EFFECT OF DRYING CONDITIONS ON DRYING BAHAVIOUR AND QULAITY OF ONION SLICES

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ABSTRACT

Drying of agricultural products is the great importance for preservation of food human beings. The drying operation is mainly affected by variation of the air temperature, air velocity,, air relative humidity and other factors. The aim of this research was to investigate influence of some factors such as drying air temperature (40, 50, 60, 70, and 80 °C) and onion slices thickness (4, 6, and 8 mm) on the thin layer convection drying behavior of white onions slices at 1.5 m/s air velocity. Drying experiments were conducted using a convection tray dryer(UOP 8 Tray Dryer, Armfield, UK, S.N : 016679-001). The dryer is equipped with controllers for controlling the temperature and airflow velocity. Temperature changes of dried samples, as well as relative humidity and temperature of drying air were measured during the drying process. Rehydratation ratio, color, texture and sensory properties were used as a parameter for the dried sample quality. The drying curves were fitted with different moisture ratio equations given by several researchers.

Pag's equation (exponential model) fitted very well the experimental data and it is possible to accurately simulate the thin layer drying behavior of onion slices at different air temperature. Two well-defined falling rate periods and a very short constant rate period at lower air temperature were observed. Drying constants (k and n) were greatly affected by drying air temperature and slice thickness. Drying time decreases considerably with increase in hot air temperature. During rehydration of dried onions,3.08 to 3.71 of rehydration ratio by the drying process was obtained. Slice thickness had a significant effect on the rehydration ratio. Drying of onion slices at range of (40 – 60°C) revealed optimum color values, meanwhile drying at 70- 80 °C gave least acceptable color values. So if the economics of the process is considered, drying at 50 to 60 °C is generally recommended

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INTRODUCTION

Energy efficiency of the process and quality of dried product are two most critical factors in food drying. Drying of food stuffs is an important and the oldest method of food processing (Koyuncu et al., 2007).Approximately one third of the global food production or 1.3 billion tons of food is lost annually due to lack of proper processing (Gustavssion et al., 2011). These significant losses should be minimized to promote food security, combat hunger and increase income in the poorer countries as well as globally.

Fruits and vegetables are highly seasonal and available in plenty amounts in particular times of the year. In the peak season, the selling prices are usually at the minimum and may lead to lower profits or even losses for the grower. Also, due to the abundant supply during the season, a glut in the market may result in the spoilage of large quantities. Preservation of these fruits and vegetables can prevent huge wastage and make them available in the off-season at remunerative prices (Parakash, et al., 2004). Drying provides not only a longer shelf-life to the food but also results in light weight transportation and comparatively smaller storage space.

The most important fruit and vegetables quality known to be affected by high temperature drying for long time includes nutritional value, structural properties and sensory attributes. In conventional hot air ventilation heating or drying, long exposure time is required to reduce food water content down to lower safe moisture content. The acceptability (visual appeal, taste, aroma, flavour and texture), structural property and nutritional value of fruits and vegetables are also highly affected (Workneh, 2011).High temperatures and long drying times required to remove the water from the fruit and vegetable materials in convection air drying may cause serious damage in flavor, color, nutrients and can reduce the bulk density and rehydration capacity of the dried product (Lin, et al., 1998). There is a growing interest in the food industry in the development of economical methods for food production with high organoleptic and nutritional value.

Drying of materials having high moisture content is a complicated process, which involves simultaneous heat and mass transfer. The materials are dried using several techniques but thin layer drying is more popular due to its faster rate in comparison to others and minimum loss of nutrients. Thin-layer drying describes the process of drying in a single layer of sample particles. Three types of thin-layer drying models are used to describe the drying phenomenon of farm product. The theoretical model considers only the internal resistance to moisture transfer between product and heating air whereas semi theoretical and empirical models consider only the external resistance (Midilli et al., 2002). Theoretical model needs assumptions of geometry of a typical food, its mass diffusivity and conductivity. Empirical model neglects the fundamentals of drying process and presents a direct relationship between average moisture and drying time by means of regression analysis (Ozdemir and Devres, 1999), and semi theoretical model is a tradeoff between the theoretical and empirical ones, derived from simplification of Fick‟s second law of diffusion or modification of the simplified model, which are widely used, such as the Lewis, Page, Modified Page, Henderson and Pabis, Logarithmic, Two term, Approximation of diffusion, Verma and Midilli Kucuk models.

Onion (*Allium cepa,L.)* is a crop of warm climate and it is grown worldwide. In Egypt, onion is the fourth major export crop after cotton, rice, and citrus. The total cultivated area was 56,786 hectares in 2011 and the total production was 1,954,000 tons(CAPMS of A.R.E). Onion has been widely used even in ancient times as seasonings, foods and for medical uses. In current times, onion is an important vegetable to serve as ingredients in dishes, as toppings on burgers, in seasonings, as chip coatings etc. (Sharma, et al., 2005).

Onion finds widespread usage in both fresh and dried forms. Dried onions are a product of considerable importance in world trade and are made in several forms: flaked, minced, chopped and powdered. It is used as flavor additives in a wide variety of food formulations such as comminuted meats, sauces, soups, salad dressings and pickle relishes (Kumar, et al., 2006).

The major challenge during drying of food materials is to reduce the moisture content of the material to the desired level without substantial loss of flavor, taste, color and nutrients.

The aim of this study was to study convection drying of onion slices in laboratory conditions and to investigate the effect of drying conditions (air temperature, slice thickness) on drying characteristics and quality in terms of final moisture content, rehydration ratio, texture and color

MATERIALS AND METHODS

1.Materials

The good quality fresh white onions (*A. cepa*) were purchased from a local super market in Al-Ehssa, Saudia Arabia. The onions were hand peeled, cut into slices (4.0, 6.0, and 8.0 mm thickness) with a sharp stainless steel knife in the direction perpendicular to the vertical axis. Fives measurements were made on each slice for its thickness using a caliper (Mitutoyo Corp. Model no SC-6, Japan) and their average values were considered. Initial moisture content of the onion was immediately measured and recorded. The initial moisture content of the samples expressed as kg water / kg dry solids which varied between 9.01 and 9.06 kg water/ kg dry solids and corresponds to about 89.9 % (w.b.).

2. Drying Equipment

Drying was performed in a pilot plant tray dryer (UOP 8 Tray Dryer, Armfield, UK, S.N : 016679-001). The dryer operates on the thermo gravimetric principle. The dryer (Fig. 1) is equipped with controllers for controlling the temperature and airflow velocity. The dryer consists of a floor standing tunnel in one end of which is mounted an axial flow fan. Air was drawn into the duct through a diffuser by a motor driven axial flow fan impeller. Downstream of the fan a bank of electrically heated elements heat the air flowing to the drying chamber. The chamber with transparent access door, contains a rack of four samples trays suspended from a balance mounted on top of the dryer. The balance continuously determined and displayed the sample weight The total capacity of the trays is approximately 3 kg of solids Ducting upstream and downstream of the drier is designed to provide a uniform airflow over the trays. Controls mounted on a panel at the fan end of the tunnel permit variation of air speed and heater power to vary temperature through the dryer. Heater power adjustable up to 3 kW. Measurements of temperature and humidity (with an aspirated wet and dry bulb psychrometer) may be made before and after the dryer chamber. The heating elements are fully protected against overheating by the use of bi-metal thermostats and heating circuits may only be switched on when the fan is running. The fan minimum speed is preset. Fan adjustable to give air velocities of 0.3 to 1.8 m/s.

