J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 6 (5): 637 - 654, 2015

INFRA-RED DRYING OF ONION SLICES.

Matouk, A. M.[1] ; M. M. El-Kholy[2] ; A. Tharwat[3] and A. M. Anter[4]

1- Agric Eng. Dept., Fac. of Agric., Mansoura Univ.
2- Agric. Eng. Res. Institute.
3- Eng. Dept., Fac. of Agric., Mansoura Univ.
4- Agric. Eng. Dept., Fac. of Agric., Mansoura Univ.

ABSTRACT

A study was carried out to test and evaluate the use of infra-red radiation as a heat energy source for drying onion slices(*Allium cepa* L.) using a laboratory scale infra-red dryer.

The studied parameters included four different levels of infra-red radiation intensity (0.861, 0.973, 1.039 and 1.161 kW/m²), three different levels of inlet air temperature (40, 50 and 60 ^{o}C) and three different thicknesses of onion slices (2, 4 and 6 mm). All the experimental runs were conducted at air velocity of 1 m/s. Meanwhile, two different drying models, simple exponential model (Lewis's 1921) and the modified exponential model (Henderson and Pabis's 1961) were examined for describing the drying behavior and predicting the changes in moisture content of onion slices during the drying process. Quality evaluation tests were also conducted for the dried onion slices. The measured parameters included, Thiosulphinates, anthocyanin and rehydration ratio. The results showed that:

1- The drying rate of onion slices increased with the increase of radiation intensity and drying air temperature while, it was decreased with the increase of slices thickness.
2- Both studied models could describe the drying behavior of onion slices satisfactory. However, the simple exponential model (Lewis's 1921) was selected .
3- The onion slices dried at radiation intensity of 0.861 kW/m^2, air temperature of 50 ^{o}C and slices thickness of 4 mm recorded the highest quality of the dried samples in terms of thiosulphinates and anthocyanin contents and the best rehydration ratio .

INTRODUCTION

Onion, *Allium cepa* L., is considered as one of the most important crops in all countries. Domestic onion is the round, edible bulb of *Allium cepa*, a species of the lily family, and one of the world's oldest cultivated vegetable crops. Red, white and gold onions represent the most known varieties of this species (Bonaccorsi et al., 2008).

Onion is a strong-flavored vegetable used in a wide variety of ways, and its characteristic flavor (pungency) or aroma, biological compounds and medical functions are mainly due to their high organo-sulphur (Corzo-Martínez et al., 2007).

Onion has different nutritional compositions, depending on the variety and stage of maturity, among others. However, according to the USDA National Nutrient Database for Standard Reference (USDA, 2007), the nutritional composition of raw onions, per 100 g of edible portion is 89.11 g of water, 1.10 g of protein, 0.10 total lipids (fat), 0.35 g of ash, 9.34 g of carbohydrate, 4.24 g of total sugars and 1.7 g of total dietary fiber, corresponding to an energy of 40 kcal. The most important minerals are potassium, calcium and selenium.

The gradually increasing production status of onion itself speaks of its high demand (The Hindu Survey, 2007). The world production of onion was 64.48 million ton from 3.45 million ha area (FAO, 2009) .The total planted area in Egypt is 101385 feddan and the production is 1,301,175 ton yearly (12.834 ton / feddan) (Agricultural Statistics, 2006).

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 wide variety of food formulations such as comminuted meats, sauces, soups, salad dressings, pickle and pickle relishes (Anonymous, 2002).

Infrared radiation has significant advantages over conventional drying. Among these advantages are higher drying rates giving significant energy savings and uniform temperature distribution giving a better quality product. Therefore, it can be used as an energy saving drying method. At present, it has been applied in various types of driers (Abdelmotaleb et al., 2009, Matouk et al., 2014a and Matouk et al., 2014b). Using the characteristics of infra-red radiators, technology development on the utilization of far infrared radiation is an energetic advance that can give an increase in drying efficiency, space saving, clean working environment, etc.(Ratti and Mujumdar, 1995) . However, research which quantitatively analyzed heating and drying of some crops such as onion by infrared radiation are very usfeul to study.

The general objective of the present work was to study, evaluate and simulate the use of infrared radiation as a heat energy source for drying onion slices under different levels of radiation intensity, air temperature and thicknesses of onion slices. It also aimed to study the effect of using infra-red radiation in decreasing the drying time and enhancing the product quality. Two different mathematical models for simulation the drying behavior of onion slices were also examined.

