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Bio-Engineering Studies for Tomato Pomace Powder Production as a Nutritional Valuable Material

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ABSTRACT

Processing tomatoes into industrial products leave behind large amounts of by-products. These by-products of tomato processing are attractive sources of high nutritional valuable components. Accordingly, the current research work aims to produce tomato pomace powder as a nutritional valuable material. Tomatoes were juiced, and the remaining pomace were further dried by various drying methods i.e., mechanical dryer at different air temperatures and velocities (60, 80 and 100 °C at 1, 1.5 and 2 m/s), oven drying (60, 80 and 100 °C) and microwave drying at different powers (200, 400, 600 and 800 W). The obtained results showed that the moisture content of the by-product decreases with growing temperature, velocity and microwave power. Dried tomato pomace samples were evaluated for quality attributes, viz. microbial activity, color, and chemical compounds (moisture content, dry matter, Ash, carbohydrate, protein, fat and total carotenoids). Drying process caused a considerable decrement in total microbial counts of tomato pomace samples (the best value was 1.9×10^3 $cfu.ml^{-1}$) at mechanical dryer (100 °C and 2 m/s). In conclusion, using the mechanical drying method at 100 °C achieved the best results of minimum value of microbial load, minimum change in color parameters and higher total carotenoids for dried samples although the drying time is greater than the microwave method. Hence, these drying methods were applied to optimize the drying conditions in order to valorization by-products of tomatoes. Therefore, the authors recommended using a large scale of mechanical dryer for tomato pomace drying at the optimum operational condition mentioned above.
Keywords: tomato by-product, drying methods, total carotenoids, color analysis, microbial analysis, chemical compounds.

INTRODUCTION

Tomato (Lycopersicum esculentum) is an important vegetable crop worldwide, comes in second after potatoes in economic importance and consumption. Egypt is the fifth largest producer of tomato crop in the world, produced over than 9 million tons of tomatoes annually (FAOSTAT 2015). In recent decades, the consumption of tomatoes has been associated with the prevention of several chronic diseases (Borguini and Da Silva Torres 2009; Omoni and Aluko 2005; Sharoni and Levi 2006). As a result, World Health Organization (WHO) and worldwide health authorities promote a high consumption and variety of fruit and vegetables. The majority of tomatoes are processed into food products such as tomato juice, ketchup, soup, paste, puree and canned tomato (Pinela *et al*., 2012). King and Zeidler, 2004 mentioned that, when tomatoes are processed into products like catsup, salsa and sauces, 10–30% of their mass becomes waste or pomace. The production of industrial tomato products leftover large quantities of tomato by-products such as peels, some pulp and seeds which causing serious environmental pollution as well as acting as a substrate for insect and microbial proliferation as mentioned by Papaioannou and Karabelas 2012; Savatović *et al*., 2010; Vega-Gálvez *et al*., 2010. These by-products called pomace, termed pomace, known as the solid material that remains after removing the juice from the pulp and consist of insoluble carbohydrates, protein and minerals. The wet tomato pomace contains about 33% seed, 27% skin and 40% pulp, while the dried pomace contains 44% seed and 56% pulp plus skin (Sogi and Bawa 1998). On the other side, the dried tomato pomace (DTP) contains 10% moisture, 20.77% crude protein, 39.8% crude fiber (CF), 7.3% ether extract (EE), 4.24% ash, 0.5% calcium and 0.45% phosphorus (Jafari *et al*., 2006). In addition, several studies have been conducted on tomato peel as a source of lycopene as one of the most important antioxidants and also β-carotene such as (Kalogeropoulos *et al*., 2012; Lavecchia and Zuorro 2010; Papaioannou and Karabelas 2012; Sarkar and Kaul 2014; USDA and ARS 2010). Tomato seeds have been reported, by Persia *et al*., 2003, containing approximately 24.5% of crude protein and highest in glutamic acid and aspartic acid. Unlike many other plant proteins, tomato seed has also been reported to have a highly lysine content (Sarkar and Kaul 2014; Savadkoohi and Farahnaky 2012). Carotenoids is a majority of pigments naturally which are widely distributed in plant and animal kingdoms. This group of fat-soluble pigments responsible for the red, orange, and yellow colors (Botella-Pavía and Rodríguez-Concepción 2006). Lycopene is a carotenoid hydrocarbon (also called carotene) (Omoni and Aluko 2005; Rodriguez and Kimura 2004). Lycopene is the major carotenoid it accumulates in the final ripening stage of tomatoes as an orange-red pigment and accounts for more than 80% of the total carotenoids in fully red-ripe fruits, where it is responsible for their characteristic color (Davis *et al*., 2003; Lenucci *et al*., 2006). Whereas, Sass-Kiss *et al*., 2005, added that lycopene in tomatoes accounted for 90-95 % of total carotenoids and it agreed with Rao and Agarwal 2000, where, found that the lycopene is the most represented carotenoid in tomato, accounting for above 90% of the total carotenoids. Also, Sarkar and Kaul 2014, concluded that, the peel of tomato fruits is more promising from a functional point of view with high amounts of lycopene (18.86 μg/g).