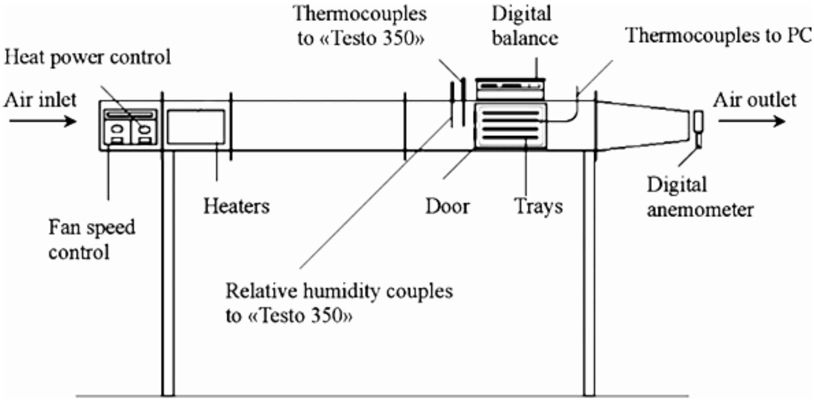

Fig. 1. Schematic diagram of convection drying equipment (uop 8 Tray Dryer, Armfield, UK)

3. Drying procedure

Drying experiments were carried out in Food Process Engineering Laboratory, Agricultural Systems Engineering Department, Faculty of Agricultural and Food Sciences, King Faisal University, Saudia Arabia. The dryer was operated at drying air temperatures of 40 °C, 50 °C, 60 °C, 70 °C and 80 °C (dry bulb temperature) combined with 1.5 m/s air velocity. Air flowed parallel to the horizontal drying surfaces of the samples. Drying process started when drying conditions were achieved (constant air temperature and air velocity). The onion slices samples were pretreated by soaking for one min in sodium metabisulphite 0.4% according to (Saad et al, 1992).Three samples were picked randomly from the pretreated onion to determine initial moisture content. The pretreated onion samples were spread (single layer) with a near uniform distribution density. The onion slices samples on trays were placed into the tunnel of the dryer and the measurement started from this point.

During the drying process temperature changes of drying air temperature were continuously recorded by thermocouples connected to a PC. ‘‘Testo 350’’ probes placed before and into the drying chamber measured relative humidity , drying air temperature and dried samples temperature. Sample weight loss was measured using a digital balance (with precision of ±0.01 g) every 5 min during the first one hour of the experiments. After wards the weight was recorded every 30 min till the sample attained constant weight. Airflow velocity was measured every 30 min with a digital anemometer that was placed at the end of the tunnel. The drying test was terminated when the decrease in the weight of the samples had almost ceased. Dried samples were kept in airtight glass jars until the beginning of quality tests experiments.

4. Measurments

4.1 Air temperature

During the drying process air temperature were continuously recorded using the thermocouples wires placed before and into the drying chamber. Temperature readings at a certain time intervals (5 min) was recorded using a data logging system and basic computer program.

4.2. Air velocity

Air velocity was measured by means of a Dwyer thermal anemometer 470 to the nearest ft/min was placed at the end of the tunnel. The readings were then converted into m/s.

4.3. Moisture content

The initial and final moisture content of the product was determined by using a standard laboratory method according to AOAC (1990). The quantity of moisture present in a material can be expressed on either the wet basis or dry basis and expressed either as decimal or percentage. Time dependent moisture content of the samples was calculated from the sample weight and dry basis weight. Weight loss data allowed the moisture content to be calculated such as follows:

$$\text{M.C.}(t) = m_w / m_{d.b.}$$

4.4. Rehydration ratio

Rehydration ratio of dried onion samples was determined according to (Kalse et al 2012) by putting 10 g of samples with 1000 ml of distilled water in beaker, it was allowed to rehydrate for 5 h at 20 ^{o}c temperature.

$$\text{Rehydration ratio} = \frac{mass\ of\ rehydrated\ samples\ (g)}{mass\ of\ dried\ samples\ (g)}$$

4.5. Texture

The firmness of samples was measured as described by AmerEssa (1998). The peak deformation force required to compress the sample to depth of 2mm using a cylindrical probe (2mm diameter) used as a measure for product firmness

4.6. Color

Color of onion slices was measured by Minolta Chroma meter (Cr300X, Minolta camera Co, Ltd, Japan) before and after drying in Food Analysis laboratory, Food and Nutrition Sciences Department, King Faisal University. The color meter was calibrated against a standard calibration plate of a white surface and set to CIE standard illuminant C. The L*, a*, b* values are average of five readings. The color brightness coordinate L* measure the whiteness value of color and ranges from black at 0 to white at 100. The chromaticity coordinate a* measures red when positive and green when negative, and chromaticity coordinate b* measures yellow when positive and blue when negative (Arslan and Ozcan, 2010 and Kalse et al., 2012) . The reading was performed on the sliced surface of the pericarp tissue of onion slices. For statistical purpose the color reading was done at three randomly selected different locations and the mean of those three reading from the same sample was reported.

5. Mathematical modelling of drying curves

There are two types of thin-layer models in use: diffusion models and empirical models. The accuracy of diffusion models to predict moisture content depends on having good assumptions concerning the geometry, moisture diffusivity and temperature profile of a piece of food. The diffusion models need more computation time and computer memory than the simpler empirical models. According to Bruce (1985), the diffusion models are more accurate and allow internal moisture movement to be modelled. However, he noted that in simulations of deep-bed drying the simpler models are expected to be useful where economy of computation is concerned. Perry and Green, (1984) concluded that empirical models are more applicable for control technology to drying, because less time is required for computation. Therefore, it was decided to look at widely used simpler models.

For mathematical modelling the drying curves were obtained for white onion slices under different drying air temperature and slices thickness and were fitted with three different moisture ratio models given by several researchers as listed in Table 1. To calculate the coefficients of each model and select the best model for describing the drying curves, the nonlinear optimization method was applied, using the computer programs (Curve Expert 3.1, 1996 and Datafit 8.0 ,2002). The coefficients determination (R^2) was used to select the best equation to account for the variation in the drying curves of the dehydrated sample. In addition to R^2 , chis square (χ^2), the mean square of the deviations between the experimental and estimated values for the models was used to determine the goodness of fit. The lower the values of the Chi square, and the higher the values of R^2 values indicate the high fit of the model (Sharma et al., 2005).