MATERIALS AND METHODS

The experimental work was carried out to analyze the effect of different levels of radiation intensity (0.861, 0.973, 1.093, and 1.161 kW/m²) , different levels of drying air temperature (40,50 and 60 ^{o}C) and different thicknesses of onion slices (2, 4 and 6 mm) on the drying behavior of onion slices and quality changes of the dried onion slices. The Behairy of onions which was available in a local market was selected for the experimental work. The raw onions had an initial moisture content of 86 – 88% (w.b.). Onion preparation included manual trimming and peeling followed by slicing with a domestic slicer.

To achieve the objectives of the present study, the experimental scale infra-red dryer developed by Matouk et al., (2014a) was used as shown in Figure (1).

The dryer consists of three shelves, each shelf was (70*50*40) cm (L*W*H). The drying trays which were made of stainless steel wire net were situated at 15 cm from each ceramic Infrared heater.

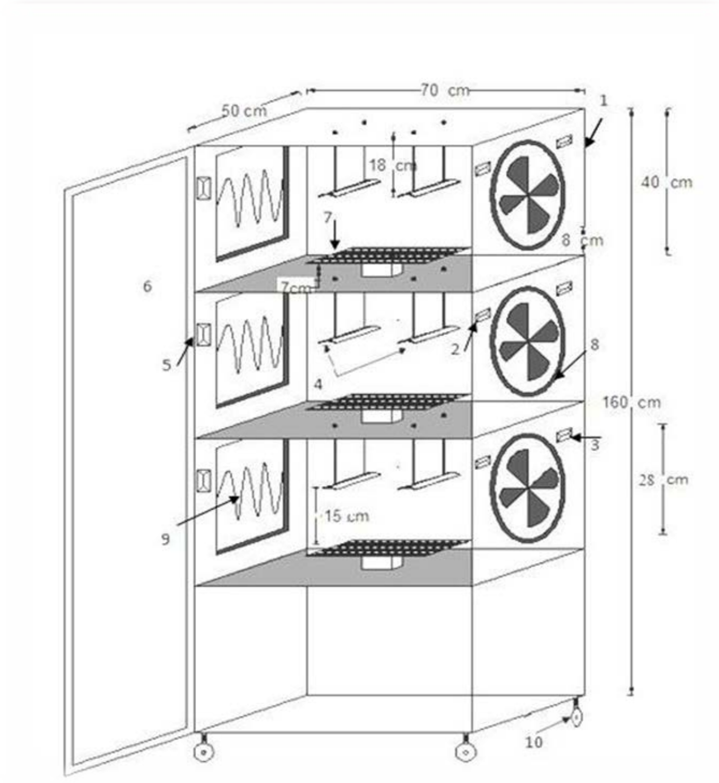


Fig.(1):Schematic diagram of the laboratory scale dryer.

1-The dryer frame 2- Fan's switch 3-Dimmers of infra-red heaters
4-Infra-red heaters 5-Thermostat 6-Tempered glass
7-Sample's tray 8- Axial Flow Fa 9- Electric heater
10- Wheel

For infrared heating process, two (1 kW, 750 ^{o}C) ceramic Infra-red heaters were fixed over two iron blades and assembled into the sealing of each drying chamber facing the drying trays .To control the radiation intensity of the infra-red heaters, electric dimmers were used .An electric heaters were also used for air heating with digital thermostat for temperature control of air. Three identical axial flow fans were used for suction of the air passing to each drying chamber over the surface of each drying tray. The drying air was supplied equally at velocity of 1 m/s as recommended by Matouk et al., (2014a). Fig.(1) illustrates schematic diagram of the laboratory scale dryer used for the experimental work.

Experimental Measurements and Instrumentation:

1- Radiation intensity measurement:

A radiation sensor with data recorder (model H-201) was used for measuring and calibrating the radiation intensity over the sample of each tray.

2- Air velocity measurement

A TRI-SENSE temperature/ humidity/ air velocity meter (model Trotec 2000S) was used for measuring the air velocity over the samples surface with an accuracy of 0.01 m/s.

3- Temperature measurement:

A temperature meter model (Trotec-2000S) connected to an Iron-Constantine thermocouple type (T) was used to measure the temperature of air passing over each drying tray.

4- Mass measurement

The mass of the samples was recorded using a digital balance with an accuracy of 0.01g and 200g max.