The majority of studies have recommended that thermal treatment and mechanic homogenization have increased bioavailability of carotenoids (lycopene extractability) due to the breaking of protein complexes where the pigment is associated inside the vegetable matrix. But taking into account the extensive in thermal treatment and time of exposure for processing may lead to greatest loss of lycopene as a result of the degradation and oxidative lycopene (Courraud *et al*., 2013; Georgé *et al*., 2011; Takeoka *et al*., 2001). By-products of plant food processing, which represent a major disposal problem for industrial concern, are very promising sources of value-added substances. Tomato pomace has generally high moisture contents, and need removal of moisture before the production of high value-added products. Drying process has always been of great importance to the preservation of agricultural products and their by-products, where, water removal halts the growth of spoilage microorganisms, as well as the occurrence of enzymatic or nonenzymatic browning reaction in the material matrix (Zhang *et al*., 2006; Argyropoulos *et al*., 2011; Kurozawa *et al*., 2012). There are many drying methods that are commonly used for fruits, such as spray drying, hot air drying, drum drying, freeze drying, and microwave- vacuum drying. Drying process help in extending the shelf life of fruits and their by-products through reducing water activity. Hot air-drying offers dehydrated products that can have an extended shelf-life of a year and removes most of the free water from the product by evaporation but unfortunately with a drastically reduced quality from that of the original foodstuff (Askari *et al*., 2009; Famurewa and Raji 2011; Fellows 2000; Feng *et al*., 2002; Horszwald *et al*., 2013; Schwannecke 2009). In hot-air drying, removing the first 33% of moisture uses about 66% of the total time of drying (Zhao 2000). There are influential factors on the rate of drying efficiency, such as the air speed and temperature rate. Low relative humidity maintains hot air drying efficiency, through the integration of fresh air and hot air in the enclosed cabin, which are connected with the product to remove moisture (Mejia-Meza 2008). Moreover, the color deterioration exhibited during drying was the most pronounced in hot air dried materials with a remarkable decrease in lightness and increase in yellowness values (Chen and Martynenko 2013). While, Zhang 1999 added, because of the low cost, hot-air drying is used for over 90% of dried vegetables. However, the quality of these dried products is poor. Drum drying has the best efficiency in terms of high rate of production and low labor requirements (Moore and Dekker 1995). Freeze drying is a gentle dehydration technique, representing the ideal process for the production of high-value products. Freeze drying method is expensive and takes a relatively long time of 12 to 24 hours (Mejia-Meza 2008). Vacuum drying is an important dehydration method usually used for high value and heat-sensitive fruits and vegetables. Drying in microwave (MW) field is another dehydration technique offering the opportunity to reduce the drying time and improve the quality of a dehydrated product (Maskan 2001). In short, the majority of tomatoes are processed into a lot of food products and remains large quantities of tomato by-products (tomato pomace), which, causing a problem for stakeholders in food industry and a serious environmental pollution. In addition to, these by-products of tomato processing are attractive sources of high nutritional valuable components and antioxidant pigments. Accordingly, the research aims to produce tomato pomace powder as a nutritional valuable material.

MATERIALS AND METHODS

Raw material

The tomato by-product used in this investigation included skins, seeds and pulp residues called tomato pomace. It was obtained from tomato processing factory SEKEM Company, Egypt. The samples were stored at −18 °C until analyzed. Drying experiments were conducted in three replications, and the results were expressed as average and standard deviation. The initial moisture content of the samples was determined by drying in electric oven at 70 °C until reached the equilibrium moisture (no discernible weight change) (AOAC 1995). The initial moisture content of tomato pomace samples was about 86.8% (wb). The tomato pomace was divided into samples according to the applied drying methods in this investigation as follows.

Draying methods

Three different drying methods were used; mechanical dryer, Microwave, and electrical oven drying in order to remove moisture from tomato pomace while saving valuable quality components, such as antioxidants and chemical compounds, the levels of the components were evaluated using different analyzing methods.

Mechanical dryer

The mechanical dryer which was previously described by (Awad 2005) used for experimental work. The samples were dried in the rectangular shelves with an iron net with dimensions of 54, 27.5 and 8 cm length, width and height respectively. Drying experiments were performed at drying temperatures of 60, 80 and 100 °C, and a three air velocities of 1, 1.5 and 2 m/s. After the dryer reached steady-state conditions for the set points (at least 30 min), the samples were distributed uniformly into the square chamber as a thin layer (layer thickness of 0.5 cm). Each experiment utilized in this method weighed 300 ± 0.5 g. Sample mass was recorded at regular time intervals (15 min). Drying process was completed when the moisture content of the samples was about 12 % ± 0.5 (wb). The dried product was cooled and packed in polyethylene bags. The drying experiments were repeated triplicate and the averages were used for data analysis.

Microwave oven

Microwave oven (LG, model MS3948ASC, 39l) cooking capacity, 1000 W power output with 5 levels, auto defrost. The oven is equipped with a controller to adjust the microwave output power and the required time for processing. The oven main outer dimensions are 30 × 65 × 40 cm, while, the inner dimensions are 23 × 37 × 36 cm, for height, width and depth respectively. For each experiment, tomato pomace sample (about 150 ± 0.5 g) was placed in a thermal glass dish (15 mm depth and 150 mm diameter) in the oven and dried at output powers of 200, 400, 600, and 800W. The sample was leveled in the Petridish and its thickness was 5 mm. Moisture loss of the sample was recorded by means of a weighing system at 5 min intervals until the sample reached to the equilibrium moisture (no discernible weight change).

Electrical oven dryer

An electrical dryer (RKI, Type 196, control heater 1000 W, Max °C 200). Outer dimensions were 70 × 113 × 65 cm and inner dimension were 50 × 60 × 50 cm for length, width and depth respectively. Mass of 150 g tomato pomace was distributed uniformly as a thin layer 5 mm was placed in a glass dish (15 mm depth and 150 mm diameter) in the oven at 60, 80 and 100°C.

Measurements

In this study, four groups of calculations, measurements and analysis were done for each drying method with its levels such as, moisture content and drying rate, microbial analysis, color assessment and chemical composition.