The values of the equilibrium moisture content are relatively small compared to instantaneous moisture content and initial moisture content the moisture ratio can be simplified to M_t /M_o.(Doymaz and pala, 2002 and Workneh et al., 2011). M_t is moisture content at any time (t), M_o is initial moisture content , expressed on a dry basis.

The drying curve for each experiment was obtained by plotting the dimensionless moisture ratio of the sample vs. the drying time. For the approximation of experimental data and calculating drying curves and drying rate curves, the higher fit (best model) for describing the drying curve equation was used.

Table 1: Mathematical models applied to the drying curves, **(Mohamed et al., 2005).**

Model number	Model name	Model expression
1	Newton	MR = $e^{(-k.t)}$
2	Page	MR = $e^{(-k.t^{n})}$
3	Henderson and Pabis	MR = $a.e^{(-k.t)}$

6. Sensory evaluation

The sensory qualities of different onion slices were carried out in Sensory Evaluation Lab., Food and Nutrition Sciences Department, Faculty of Agricultural and Food Sciences, King Faisal University. The sensory evaluation were analyzed in terms of its appearance, color, flavor, texture and taste. A ten number panel, all of whom were experienced in the sensory evaluation of food. A ten point scale was used where 10 = excellent and 1 = extremely poor. Accuracy and precision were statistically analyzed.

7. Statistical analysis

An ANOVA procedure for the statistical analysis of the results was done by using the SAS software. Least significance difference test was used to determine difference between means. Significance was assumed at $p \leq 0.05$

RESULTS AND DISCUSSIONS

1. Drying curves

The onion slices were dried as a single layer with thickness of 4, 6 and 8 mm at drying air temperatures of 40, 50, 60, 70, and 80 °C in convection dryer. The relationship between dimensionless moisture content(moisture ratio) and drying time of onion slices (4, 6, and 8mm thickness) at different air temperatures are shown in Fig. 2. Results show that the air temperature had a high significant effect on drying rates of onion slices. With the increase of the air temperature, the time required to achieve certain moisture content decreased.

The drying time for onion slices (4 mm thickness) at 40, 50, 60, 70, and 80 ^{o} c were 9, 6.5, 5.5, 4, and 3.5 h, respectively. The time required for the onion slices (6 mm) at 40, 50, 60, 70, and 80 ^{o} c were 10, 7.5, 6.5, 5,

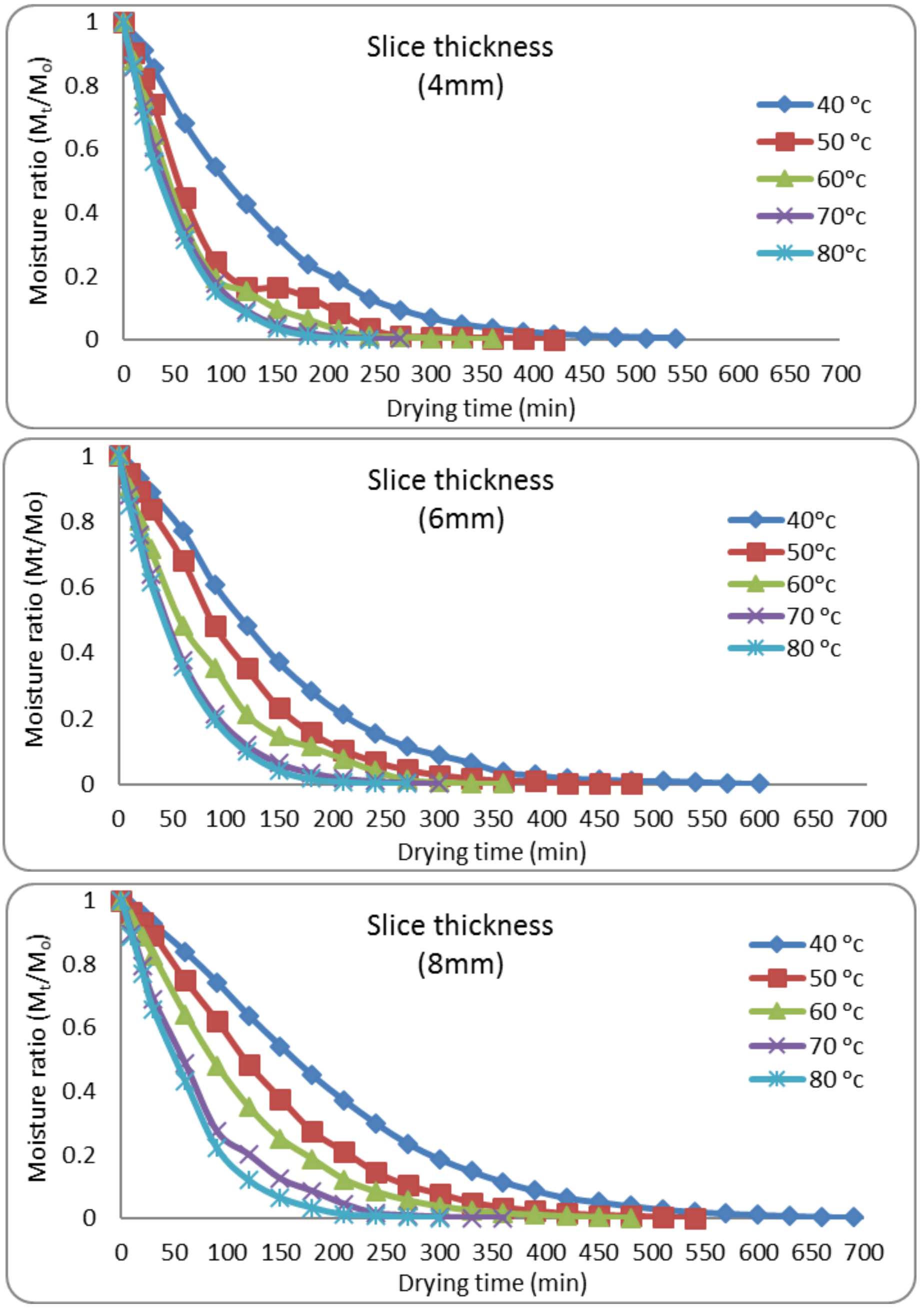

Fig.2. Experimental moisture ratio Vs. drying time at different drying air temperatures and slices thickness.

and 4.5 h respectively. While The time required for the onion slices (8 mm) at 40, 50, 60, 70, and 80 °C were 11.5, 9, 7.5, 6, and 5 h respectively. The highest decrease in drying time observed at increase air temperature from 40 °C to 50 °C.