5- Moisture content of onion slices:

The initial and final moisture contents of onion slices were determined by oven method at 70 ^{o}C for 16 h as recommended by A.O.A.C. (1995) .

Experimental Procedure:

The onion bulbs were peeled and cut into slices with thickness of 2, 4 and 6 mm. After that, onion slices were pre-treated by dipping into a solution of 0.5% sodium chloride (NaCl) plus 1% citric acid for 5 min as recommended by Hareedy ,(2000). Prior to each experimental run, the radiation intensity, air temperature and air velocity were adjusted in presence of dummy samples and left until stable operation condition. The pre-treated onion slices were distributed uniformly in a single layer at each perforated tray and placed directly inside the drying bed. At the same time three sub samples each of 10 g were taken from the pre-treated onions and kept in tins to determine the initial moisture content During the drying process, the weight changes of the samples were recorded every 5 min for one hour ,every 10 min for the next two hours and every 20 min until the end of each experimental run, or in other words at final moisture content of 6-8 % d.b. In order to minimize the experimental errors of each run, it was replicated three times, and the average was considered.

Simulation of the Drying Data:

The obtained data of the laboratory experiments was employed to examine the applicability of two thin layer drying models (Lewis's 1921 and Henderson and Pabis's equations 1961) for describing and simulating the drying data.

The examined drying models could be presented as follows:

Lewis's model:

$$\mathrm{MR} = \frac{M - M_f}{M_O - M_f} = \exp(-k_L\ t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

MR: Moisture ratio, dimensionless

M: Instantaneous moisture content during the drying process, % (d.b.).

M_f: Final moisture content of onion slices, representing the equilibrium moisture content, % (d.b.) .

M_o: Initial moisture content of onion slices,% (d.b.).

t: Time, min

k_L: Drying constant , min-1

The values of the drying constant (kL) for the Lewis's model (1) could be obtained from the linear relationship between the moisture ratio (MR) of the tested sample versus the drying time (t) as follow

$\text{Ln } MR = - K_L t$

The slope of the equation represents the drying constant (kL).

Henderson and Pabis's model:

$$MR = A\exp(-k_h t) \quad \cdots\cdots\cdots\cdots\cdots\cdots \text{(2)}$$

Where:

A: Drying constant, dimensionless.

k_h: Drying constant , min -1

The values of drying constants (kh) and (A) for Henderson and Pabis's (equation 2) could be obtained from the linear relationship between (MR) versus the drying time (t) as follow

$\text{Ln } MR = \text{Ln } A - K_h t$

The slope of the drying curve represents the drying constant (kh) while the constant (A) could be calculated from the intercept.

Quality evaluation of the dried onion:

The quality evaluation tests for the dried onion slices included: 1- The amount of thiosulphinates (µmol/g) which was determined as proceeded by Freeman (1974) and then modified by Samaniego et al. (1991), 2- The amount of anthocyanins as proceeded by Fossen et al., (1996) with some modification by Gennaro et al.(2002) and 3- The rehydration ratio of the dried slices as proceeded by Kim and Toledo (1987).

RESULTS AND DISCUSSION

Moisture ratio of onion slices:

The changes in onion slices moisture ratio as related to drying time at different levels of drying air temperature, radiation intensity and slices thickness are illustrated in Figures (2 to 4). As shown in the figures, the moisture ratio of onion slices varied with the experimental treatments and it was decreased with the increase of radiation intensity, and drying air temperature, it was increased with the increase of slices thickness. This was occurred due to the increase in slices temperature as the radiation intensity and the drying air temperature increased while the slices thickness increased. The increase in slices temperature increases the vapor pressure inside the onion slices and the accelerate the drying process.