Calculation of changes in moisture content and drying rate

The moisture content and drying rate for each drying treatment were calculated at all specified drying methods according to the following equations:-

$$WD = \frac{W_o}{1 + M_o} \quad \text{.........................(1)}$$

$$WW_i = W_o - WD \quad \text{......................(2)}$$

$$M_t = \frac{WW_i}{WD} \quad \text{...........................(3)}$$

$$DR = \frac{M_{t1} - M_{tp}}{\Delta t} \quad \text{....................(4)}$$

Where: **WD mass of dry matter (g), W_o initial mass of sample (g), M_o initial moisture content (desimal), WW_i initial mass of water, M_t Moisture content at time (t, min), DR drying rate, M_{t1} moisture content at each point, M_{tp} moisture content at the previous point and Δt time difference at the same points.**

Microbial analysis

It is often necessary to determine how many live bacteria are actually in a sample, especially when measuring growth rates or determining process effectiveness. Total plate count method (TPC) procedure was used to determine the number of microorganisms in the fresh and dried tomato pomace samples. For microbial determinations, samples were kept at 4 ºC in plastic bags to stabilize the microbiological activity. Plate count technique was done by the standard method of (Difco 1985), in the Skha microbiology laboratory, solid water research institute, Kafer Elsheakh governorate.

Color assessment

The surface color of each sample for both wet and dried samples were measured with a portable color analyzer, Lutron, Model RGB-1002 equipped with an external sensor probe having a 45°/0° color measuring geometry. The color value of each sample was shown by color indices (RGB and HSL). H (hue angle) index for different samples varies in the range 0-360° that is describing a set of colors, S (saturation) shows purity and color saturation, it measures the intensity of color from 0% (a neutral gray) to 100% (fully saturated or pure hue) and L (luminance) is the amount of illumination (luminosity) from 0.0% (no light) to 100% (full light) as described by (Agoston 2005; Poynton 2006).

Chemical Composition

All fresh and dried tomato pomace samples were divided into two types (whole tomato pomace and tomato pomace without seeds). They were grounded in a mill for homogenization before analysis. The chemical composition were analyzed and determined in feed, water and food analysis laboratory, Faculty of Veterinary Medicine, Kafer El Sheikh University (dry matter, moisture, ash, soluble carbohydrate, crude protein, crude fat, total carotenoids content) of the samples. Dry matter, Moisture content, Ash and soluble carbohydrate were determined by standard method (AOAC 2010). While, crude protein and fat were determined according to (AOAC 2002) and (AOCS 2005) respectively. Finally, total carotenoids for fresh and dried tomato pomace samples were assessed as an indicator for lycopene compound by using spectrophotometer instrument Model 6300 at wavelength 470 nm. The carotenoids concentration expressed as μg.kg^{-1}, and calculated by the following equation.

$$C_{(X+C)} = (1000A_{470} - 1.90\ C_a - 63.14\ C_b) / 214 \quad \text{..(5)}$$

Where: **$C_{(X+C)}$: Carotenoids, A_{470}: absorbance value of the sample extract at 470nm, C_a: Chlorophyll a, and C_b: Chlorophyll b (Lichtenthaler and Buschmann, 2001).**

Statistical analysis

A completely randomized design (CRD) was taken to study the significance of variables at different drying methods and its effect on the nutritional quality of tomato pomace powder and the measurements of dry matter, moisture, ash, soluble carbohydrate, crude protein, crude fat, and total carotenoids content using SPSS program version 20, for the treatment analysis. The data were subjected to the proper statistical analysis of variance according to (Snedecor and Cochran 1980).

RESULTS AND DISCUSSION

At first, it was noted from Fig.(1) that, the drying curves of tomato by-products (tomato pomace) correspond to the drying behavior of fruits and vegetables. Where, the moisture content of tomato pomace was decreased dramatically with increasing duration of drying time. As we expected from this investigation the air temperature, velocity and microwave power had a significant effect on the moisture content of the tomato pomace. The results showed that the increase in drying air temperature, velocity and microwave power for the mechanical dryer, oven dryer and microwave method respectively resulted in a decrease in the drying time as was noticed from Figs. (1 to 3). Where, the drying time decreased greatly when the air temperature increased and the microwave power also increased. The lowest value of drying time was (25 min.) at microwave power 800 W. While, the longest value 390 min., was observed in the mechanical drying method, at the lowest temperature and air velocity.

Indeed drying rate was increased by increasing both air temperature, velocity and microwave power as shown in Figs. (4 to 6). The drying rate reached its maximum values 0.09 g water/(g dry matter. min.), at higher drying air temperature (100 °C), air velocity (2 m/s) and drying time (30 min.) for mechanical dryer method. While, in the case of microwave drying method the maximum value of drying rate 1.81 g water/(g dry matter. min.), was observed at power treatment 800 W, and time 10 min. Similarly, the maximum value of drying rate for oven dryer method was 0.11 g water/(g dry matter. min.) at temperature 100 °C and drying time 10 min. Obviously, it could also be said that the drying rate decreases continuously with decreasing the moisture content or growing drying time. The results of decrement percentages in moisture content and drying rate were consistent with observations made by different researchers on drying various agricultural products and by-products (Al-Harahsheha *et al.*, 2009; Celen and Kahveci 2013; Shafiq Alam *et al.*, 2013; Veerachandra *et al.*, 2013; Sharma and Yadav 2017).

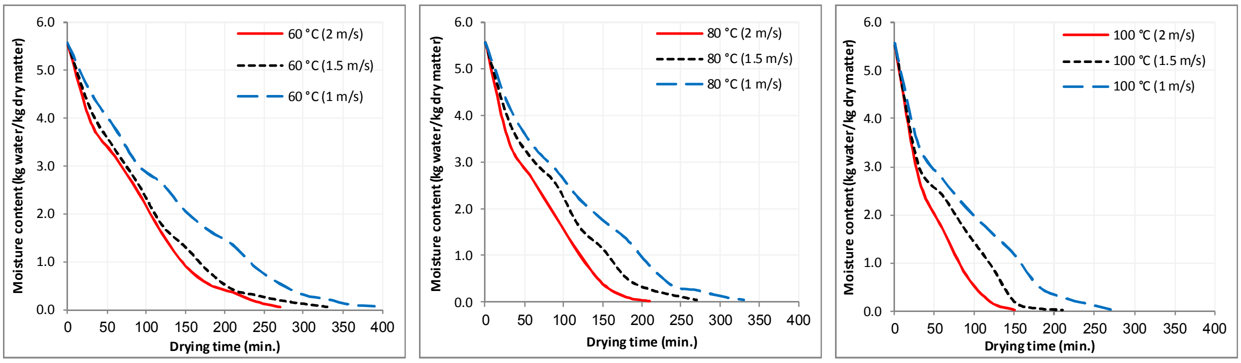

Fig. 1. Changes in the decrement percentages of tomato pomace moisture content for mechanical dryer.