In general, increasing air temperature by 10°C starting from 40 to 50, 60, 70 or 80°C reduced the drying time by percent reductions compared to the drying time required to reduce moisture content to about .03 kg water/ kg dry matter at 40°C drying air temperature are shown in Table 2.The reduction in drying time with increase of drying air temperature is due to the fact that high temperature provides more heating energy which speeds up the movement of water molecules. The higher temperatures also provide a larger water pressure deficit (the difference between the saturated water vapor pressure and partial pressure of water vapor in air at a given temperature), which is one of the driving forces for outward moisture diffusion process. Similar behavior of decrease in drying time with increase of drying air temperature were obtained by Doymaz (2004) for carrot cubes; Shi et al. (2008) for blueberries, (Hathan and Malhotra, 2012) for carrots shards, Workneh et al.(2011)for Tomato slices and Berinyuy et al.(2012) for African leafy vegetables

Fig.3 shows typical drying curves, which are characterized by two falling rate periods with no undoubtedly apparent constant rate period. However, it might be possible to have a very short constant rate period at lower drying air temperatures (40 and 50 °c) followed after the initial period of increasing drying rate. In this period samples retained almost constant temperature (Fig.4) and then kept growing. After the first critical point (in interval from 0.8176 to 0.9186 kgw kgdb1), the internal resistance of product increase, resulted in the first falling rate period. The second falling rate period started after the second critical point (around 0.3 kgw / kgdb according to air temperature).If the slope of tangent to the drying curve (dMR/dt) was considered as the drying rate of the sample, the results suggested that in the second period drying was faster than in the first falling rate period. Similar results were obtained during the drying of sweet potato slices (Diamante, 1994) and during drying of apple (Velic et. al., 2004)

Fig. 4 shows the internal onion slices temperature for drying at drying air temperature of 40, 60, 70, 80°C. The internal temperature sharply increased to the peak value depending on the set temperature and remained almost constant with small variations thereafter during the first 2 to 3 hours . In this case, where the drying air temperature was set to 40 and 50°C, the material internal temperature showed a slight increase and remained to be below 34 and 43.0°C respectively. Whereas for 60, 70 and 80°C drying air temperature for hot air ventilation heating alone the internal 0nion slice temperature sharply increased to a maximum temperatures of about 56, 67 and 75°C and remained constant thereafter. The difference in internal onion slices temperature depending on slices thickness was little bite. Increasing slice thickness 2mm decreased slice temperature about (1.0 – 1.5 °c).

Table 2. Effects of different drying air temperature and slice thickness on drying time of onion slices.

Onion slice thickness (4 mm)		
Temperature °C	Time (h)	Percent reduction in drying time
40	9.0	0
50	6.5	27.7
60	5.5	38.8
70	4	55.5
80	3.5	61.2
Onion slice thickness (6 mm;)		
Temperature °C	Time (h)	Percent reduction in drying time
40	10	0
50	7.5	25
60	6.5	35
70	5	50
80	4.5	55
Onion slice thickness (8 mm;)		
Temperature °C	Time (h)	Percent reduction in drying time
40	11.5	0
50	9	21.7
60	7.5	34.8
70	6	47.8
80	5	56.5

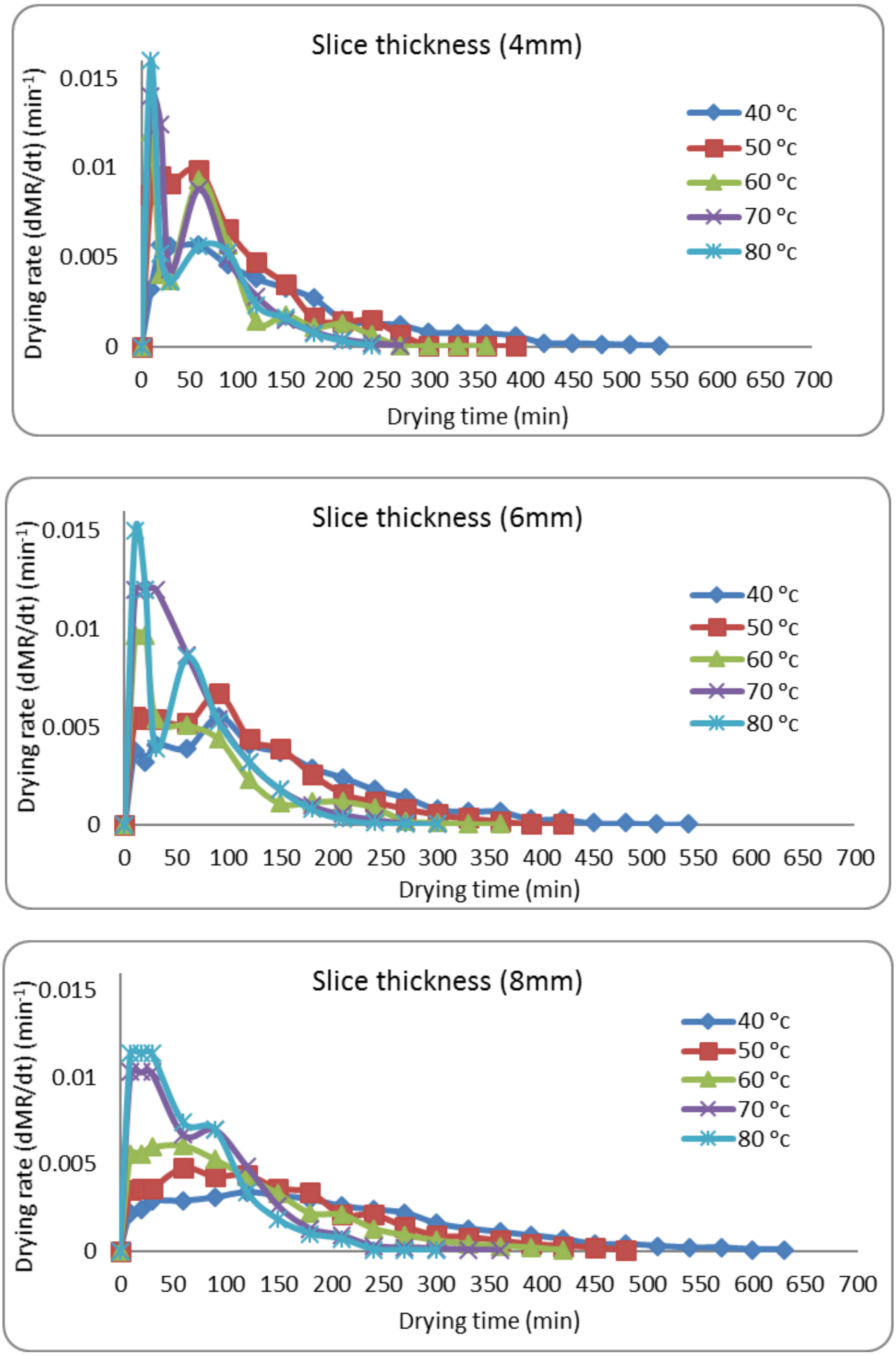

Fig.3. Drying rate Vs. drying time at different drying air temperatures and slices thickness