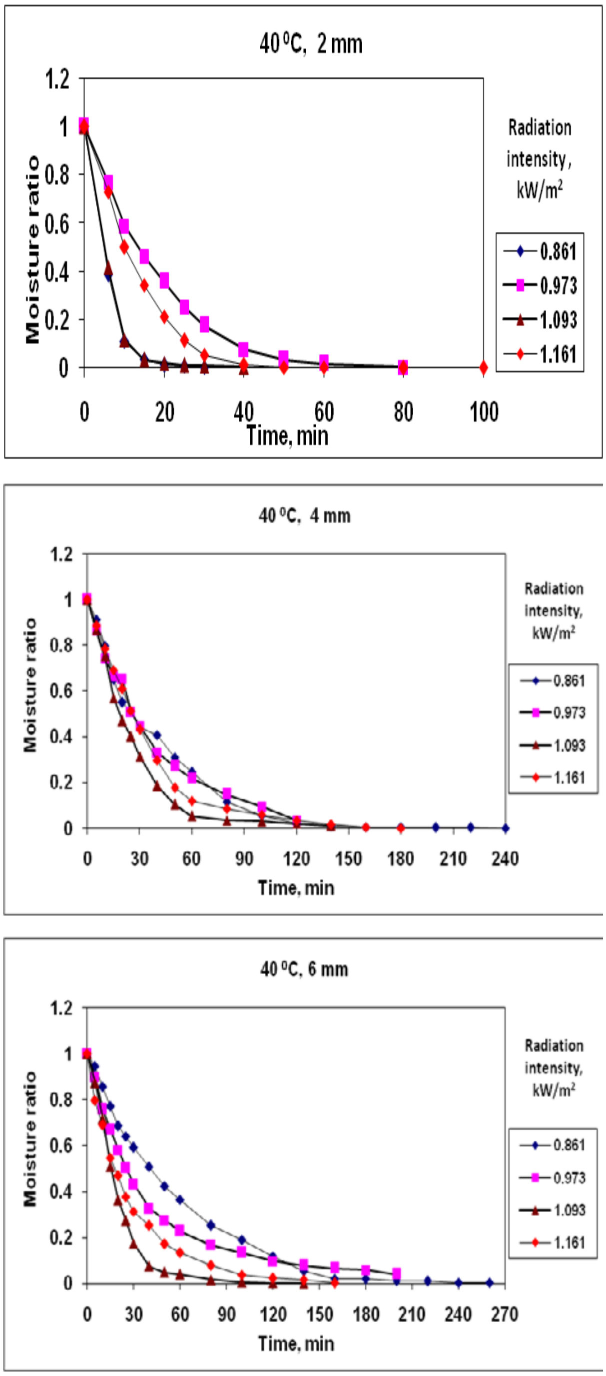


Fig. (2) Moisture ratio of onion slices as related to drying time at different levels of radiation intensity, drying air temperature of 40 °C and different thicknesses of onion slices.

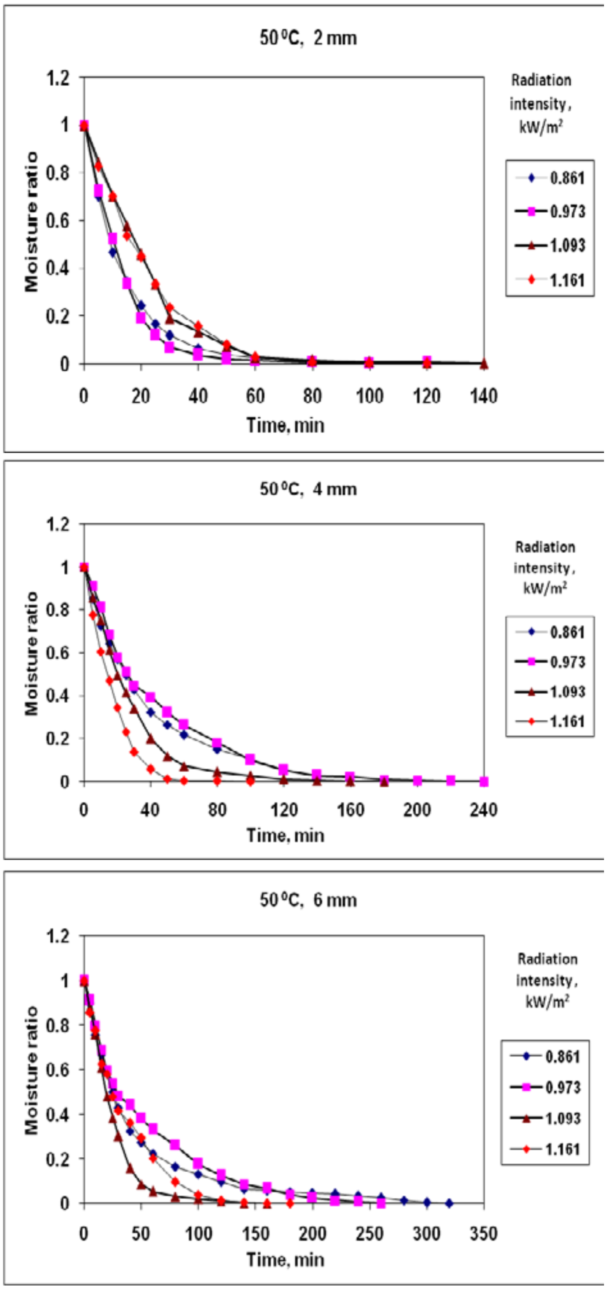


Fig. (3) Moisture ratio of onion slices as related to drying time at different levels of radiation intensity, drying air temperature of 50 °C and different thicknesses of onion slices.