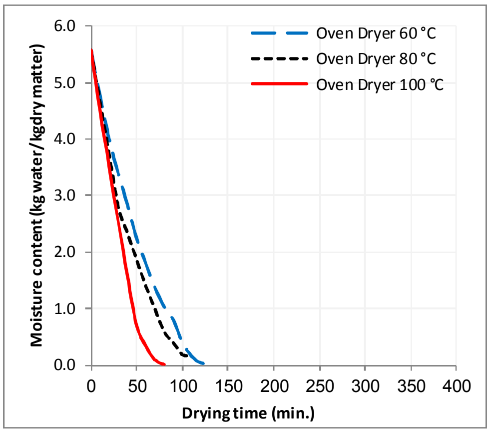

Fig. 2. Changes in the decrement percentages of tomato pomace moisture content for oven drying.

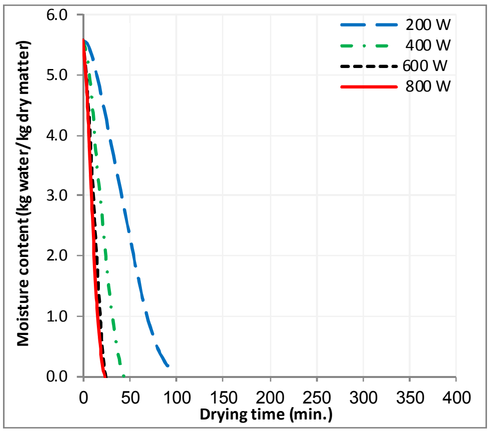

Fig. 3. Changes in the decrement percentages of tomato pomace moisture content for microwave oven.

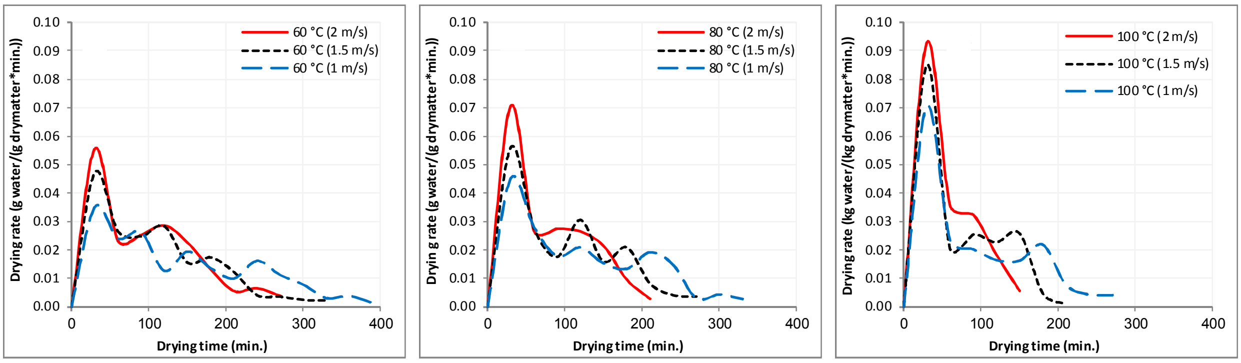

Fig. 4. Variation of tomato pomace drying rate for mechanical dryer.

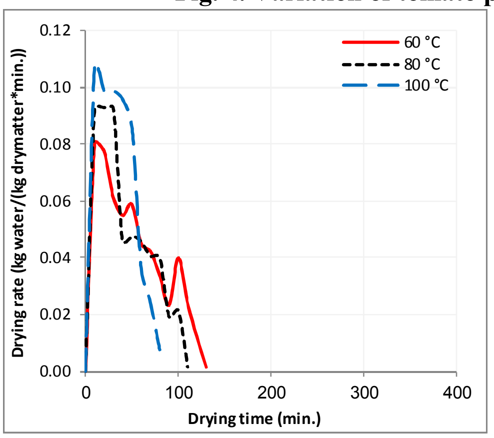

Fig. 5. Variation of tomato pomace drying rate for oven drying.

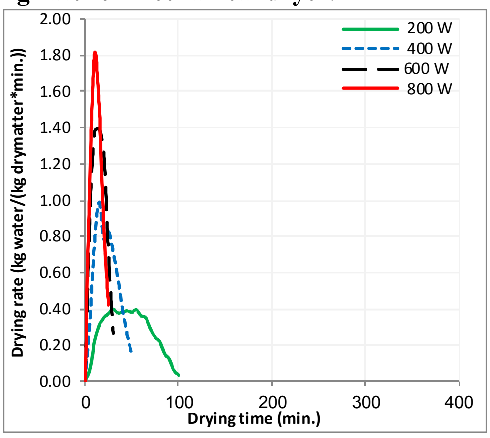

Fig. 6. Variation of tomato pomace drying rate for microwave oven.

Microbiological analysis

The microbial load of fresh and dried tomato pomace samples was measured in order to determine drying processes effectiveness. Where, drying processes reduces the water activity of the products, which inhibits microbial growth and decreases degradative reactions, thus, drying process will help extend the shelf life of the dried products. Indeed, the results showed generally that, there was a significant reduction in the content of microorganisms with different drying methods and its condition levels as observed in Table (1).

Table 1. Total microbial load of fresh and dried tomato pomace samples at the final moisture content.