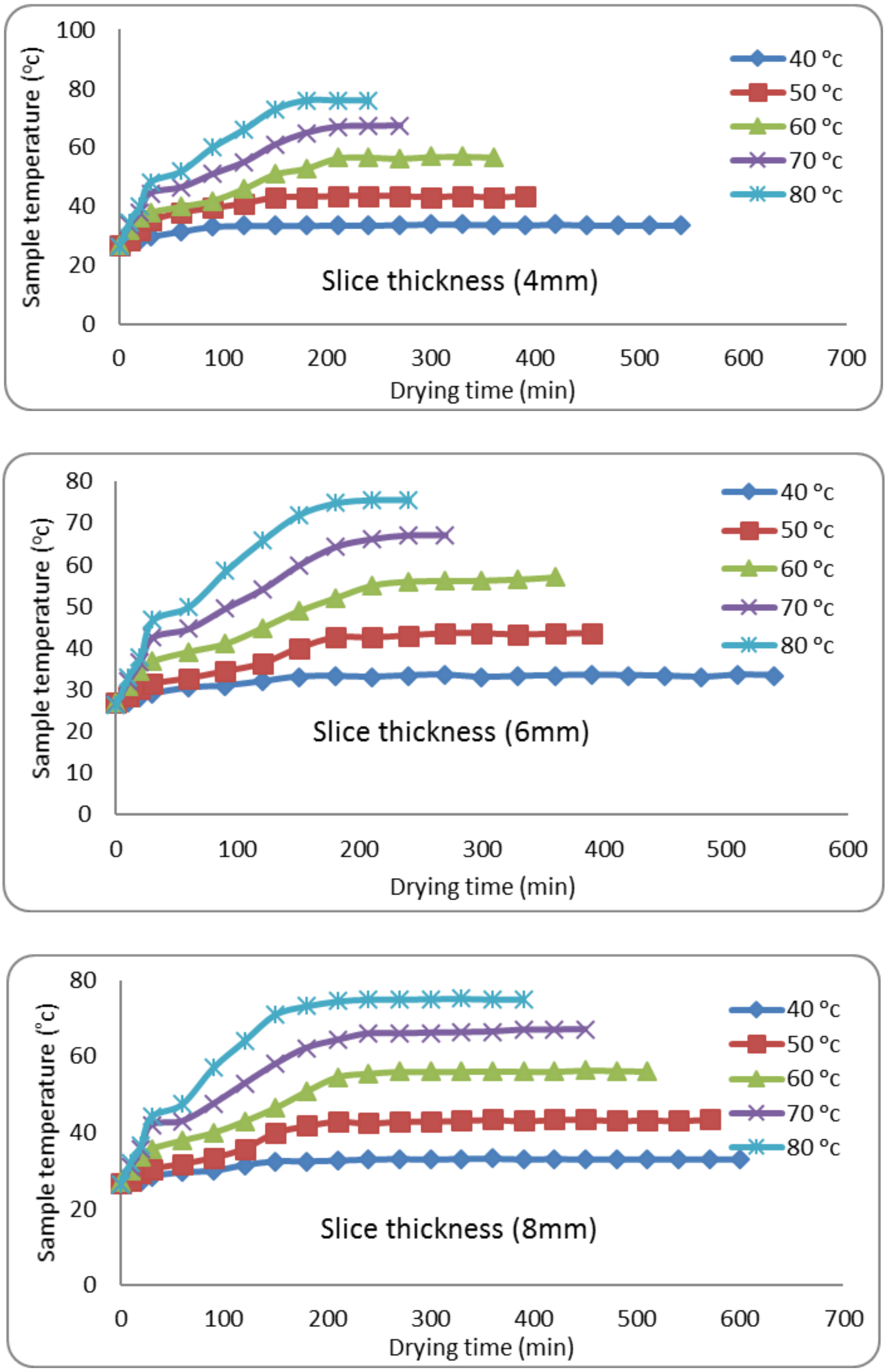

Fig.4. Temperature of sample Vs. drying time at different drying air temperatures and slices thickness

2. Mathematical modeling of drying curves

The drying curves were fitted to three drying equations presented in table 1. All equations gave consistently high (R^2) values in range of .0.994 - .999. This indicates that all equations could satisfactorily describe the drying rate of onion slices. Exponential equation (Page model) gave higher (R^2) values and lower (χ^2) values with other equations. In general, the page equation best fitted to the experimental dimensionless moisture content data followed by the Henderson and Pabis equation then Newton equation.

The linear regression of the moisture reduction with drying using exponential equation time yielded drying constants (k) and (n) according to drying air temperature (T) and slice thickness (Th). The results of numerical adoptions of experimental data are summarized in tables 3. a, b and c.

The reliability of the Page's model is evaluated by comparing the experimental and predicted curves. The results revealed that, the model fitted very well the experimental data for the various slices thicknesses of onion, which is indicated by high values of (R^2) in the range of 0.998 – 0.999 as illustrated in Figures 5 and 6 . The regression equations between predicted moisture content and measured moisture content at recommended temperature (60 °C) were as follow:

$M_p = 0.9914\ M_m - 0.0029$ ($R^2 = 0.998$) --------for 4 mm thickness

$M_p = 1.0006\ M_m + 0.0135$ ($R^2 = 0.999$) --------for 6 mm thickness

$M_p = 1.0006\ M_m - 0.0009$ ($R^2 = 0.999$) --------for 8 mm thickness

It can be seen that a good agreement between experimental data and chosen mathematical model exists, which is confirmed by high values of correlation determination (0.998 – 0.9995).

Fig.5. shows typical drying curves , which are characterized by two falling rate periods with no undoubtedly apparent constant rate period at lower air temperature (40 and 50 °C) followed after the initial period of increasing drying rate.