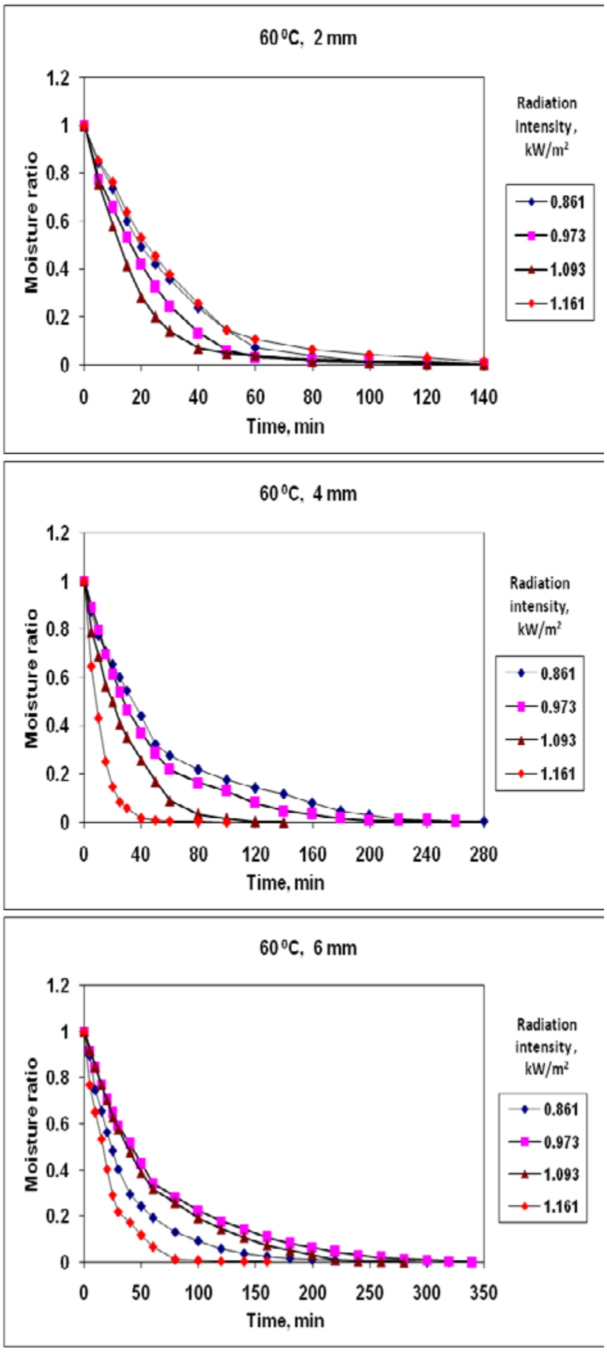


Fig. (4) Moisture ratio of onion slices as related to drying time at different levels of radiation intensity, drying air temperature of 60 °C and different thicknesses of onion slices.

Drying analysis of onion slices using Lewis's model:

Figure (5) illustrates the method of determining the drying constant (k_L) of Lewis's model and table (1) presented the obtained data at different levels of radiation intensity, air temperature and slices thicknesses.