Tomato pomace samples			T.C.B. (cfu. ml^{-1}) Min. Value	Max. Value	Average	M.C. (%) Min. Value	Max. Value	Average
Fresh samples			3.2×10^6	6.3×10^6	4.8×10^6	84.0	86.00	85.50
Mechanical Dryer	100 °C	2.0 m/s	1.8×10^3	2×10^3	1.9×10^3	10.8	11.55	11.23
		1.5 m/s	6.2×10^3	6.6×10^3	6.5×10^3	11.66	11.8	11.74
		1.0 m/s	1.2×10^4	1.9×10^4	1.4×10^4	11.9	12.68	12.33
	80 °C	2.0 m/s	4.4×10^3	1.2×10^4	6.9×10^3	11.89	12.9	12.41
		1.5 m/s	4.5×10^3	1.3×10^4	7.2×10^3	12.85	13.08	12.97
		1.0 m/s	1.3×10^4	1.9×10^4	1.6×10^4	13.4	13.68	13.66
	60 °C	2.0 m/s	2.5×10^4	5×10^4	3.3×10^4	13.88	14.08	13.96
		1.5 m/s	3.5×10^4	4.5×10^4	3.9×10^4	14.18	14.92	14.45
		1.0 m/s	7.5×10^4	10^5	8.7×10^4	14.98	15.28	15.12
Oven Dryer	100 °C		5.5×10^3	7.6×10^3	6.6×10^3	11.91	12.27	12.12
	80 °C		9.1×10^3	1.1×10^4	10^4	12.75	13.22	13.01
	60 °C		2.5×10^4	4.5×10^4	3.3×10^4	14.55	15.08	14.84
Microwave Dryer	800 W		3.9×10^3	6.3×10^3	5.2×10^3	11.99	12.35	12.15
	600 W		3.2×10^3	6.3×10^3	4.7×10^3	12.44	13.05	12.66
	400 W		9.5×10^3	1.6×10^4	1.3×10^4	12.89	13.59	13.21
	200 W		3.2×10^4	5×10^4	3.8×10^4	13.95	14.11	14.05

T.C.B.: total count of bacterial; Cfu : colony forming unit; M.C.: moisture content (% w b).

Tomato pomace powder obtained by mechanical dryer at 100 °C and velocities 2 m/s presented the lowest average microbial load 1.8×10^3 (cfu.ml^{-1}) at average moisture content of 11.23%. It was slightly higher than the same temperature but at velocity 1.5 m/s. Among all drying methods it was noticed that, the highest average microbial load was 8.7×10^4 (cfu.ml^{-1}) at average moisture content of 15.12 % for the mechanical dryer at 60 °C and air velocity of 1 m/s. While, the second highest average value of microbial load was 3.8×10^4 (cfu.ml^{-1}) at average moisture content of 14.05% for the microwave treatment at 200 W.

This dramatically decrease in microbial load from 6.3×10^6 to 1.8×103 (cfu.ml^{-1}) of fresh tomato pomace sample compared to the dried sample is due to the dramatic decrease in moisture content from 86 to 10.8 % for fresh and dried samples respectively. This amount of water that was removed from the tomato pomace sample as a result of drying process greatly minimized the microbial spoilage and deterioration reactions. It is clear from the existing results in Table (1) that the counts of the microorganisms were within the acceptable standards of $<10^5$ for bacteria (International Commission on Microbiological Specification for Foods (ICMSF), 1998).

Color analysis

The data recorded in Table (2) cleared that there are significant differences between HSL color parameters for the fresh and dried tomato pomace samples. Certainly, the hue angle (H°) is the main factor for measuring the color and specifying it with a point on the color map of the color measurement model HSL. The value of (H°) for fresh pomace was in range 7 - 9° with average 8°. While, the best value of (H°) was 13° for mechanical dryer at 100 °C and air velocity 1.5 m/s. These results may be due to the highest value of saturation (S) 80% within the range of 78 to 82% and lightness value 50%. Similarly, the best value of (H°) for oven dryer was observed at treatment of 100 °C was 12° with 73% saturation and 55% lightness. Similarly, the best treatment for microwave dryer was identified at treatment of 600 W, where, (H°) value was 11° with saturation value 73% and 50% lightness.

Table 2. Color analysis for fresh and dried tomato pomace samples.

Drying Method	T.P. Samples		H° Range	Average	S (%) Range	Average	L (%) Range	Average
Fresh sample			7 - 9	8	70 - 85	72	47 - 62	53
Mechanical Dryer	100 °C	2.0 m/s	10 - 13	12	70 - 81	74	52 - 59	55
		1.5 m/s	13 - 13	13	78 - 82	80	48 - 52	50
		1.0 m/s	13 - 15	14	65 - 73	70	54 - 60	56
	80 °C	2.0 m/s	11 - 13	12	62 - 75	67	43 - 50	46
		1.5 m/s	13 - 14	13	67 - 70	69	42 - 56	47
		1.0 m/s	14 - 15	14	65- 74	68	41 - 50	45
	60 °C	2.0 m/s	13 - 14	13	62 - 74	68	40 - 50	45
		1.5 m/s	12 - 15	13	68 - 71	70	44 - 52	48
		1.0 m/s	13 - 15	14	67 - 73	69	43 - 49	46
Oven Dryer	100 °C		12 - 13	12	68 - 79	73	54 - 57	55
	80 °C		12 - 13	12	57 - 92	78	58 - 67	62
	60 °C		10 - 11	11	64 - 75	71	57 - 96	82
Microwave Dryer	800 W		12 - 17	15	77 - 88	81	30 - 46	38
	600 W		11 - 12	11	68 - 76	73	48 - 52	50
	400 W		7 - 11	10	55 - 75	64	38 - 50	44
	200 W		10 - 12	11	69 - 73	71	19 - 61	39

T.P. tomato pomace, H° Hue angle, S Saturation, L Lightness

In general, all fresh and dried tomato pomace samples were located within the range of red color, but the best chromatic values were chosen in the previous paragraph were based on the values of three color parameters H, S and L. However, all the hue angles for all samples were located within the range of red color but the value of the saturation which determine the degree of red color saturation which ranged from 0 to 100% play an important role. In other words, when the degree of saturation was closer to the final grade of saturation (100%), it means close to the purity of the red color. In contrast, when the degree of lightness was close to the final value it means, the color was lighter.