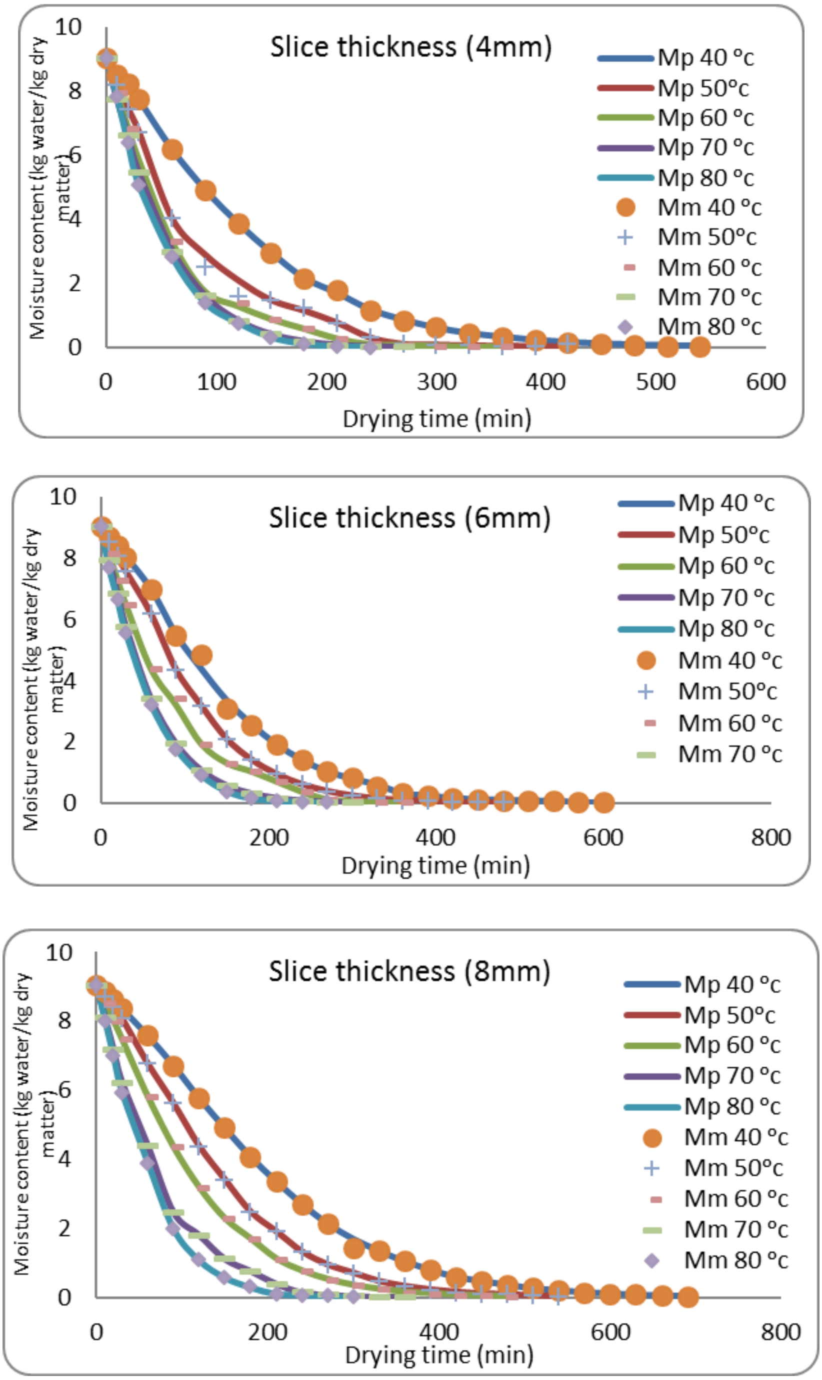

Fig.5. Comparison of measured and predicted moisture content at different drying air temperatures and slices thickness

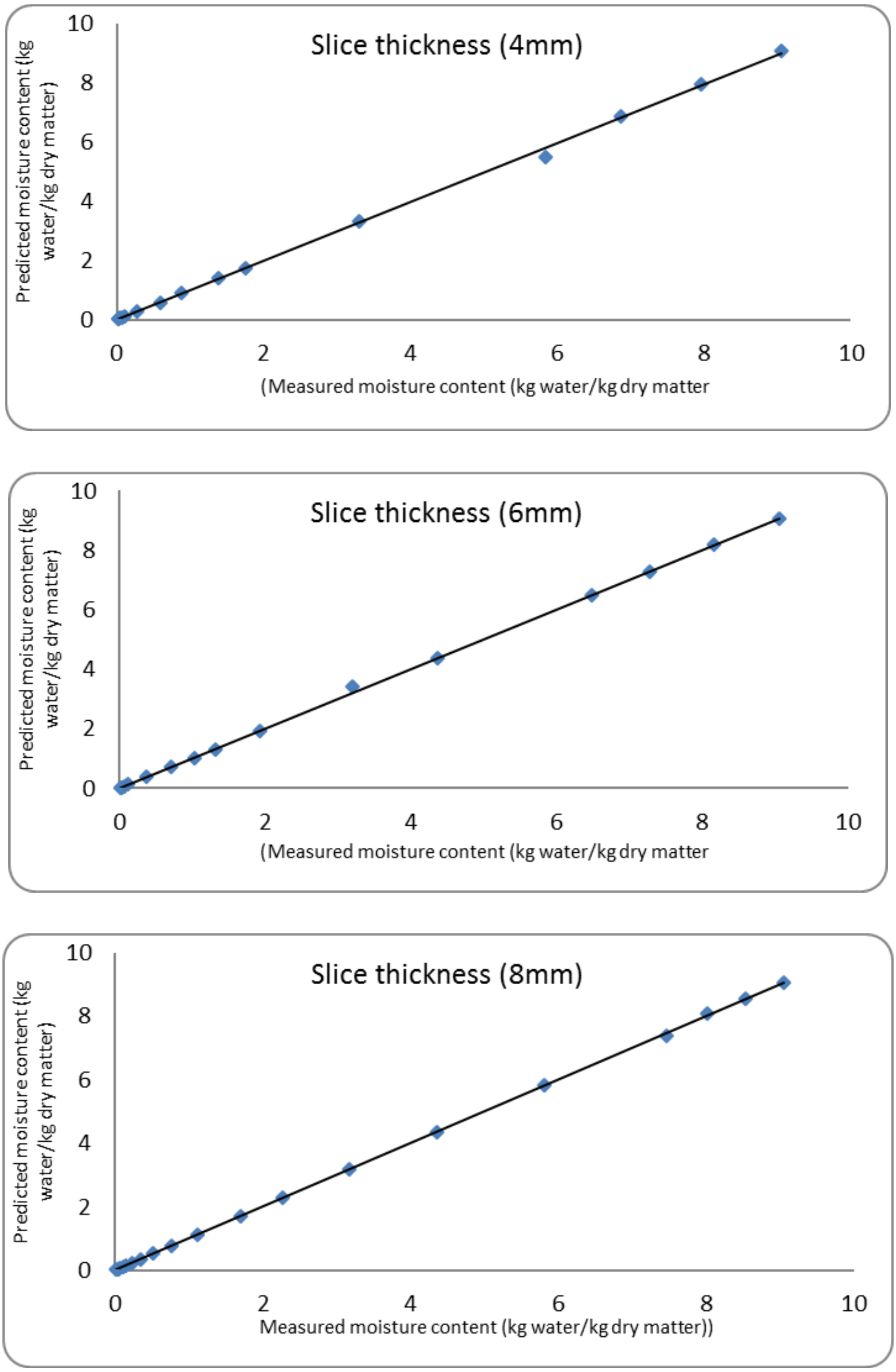

Fig.6. Comparison of measured and predicted moisture content at slices thickness with drying air temperatures (60 °C)

Table 3. a. Results of numerical analyses [Page model]. Time, dimensionless moisture and drying rate in the first and second critical points at different drying air temperatures with slice thickness 4mm

T (^{o}c)		40	50	60	70	80
k		0.002351	0.004057	0.007591	0.011895	0.016634
n		1.234841	1.298510	1.199215	1.102358	1.043251
R^2		0.9981	0.9993	0.9991	0.9994	0.9995
t (min)	CP_1	30	20	15	10	5
	CP_2	150	80	65	60	50
MR	CP_1	0.8549	0.82001	0.8225	0.86022	0.9146
	CP_2	0.3265	0.3010	0.3219	0.3378	0.3734
d MR/d t	CP_1	0.0056	0.0095	0.0080	0.0140	0.01496
(min^1)	CP_2	0.0033	0.0056	0.0057	0.00658	0.0071