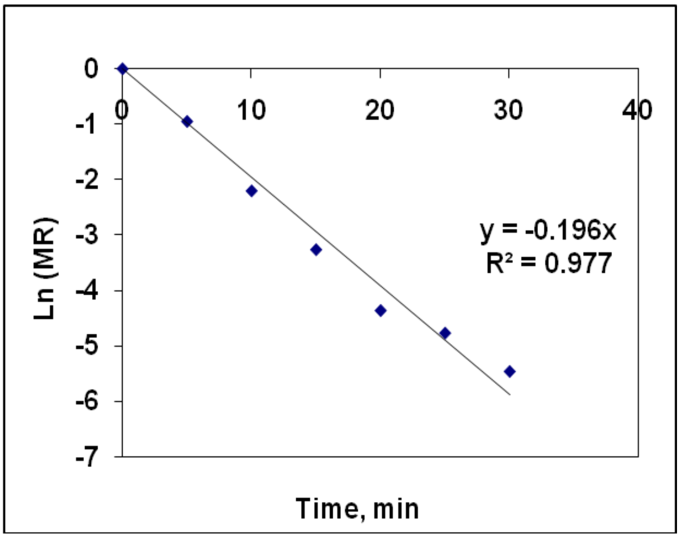


Fig.(5) Determination of the drying constant (k_L) of Lewis's equation at the minimum radiation intensity of 0.861 kW/m^2, air temperature of 40 ^{o}C and 2 mm slices thickness.

Table (1): Drying constant (k_L) for Lewis's equation at different levels of radiation intensity, air temperature and slices thickness.

Air temp., ^{o}C	Slices thickness, mm	Radiation intensity, kW/m^2			
		0.861	**0.973**	**1.093**	**1.161**
40	2	0.0527	0.0663	0.0712	0.0756
	4	0.0202	0.0258	0.0355	0.0424
	6	0.0119	0.0148	0.0290	0.0334
50	2	0.0564	0.0705	0.0799	0.0904
	4	0.0252	0.0284	0.0450	0.0593
	6	0.0161	0.0191	0.0402	0.0495
60	2	0.0597	0.0756	0.0835	0.1069
	4	0.0325	0.0405	0.0471	0.0730
	6	0.0274	0.0360	0.0430	0.0535

As shown in table (1) the drying constant (k_L) increased with the increase of drying air temperature and the increase of radiation intensity. While, it was decreased with the increase of slices thickness.

A multiple regression analysis was made to relate the radiation intensity (I), drying air temperature (T) and slices thickness (T_h) with the drying constant (k_L) at constant air velocity of 1 m/sec. The nature of dependence could be expressed by the following equation:

$$K_L = 0.100696\, I + 0.000833\, T - 0.01073\, T_h - 0.05341 \quad \ldots\ldots (3)$$

$$(R^2 = 0.9032 \quad ; \quad S.E = 0.00809)$$

Drying analysis of thin layer drying of onion slices using Henderson and Pabis's model:

Figure (6) illustrates the method of determining the drying constants (k_h) , (A) of Heneron and Papis's model.

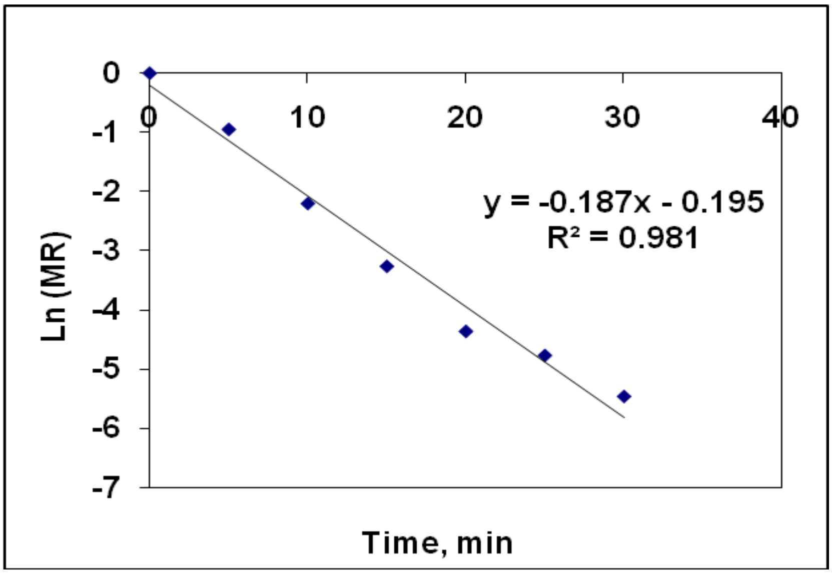


Fig.(6) Determination of the drying constants; (k_h, A) of Henderson and Pabis's model at the minimum radiation intensity of 0.861 kW/m^2, air temperature of 40 ^{o}C and slices thickness of 2 mm .

Table (2): Drying constants (k_h) and (A) of Henderson and Papis`s model at different levels of drying air temperature and radiation intensity.

