–401.

تأثير طرق التجفيف على جودة الطماطم المجففة

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الملخص العربي

يهدف هذا البحث الى دراسة تأثير نظم تجفيف مختلفة (شمسي طبيعي – شمسي – فرن) ومعاملات كيميائية قبل التجفيف (حمض الستريك ٢% ـ بدون معاملة) وخمس مقاسات مختلفة (نصف ثمرة – ربع ثمرة – ٧ مم سمك – ٥ مم سمك – ٣ مم سمك) على جودة ثمار الطماطم المجففة. وتم إجراء هذه التجربة فى قسم هندسة النظم الزراعية والحيوية بمشتهر – كلية الزراعة بمشتهر – جامعة بنها – محافظة القليوبية. وتم تقدير كلا من الفاقد فى الوزن والمحتوى الرطوبى ومعدل التجفيف. وكانت أهم النتائج المتحصل عليها كما يلي: كان الفاقد التراكمي فى الوزن لثمار الطماطم المعاملة بحمض الستريك قبل التجفيف اقل من الفاقد التراكمي فى الوزن لثمار الطماطم الغير معاملة. تراوح الفاقد فى الوزن التراكمي لثمار الطماطم المجففة من ٢٫٠٠ الى ٩٤٫٧٣ % لجميع المعاملات. كانت اعلى قيمة للمحتوى الرطوبى لثمار الطماطم المجففة هي ٨٧٠٫٠٨ و ٨٣٩٫٣٢ و ٨١٩٫١٥ و ٧٩٠٫٧٣ و ٧٣٤٫٨٨ % على اساس الوزن الجاف لكل من نصف الثمرة وربع الثمرة و٧مم سمك و٥ مم سمك و٣ مم سمك على الترتيب. تراوح معدل التجفيف لثمار الطماطم المجففة ما بين ٠٫٠٠ إلى ١٧٧٫٦٥ ومن ٠٫٠٠ إلى ٧١٫٠٣ ومن ٠٫٠٠١ إلى ١٦٣٫٣٦ كجم / كجم. ساعة لكل من نظام التجفيف الشمسي الطبيعي ونظام التجفيف الشمسي والتجفيف فى الفرن على الترتيب. كانت اعلى قيمة لمعدل التجفيف لثمار الطماطم المجففة هي ١٧٧٫٦٥ كجم / كجم. ساعة مع ٧ مم سمك شرائح ثمار الطماطم المعاملة بحمض الستريك ٢% قبل التجفيف والمجفف فى نظام التجفيف الشمسي الطبيعي. كان محتوى الطماطم المجففة من السكر والرماد والليكوبين اعلى فى ثمار الطماطم التي تم معاملاتها بحمض الستريك ٢% قبل التجفيف من الثمار الغير معاملة.