Table 3. b. Results of numerical analyses [Page model]. Time, dimensionless moisture and drying rate in the first and second critical points at different drying air temperatures with slice thickness 6mm

T (^{o}c)		40	50	60	70	80
K		0.001025	0.002145	0.005820	0.009946	0.011468
N		1.374810	1.301215	1.201714	1.120121	1.101336
R^2		0.999140	0.999309	0.999186	0.999486	0.999516
t (min)	CP_1	35	30	20	15	10
	CP_2	160	120	80	70	60
MR	CP_1	0.8428	0.8358	0.8480	0.8323	0.8651
	CP_2	0.3332	0.3366	0.3240	0.3355	0.3527
d MR/d t	CP_1	0.0041	0.0067	0.00991	0.0120	0.0130
(min^1)	CP_2	0.0031	0.0044	0.00444	0.0051	0.0066

Table 3. c. Results of numerical analyses [Page model]. Time, dimensionless moisture and drying rate in the first and second critical points at different drying air temperatures with slice thickness 8mm

T (°c)		40	50	60	70	80
k		0.000574	0.001068	0.002734	0.006018	0.007889
n		1.398714	1.36821	1.242150	1.212358	1.168425
R^2		0.999140	0.999309	0.999186	0.999486	0.999516
t (min)	CP_1	50	40	30	18	15
	CP_2	210	150	120	80	70
MR	CP_1	0.8723	0.8469	0.8447	0.8596	0.8296
	CP_2	0.3619	0.3762	0.3514	0.2994	0.3232
d MR/d	CP_1	0.0038	0.0042	0.0060	0.0103	0.0114
t (min^1)	CP_2	0.0026	0.0036	0.0043	0.0077	0.0074

CP_1—first critical point; CP_2—second critical point.

3. Quality of dried onion slices

The quality of dried onion slices were measured by testing final moisture content, rehydration ratio, texture and color. The difference in final moisture content of the dried onion slices was not significant for all drying condition. Average final moisture content foe dried product was about .03 kg water/ kg d.m. The slices thickness had significant effect on rehydration ratio. 8 mm thickness had significantly ($p\leq 0.05$) lower rehydration ratio than 6mm and 4mm thickness (3.08, 3.35 and 3.71, respectively). This could be due to the deformation of cell structure as a result of cutting process, which resulted in more quick water transfer. In all cases dried materials did not rehydrate to their initial moisture content on reconstitution. Rehydration did not show a clear dependence of rehydration ability of dried onion on drying air temperature. No significant differences ($P \leq 0.05$) were noticed among drying air temperatures and slices thickness in texture of dried samples. The mean texture value was around 18 N. The color is an important one among several subjective quality attributes of dried onion slices which indicates the level of effects of different drying conditions. The color plays a crucial role especially when it comes to consumer's preference. Table 3 display the change in color of fresh and dried onion slices that were subjected to different drying air temperature during hot air ventilation drying. The data clearly showed the dried onion slices were found to be relatively darker than fresh ones as the result of L* value decreased for all dried samples when compared with L* values for fresh onion slices. However, the color of onion slices subjected to 70 and 80°C were found to be significantly ($p \le .05$) darker than the others.. Drying using hot air at 40, 50 and 60 °C produced brighter and less dark onion product. Drying using 40, 50 and 60 °C was found to be the best in terms of maintaining the color quality of the onion slices. The higher a* values of slices were found in onion samples subjected to 70 and 80 °C which means higher redness in color of these samples. But the b* value increased after drying compared to the b* values for fresh slices. The reduction in b* values were savior in onion slices subjected to high temperature. No significantly differences ($p \le .05$) were found among above mentioned three slice thickness on color of onion slices. No significant differences were noticed in all evaluated sensory properties except for 80 °C hade the lowest color and overall acceptability.

Table 3. Colour changes during drying of onion slices using different drying air temperature. ($p \le 0.05$)

Drying temperature (^{o} c)	L*	± SD	a*	± SD	b*	± SD
Fresh	63.41	1.27	-1.11	0.3	6.11	0.52
40	50.23	1.45	0.35	0.10	10.5	.08
50	48.50	1.10	0.42	0.02	12.52	.07
60	46.5	0.94	0.75	0.52	12.95	0.23
70	42.5	0.95	3.1	0.17	14.8	1.12
80	37.21	1.01	3.9	.25	15.11	1.32

CONCLUSSION

1 –Page's equation (exponential model) fitted very well the experimental data and it is possible to accurately simulate the thin layer drying behavior of onion slices at different air temperature.

2- An increasing of air temperature resulted in increase of moisture removal rate and decrease in required drying time

3 –Drying constants (k and n) were greatly affected by drying air temperature and slice thickness.

4 –Two well-defined falling rate periods with different drying rates were observed at all examined air temperature and slice thickness and a very short rate period at lower air temperature (40 °C) were observed.

5 – During rehydration of dried onions,3.08 to 3.71 of rehydration ratio by the drying process was obtained. The rehydration ratio was affected by slices thickness of dried onion.

6 – Drying of onion slices at range of (40 – 60°C) revealed optimum color values, meanwhile drying at 70- 80 °C gave least acceptable color values. So if the economics of the process is considered, drying at 50 to 60 °C is generally recommended

7 – The quality of the dried onion is acceptable in taste and appearance.

REFERENCES

AmerEssa, A. H. (1998). The engineering factors affecting handling and loss reduction of egg production. *Ph.D. thesis*, University of Minoufiya, Egypt.

AOAC (1990). *Official methods of analysis* (13th ed.) Washington, DC, USA, Association of official analytical chemists.

Arslan, D. and Ozcan, M. M. (2010). Study the effect of sun, oven and microwave drying on quality of onion slices. *LWT – Food science and Technology*, 43, 1121 – 1127

Berinyuy, J. E., Tangka, J. K. and Weka, Fotso, G. M. (2012). Enhancing natural convection solar drying of high moisture vegetables with heat storage

Bruce, M.(1985). Exposed layer barley drying: three models fitted to new data up to150°C. *J. Agric. Eng. Resear.*, 32: 337-347.

Diamante, L. M. (1994). Drying characteristics of sweet potato slices. In Proceedings of the international conference of preservation and security (pp. 187–199).

CAPMS. (2011). Annual year book for general statistics. Central Agency for public Mobilization and Statistics of A.R.E., Egypt.

Doymaz, I., and Pala, M. (2002). The effects of dipping pretreatments on air-drying rates of the seedless grapes. *Journal of Food Engineering,* 52(4), 413–417

Doymaz, I. (2004).Convective air drying characteristics of thin layer carrots. *J. Food Eng.*, **61**: 359–364.