Air temp.,^{o}C	Thickness, mm	Radiation intensity, kW/m^2							
		0.861		0.973		1.093		1.161	
		K_h	A	K_h	A	K_h	A	K_h	A
40	2	0.0460	0.5412	0.0589	0.6399	0.0621	0.6970	0.0766	0.7089
	4	0.0214	0.9325	0.0238	0.9561	0.0333	1.0798	0.0388	1.1407
	6	0.0117	0.9443	0.0150	0.9607	0.0280	1.1733	0.0331	1.2541
50	2	0.0500	0.6775	0.0652	0.8310	0.0721	0.9569	0.0815	1.0784
	4	0.0229	0.9444	0.0273	0.9901	0.0444	1.1868	0.0611	1.3107
	6	0.0173	0.9845	0.0194	1.0251	0.0381	1.1848	0.0388	1.3101
60	2	0.0603	0.9581	0.0787	1.0208	0.0861	1.1591	0.0987	1.3079
	4	0.0295	1.0140	0.0386	1.0705	0.0483	1.2104	0.0712	1.3530
	6	0.0239	1.0392	0.0311	1.1118	0.0430	1.2136	0.0479	1.3529

As shown in Table (2) the drying constant (k_h) and (A) increased with the increase of drying air temperature and the radiation intensity but they were decreased with the increase of slices thickness.

A multiple regression analysis was also made to relate the studied parameters (I, T and T_h) with the drying constant (k_h) at constant air velocity of 1 m/sec. The nature of dependence could be expressed by the following equation:

$$K_h = 0.095716\, I + 0.000869\, T - 0.01019\, T_h - 0.05487 \qquad \ldots..\ (4)$$
$$(R^2 = 0.908686 \quad ; \quad SE = 0.007115)$$

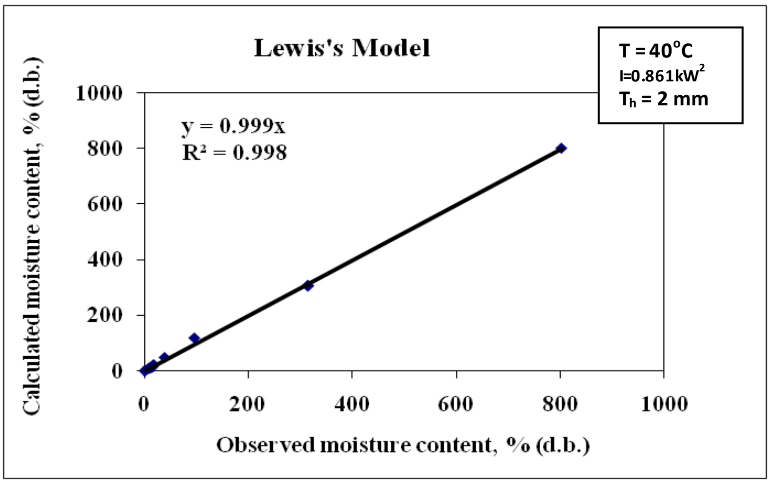
Also a multiple regression analysis was made to relate the studied parameters with the drying constant (A) at constant air velocity of 1 m/sec. The nature of dependence could be expressed by the following equation:

$$A = 1.02976\, I + 0.011595\, T + 0.062034\, T_h - 0.84364 \qquad \ldots\ldots\ (5)$$
$$(R^2 = 0.80349 \quad ; \quad SE = 0.095564)$$

The applicability of the studied models in simulating the laboratory drying data:

1- Lewis's model:

Figure (7) illustrates the observed and predicted moisture content of onion slices at the minimum and maximum radiation intensity of 0.861 and the maximum radiation intensity of 1.161 kW/m^2, drying air temperature of 40^{0}C and slices thickness of 2, 6 mm. The results showed that, Lewis's model described the drying behavior of onion slices satisfactorily as indicated by the high values of coefficient of determination (R^2) and low values of standard error (SE).