Nutritional composition of tomato pomace

The effects of drying temperature and drying duration on the nutritional composition of the dried whole tomato pomace and tomato pomace without seeds are presented in Tables (3 and 4). There was a significant ($p \leq 0.05$) difference in moisture content between the control (fresh) and all dried tomato pomace samples. The moisture content of the fresh whole tomato pomace and pomace without seeds samples before drying determined as 85.97%±0.21 and 85.67% ±0.31 (wet basis) respectively. The largest reduction in moisture content (10.57% ±0.47) of all tomato pomace samples (whole tomato pomace) has occurred at treatment 100 °C and 2 m/s velocity for the mechanical dryer compared with tomato pomace without seeds samples (11.05% ±0.05) at the same drying method and treatments. On the contrary, the highest rise in dry matter content of both whole tomato pomace (89.37% ±0.45) and pomace without seeds (88.95% ±0.05) was recorded at the same method and same treatment of moisture content. However, the dry matter values of fresh whole tomato pomace and pomace without seeds samples were 14.03% ±0.21 and 14.33% ±0.31 respectively. The results for moisture content consistent with Jafari *et al.*, 2006; Knoblich *et al.*, 2005; Lavelli and Torresani 2011.

Then comes to the ash content of both whole and pomace without seeds samples where the results explained that the maximum ash content (dry base) was found as 8.27%±0.07 when using the mechanical dryer at 100 °C and air velocity of 2 m/s compared with 6.18%±0.07 when using oven dryer at 100 °C. Also, it could be observed that the Ash content values were higher than that obtained with other treatment combinations for both whole pomace and pomace without seeds (Table 3 and 4). This is may be due to the removal of water and organic matter by different studied drying methods which tends to increase the concentration of nutrients as mentioned by Morris *et al.*, 2004. Conversely, there was a decrease in the content of soluble carbohydrates by increasing the drying temperature of the mechanical and oven dryers and also by increasing the microwave power. The maximum values of soluble carbohydrates content (dry base) were 34.77% ±0.13 and 37.30% ±0.46 for both fresh samples of whole tomato pomce and tomato pomace without seeds. It is clear from (Table 3 and 4) that there are no significant differences between different levels of temperature for the mechanical or oven dryers, also at different powers of microwave for soluble carbohydrates.

Table 3. Nutritional composition of whole tomato pomace samples at different drying methods.

Samples			M.C. %	D.M. %	Ash %	S. Carbo. %	Crude Pro. %	Crude Fat %	T. Carotenoids ($\mu g.kg^{-1}$)
			Average ± SD						
Control			85.97±0.21	14.03±0.21	5.06±0.19	34.77±0.13	15.39±0.15	6.51±0.07	4011.70±84.72
Mechanical Dryer	100 °C	2.0 m/s	10.57±0.47	89.37±0.45	8.27±0.07	29.92±0.29	14.33±0.25	6.40±0.12	5088.40±42.22
		1.5 m/s	11.53±0.15	88.47±0.15	8.17±0.04	29.63±0.25	14.24±0.20	6.37±0.16	5661.31±277.60
		1.0 m/s	12.10±0.26	87.90±0.26	8.09±0.02	29.38±0.13	14.25±0.13	6.32±0.12	4959.34±36.02
	80 °C	2.0 m/s	12.39±0.52	87.61±0.52	8.22±0.03	29.70±0.13	14.30±0.13	6.33±0.08	5172.11±82.17
		1.5 m/s	12.97±0.09	87.03±0.09	8.14±0.05	29.52±0.13	14.24±0.14	6.28±0.06	5525.35±93.00
		1.0 m/s	13.64±0.25	86.36±0.25	8.05±0.06	29.25±0.06	14.22±0.12	6.25±0.04	4918.03±239.13
	60 °C	2.0 m/s	13.92±0.07	86.08±0.07	8.12±0.08	29.68±0.07	14.32±0.03	6.28±0.03	5262.52±57.59
		1.5 m/s	14.41±0.41	85.56±0.41	8.08±0.04	29.57±0.10	14.02±0.16	6.21±0.04	5521.77±68.04
		1.0 m/s	15.04±0.14	84.96±0.14	7.99±0.04	29.11±0.26	13.85±0.12	6.19±0.04	4725.60±156.76
Oven Dryer	100 °C		11.33±0.31	88.67±0.31	8.13±0.09	29.72±0.62	14.52±0.08	6.21±0.12	5598.81±196.35
	80 °C		12.35±0.30	87.65±0.30	8.04±0.06	29.42±0.10	14.25±0.15	6.14±0.15	5389.19±86.22
	60 °C		14.02±0.03	85.98±0.03	8.04±0.06	29.27±0.25	14.17±0.11	6.16±0.16	5158.66±75.66
Microwave Dryer	800 W		12.30±0.17	87.70±0.17	8.18±0.14	29.98±0.26	14.34±0.09	6.19±0.10	5269.27±73.48
	600 W		12.45±0.18	87.55±0.18	8.22±0.10	30.23±0.38	14.40±0.15	6.23±0.12	5527.59±380.89
	400 W		13.08±0.38	86.92±0.38	8.25±0.11	29.95±0.39	14.28±0.10	6.12±0.13	5267.80±168.90
	200 W		14.05±0.13	85.95±0.13	8.17±0.15	29.60±0.13	14.12±0.10	5.98±0.03	5017.42±102.86

M.C. (%) moisture content; D.M. (%) dry matter; S. Carbo. (%) soluble carbohydrates; Pro. Protein; T. total carotenoids.