Gustavssion, J., Cederberg, C. and Sonesson, U. (2011).Global food losses and food waste.

Hathan, B. S. and Malhotra, T. (2012) Drying kinetics of osmotically pretreated carrot sheared to be used for preparation of sweet meat.*Agric. Eng. Int. :CIGR Journal, 14 (1) 125-135*

Kalse, S. B., Patil, M. M., and Jain, S. K. (2012) Microwave Drying of onion slices. Research Journal of Chemical Sciences, 2(4), 57-60

Koyuncu, T, Tosun, I.andpinar, Y. (2007). Drying charateristics and heat energy requirement of cornelian cherry fruits (cornus mas L). *journal of Food Engineering.* 78 (2), 737 – 739

Kummar, D. G. P., Hebbar, H. U., and Ramesh, M. N. (2006). Suitability of thin layer models for infrared-hot air-drying of onion slices. *LebensmittelWissenschaft Und Technologie,* 39, 700- 705

Lin, T. M., Durance, T. D. and Scaman, C. H. (1998). Characterization of vacuum microwave air and freeze dried carrot slices. *Food Research International,* 4, 111-117

Mohamed, M. A., Gamea, G.R. and Keshek, M. H. (2005). Drying characteristics of okra by different solar dryers.*Misr j. Agr. Eng.*, 27 (1) 294-312**.**

Midilli, A., Kucuk, H. and Yapar, Z. (2002). A new model for single layer drying. *Drying technology,* 20(10): 1503-1513.

Ozdemir, M. and Devres, Y. O. (1999). The thin layer drying characteristics of hazel-nuts during roasting. *Journal of Food Engineering*, 42, 225-233

Parakash, S., Jha, S.K. and Datta, N. (2004). Performance evaluation of balanced carrots dried by three different driers. *Journal of Food Engineering.,* 62, 305-313.

Perry, H.and D.R. Green, D.R.(1984).*Perry's chemical engineering handbook (6th ed.). New York: McGraw-Hill.*

Saad, M. M., RizkS. S. and Metweally, M. N. (1992). Using the solar energy in drying of agricultural products. *El-Dar El-Dawlia for Pub.And Delivering, Cairo, Egypt*

Sharma,G P., Verma, R. C. and Pathare, P. (2005). Mathematical modeling of infrared radiation thin layer drying of onion slices. *J. Food Eng.,* **71**: 282–286

Shi, J., Tara, H., McHugh, D. Wood, E. Hirscberg and Olson. (2008). Drying and quality characteristics of fresh and sugar-infused blueberries dried with infrared radiation heating. *LWT- Food science and Technology,* 41 (10): 1962-1972

Velice, D., Planinic, M., Tomas, S. and Bilic, M. (2004). Influence of airflow velocity on kinetics of convection apple drying. *Journal of Food Engineering* 64 , 79-102

Workneh, T. S., Raghavan, V. and Gariepy, Y. (2011). Microwave assisted hot air ventilation drying of tomato slices. *International conference on food engineering biotechnology*. Singapoor.IPCBEV, vol.9, 150-162.

الملخص العربى

تأثير ظروف التجفيف على سلوك التجفيف والجودة لشرائح البصل

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يعتبر التجفيف من الطرق الهامة لحفظ الخضروات والفاكهة , ومن العوامل الأساسية التي تؤثر على جودة المنتجات المجففة وقابليتها لدى المستهلكين وتكلفة التجفيف بالإضافة الي سلوك التغير في المحتوى الرطوبى للمنتجات اثناء التجفيف هى درجة حرارة هواء التجفيف وسرعة الهواء والرطوبة النسبية وشكل المنتج المجفف ومعاملات ما قبل التجفيف.

لذلك كان الهدف الأساسى لهذا البحث دراسة تأثير بعض العوامل الهامة مثل درجة الحرارة وسمك الشرائح على سلوك التجفيف والجودة لشرائح البصل الأبيض وتحديد الظروف المثلى التى تعطى افضل جودة للمنتج مع اعلى معدل تجفيف.

***استاذ مساعد بقسم الهندسة الزراعية – كلية الزراعة – جامعة المنوفية – مصر.**

تم اجراء تجارب التجفيف باستخدام مجفف الصواني التجريبي المزود بآلية للتحكم فى مستوى درجات الحرارة ومعدل تصرف الهواء خلال حجرة التجفيف . وكذلك مزود بميزان حساس دقيق لقياس الفقد فى الرطوبة من المنتج اثناء التجفيف دون فتح حجرة التجفيف

تم دراسة تأثير خمس مستويات من درجة حرارة هواء التجفيف (٤٠، ٥٠، ٦٠، ٧٠، ٨٠ °م) وثلاث مستويات من سمك شرائح البصل (٤، ٦، ٨ مم) عند سرعة هواء ١,٥ م|ث على خصائص التجفيف وجودة المنتج المجفف (المحتوى الرطوبي النهائي، القوام اللون ، نسبة الاسترجاع ، القابلية لدى المستهلك). تم قياس التغيرات فى درجة حرارة المنتج وكذلك درجة حرارة هواء التجفيف ورطوبته النسبية وسرعة الهواء والفقد فى الرطوبة للمنتج خلال تجارب التجفيف. تم استخدام برنامج حاسب آلي لانتقاء الموديل الرياضي الذى بصف منحنيات التجفيف.

ومن اهم النتائج التى تم الحصول عليها:

- معادلة بيج Pag's equation (exponential model) كانت افضل الموديلات التي تمثل منحنيات التجفيف تمثيلا جيدا : $MR = e^{(-k.t^n)}$
- زيادة درجة حرارة هواء التجفيف ادت الى انخفاض الوقت اللازم للتجفيف وزيادة معدل فقد الرطوبة من المنتج
- تأثرت ثوابت التجفيف في الموديل الرياضي لوصف سلوك التجفيف بدرجات الحرارة وسمك شرائح البصل
- لوحظ مرحلتين لمعدل التجفيف المتناقص من خلال منحنيات التجفيف ومرور المنحنيات بمعدل تجفيف ثابت خلال فترة قصيرة جدا عند استخدام درجات الحرارة المنخفضة (٤٠ ، ٥٠ °م)
- نسبة الاسترجاع لشرائح البصل المجففة تراوحت بين ٣,٠٨ الى ٣,٧١ حيث زادت نسبة الاسترجاع عند انخفاض سمك الشرائح ولم تتأثر بشكل واضح بدرجة الحرارة.
- اعطت درجات الحرارة المنخفضة (٤٠ ، ٥٠ °م) افضل درجة للون المقبول لشرائح البصل المجففة بينما اعطت درجات الحرارة العالية (٧٠، ٨٠ °م) اقل درجة للون المقبول لذلك يوصى البحث باختيار نطاق من ٥٠ °م – ٦٠ °م تكون مقبولة من ناحية الجودة والمعدل وكذلك اقتصاديا فيما يتعلق بالطاقة المستهلكة.