Regarding to crude protein content affected by different drying methods and treatments it could be clear that there is a significant difference ($p \leq 0.05$) between dried and control (fresh) tomato pomace samples (whole and pomace without seeds samples). The protein content in control samples for both whole pomace (15.39% ±0.15) and pomace without seeds (12.61% ±0.28) was higher than that obtained with all dried samples and the difference between fresh pomace values may be due to tomato seeds.

In the same context, crude fat value of the whole tomato pomace samples were higher than the tomato pomace without seeds samples by about 70.81% and this may be due to the presence of oil in tomato seeds. Also, the results showed that by using higher drying temperature and microwave power the fat content was decreased. This could be attributed to the oxidation of fat at higher temperature and microwave power and also the long duration exposure to drying treatment. These results in the same trend with Famurewa and Raji 2011; Kalogeropoulos *et al*., 2012. It is clear from the results presented in (Table 3 and 4) that there is a difference in the values of total carotenoids as indicator to lycopene value between fresh whole tomato pomace samples and the samples without seeds where the values were 4011.70 and 4390.20 µg.kg^{-1} respectively and this difference between the whole tomato pomace and the pomace without seeds due to the lower amount of total carotenoids in tomato seeds as mentioned by (Davis *et al*., 2003; Lenucci *et al*., 2006; Rodriguez and Kimura 2004; Sass-Kiss *et al*., 2005).

Table 4. Nutritional composition of tomato pomace without seeds samples at different drying methods.

Samples			MC %	DM %	Ash %	S. Carbo. %	Crude Pro. %	Crude Fat %	T. Carotenoids (µg.kg^{-1})
			Average ± SD						
Control			85.67±0.31	14.33±0.31	3.02±0.09	37.30±0.46	12.61±0.28	1.09±0.18	4390.20±15.99
Mechanical Dryer	100 °C	2.0 m/s	11.05±0.05	88.95±0.05	6.18±0.07	34.26±0.29	11.59±0.24	1.05±0.13	5569.90±110.87
		1.5 m/s	11.90±0.10	88.10±0.10	6.09±0.04	33.97±0.25	11.50±0.19	0.98±0.04	6193.43±196.76
		1.0 m/s	12.13±0.31	87.87±0.31	6.01±0.02	33.72±0.13	11.51±0.13	0.97±0.04	5428.14±56.57
	80 °C	2.0 m/s	12.47±0.48	87.53±0.48	6.09±0.08	34.04±0.13	11.56±0.13	1.03±0.06	5660.53±39.60
		1.5 m/s	13.06±0.05	86.94±0.05	6.05±0.06	33.85±0.13	11.50±0.14	0.98±0.03	6046.97±8.28
		1.0 m/s	13.87±0.18	86.13±0.18	6.01±0.11	33.58±0.06	11.48±0.12	0.96±0.05	5380.37±169.46
	60 °C	2.0 m/s	14.04±0.04	85.96±0.04	6.03±0.07	34.02±0.07	11.58±0.02	0.94±0.02	5759.85±59.85
		1.5 m/s	14.63±0.45	85.37±0.45	5.99±0.04	33.91±0.10	11.28±0.15	0.95±0.02	6043.43±46.18
		1.0 m/s	15.38±0.34	84.62±0.34	5.91±0.04	33.45±0.26	11.13±0.12	0.94±0.02	5170.73±81.65
Oven Dryer	100 °C		11.08±0.11	88.92±0.11	6.18±0.03	34.25±0.30	11.63±0.13	1.01±0.08	6127.19±180.25
	80 °C		13.08±0.10	86.92±0.10	6.07±0.10	33.84±0.12	11.52±0.10	0.94±0.02	5898.02±10.74
	60 °C		14.62±0.36	85.41±0.41	5.98±0.13	33.79±0.15	11.24±0.09	0.92±0.02	5645.85±31.63
Microwave Dryer	800 W		12.12±0.23	87.88±0.23	5.85±0.13	33.54±0.23	11.67±0.10	0.99±0.03	5767.02±46.75
	600 W		12.27±0.31	87.73±0.31	5.98±0.13	33.61±0.21	11.65±0.13	0.98±0.03	6045.85±317.43
	400 W		12.93±0.25	87.07±0.25	5.82±0.08	33.37±0.10	11.43±0.06	0.93±0.02	5764.41±114.95
	200 W		13.93±0.06	86.07±0.06	5.78±0.03	33.77±0.06	11.27±0.11	0.89±0.01	5490.92±34.06

M.C. (%) moisture content, D.M. (%) dry matter, S. Carbo. (%) soluble carbohydrates, Pro. Protein, T. total carotenoids.

It is also noted from Tables (3) and (4) that by using different drying methods, the content of total carotenoids increases for all samples of tomato poamce. But there are differences between the drying treatments of different methods. This is, may be due to the time period of exposure to temperature as well as air velocity, which leads to oxidation and hence reduces the amount of carotenoids according to (Courraud *et al*., 2013; Georgé *et al*., 2011; Takeoka *et al*., 2001). It is observed that the highest value 6193.43 µg.kg^{-1} of total carotenoids was recorded for the mechanical drying method at 100 °C and velocity 1.5 m/s for the samples of tomato pomace without seeds. On the other hand the whole tomato pomace samples recorded the highest value 5661.31 µg.kg^{-1} at the same drying method and the same treatments.

ANOVA indicated that all different drying methods and its conditions levels has significant ($p < 0.05$) effect on the chemical compounds of all different tomato pomace samples and table (5) showed ANOVA analysis of tomato pomace without seeds samples.

Table 5. Experimental parameters ANOVA analysis for tomato pomace without seeds.

Experimental Parameters		Sum of Squares	df	Mean Square	F	Sig.
Dry matter	Between Groups	73.901	15	4.927	71.85	0.000
	Within Groups	2.194	32	0.069		
MC	Between Groups	74.215	15	4.948	75.14	0.000
	Within Groups	2.107	32	0.066		
Ash	Between Groups	0.613	15	0.041	6.22	0.000
	Within Groups	0.210	32	0.007		
Soluble carbohydrate	Between Groups	4.674	15	0.312	9.69	0.000
	Within Groups	1.028	32	0.032		
Crude protein	Between Groups	1.134	15	0.076	4.45	0.000
	Within Groups	0.548	32	0.017		
Crude fat	Between Groups	0.079	15	0.005	2.27	0.025
	Within Groups	0.074	32	0.002		
Total carotenoids	Between Groups	3952243.31	15	263482.89	17.01	0.000
	Within Groups	495723.11	32	15491.35		

Table (6) concludes the results of the statistical analysis of ANOVA for the effect of different drying methods and its conditions levels on carotenoids content of tomato pomace without seeds samples.

Table 6. Least Significant Difference (LSD) analysis of Carotenoids for tomato pomace without seeds samples.

Dependent Variable of Carotenoids			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Mechanical Dryer 100 °C (2m/s)	Mechanical Dryer	100 °C (1.5m/s)	623.53*	101.62	0.000	830.53	416.52
		100 °C (1.0 m/s)	141.76	101.62	0.173	65.23	348.76
		80 °C (2.0 m/s)	90.62	101.62	0.379	297.62	116.37
		80 °C (1.5m/s)	477.07*	101.62	0.000	684.07	270.06
		80 °C (1.0 m/s)	189.53	101.62	0.071	17.46	396.53
		60°C (2.0 m/s)	189.94	101.62	0.071	396.94	17.05
		60 °C (1.5m/s)	473.52*	101.62	0.000	680.52	266.52
		60 °C (1.0 m/s)	399.17*	101.62	0.000	192.17	606.17
	Oven Dryer	100 °C	557.28*	101.62	0.000	764.28	350.28
		80 °C	328.11*	101.62	0.003	535.11	121.11
		60 °C	75.94	101.62	0.460	282.94	131.05
	Microwave Dryer	800 W	197.11	101.62	0.061	404.11	9.8926
		600 W	475.94*	101.62	0.000	682.94	268.94
		400 W	194.51	101.62	0.065	401.51	12.49
		200 W	78.99	101.62	0.443	128.01	285.99

CONCLUSION

In the final analysis, color parameters are represented by HSL color space showed that there were clear differences between HSL color parameters for the fresh and dried tomato pomace samples. The best value of (H°) was 13° for mechanical dryer was achieved at 100 °C and air velocity 1.5 m/s due to the highest value of saturation (S) 80% within range 78 to 82% and lightness value 50%. The best result of microbial counts was achieved at mechanical drying method than the microwave method with a slight decrease. Finally, there were differences in the proportion of Ash, carbohydrates, protein, fat and total carotenoids between the samples of whole tomato pomace and tomato pomace without seeds and these differences are due to the presence of seeds.

Therefore it was chosen the most suitable method for drying tomato pomace according to the highest values of antioxidants represented in total carotenoids content and the least microbial counts. In conclusion, there is a tomato pomace powder rich by antioxidants can be added to many food industries or used as an independent product.

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معالجة ثمار الطماطم وتحويلها الى منتجات صناعية، تخلف ورائها كميات كبيره من المنتجات الثانوية. هذه المنتجات الثانوية لعمليات تصنيع الطماطم هى مصادر غنية بالمكونات عالية القمية الغذائية. وبناءا على ذلك, يهدف البحث الى انتاج مسحوق تفل الطماطم كمادة عالية القيمة الغذائية. بعد استخراج عصير الطماطم تم اخذ المتبقى من المنتجات الثانوية (تفل الطماطم) وتجفيفها بطرق مختلفة, مثل المجفف الميكانيكى عند درجات حرارة مختلفة (60، 80 و 100 درجة مئوية) وسرعات مختلفة (1,0, 1,5 و 2,0 م/ث)، فرن التجفيف عند (60, 80 و 100 درجة مئوية), وفرن الميكروويف عند قدرات مختلفة (200، 400، 600 و 800 وات). وأظهرت النتائج المتحصل عليها ان المحتوى الرطوبى لتفل الطماطم يتناقص بتزايد كل من درجات الحراره, سرعة الهواء وقدرة الميكروويف. تم تقييم عينات تفل الطماطم المجففة طبقا لصفات الجودة التالية حجم النشاط الميكروبى, اللون ومحتوى هذه العينات من المركبات الكيميائية (المحتوى الرطوبى, المادة الجافة، الرماد، الكربوهيدرات، البروتين، الدهن, الكاروتينات الكلية). تسببت عملية التجفيف في انخفاض كبير في اجمالى الحمل الميكروبى لعينات تفل الطماطم حيث كانت أفضل قيمة ($1,9 \times 10^3$ $cfu.ml^{-1}$) عند المجفف الميكانيكي (100 درجة مئوية وسرعة 2,0 متر / ثانية). في الختام، خلصت النتائج الى ان استخدام طريقة التجفيف الميكانيكي عند 100 درجة مئوية حقق أفضل النتائج من، الحد الأدنى لقيمة الحمل الميكروبي، الحد الأدنى للتغير في عوامل اللون، اعلى معدل للكاروتينات الكلية، للعينات المجففة على الرغم من أن وقت التجفيف أكبر من طريقة الميكروويف. ولهذا تم تطبيق هذة الطرق المختلفه للتجفيف للاستفادة من افضل ظروف لعملية التجفيف من أجل تثمين المنتجات الثانوية للطماطم. لذلك، يوصى القائمون على البحث باستخدام احجام كبيرة من المجفف الميكانيكى لتجفيف المنتجات الثانوية للطماطم (تفل الطماطم) عند ظروف التشغيل المثلى المذكورة أعلاة.