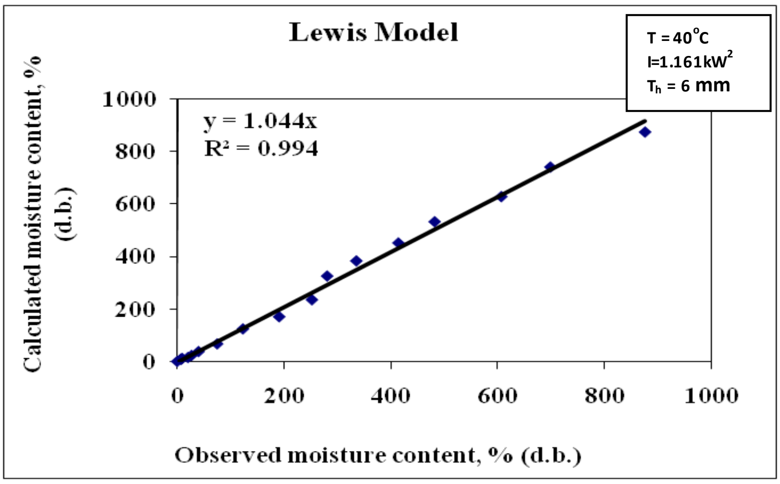


Fig. (7): The observed and predicted values of onion slices moisture content using Lewis's model.

2- Henderson and Pabis's model:

Figure (8) shows the observed and the predicted values of onion slices moisture content at the minimum and maximum radiation intensity of 0.861, 1.161 kW/m^2, drying air temperature and slices thickness of 2, 6 mm. Henderson and Pabis's model described the drying behavior and predicted the change in moisture content of onion slices satisfactorily as indicated by the high values of coefficient of determination and low values of standard error.

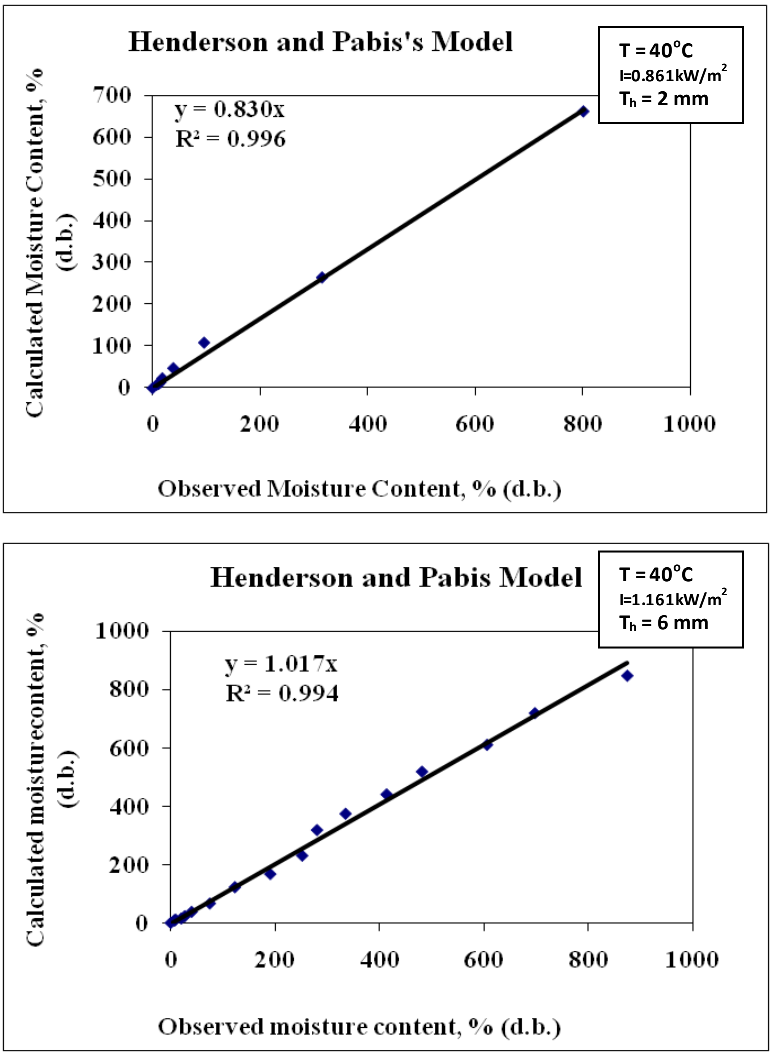


Fig. (8): The observed and predicted values of onion slices moisture content using Henderson and Pabis's model.

Comparative evaluation of the studied drying models:

In general, both studied models could describe the drying behavior of onion slices. However, Lewis's model could be considered more proper for describing the drying behavior of onion slices and predicting the change in moisture content during infra-red drying process due to more simplicity of calculations.

Quality of onion slices :

Thiosulphinates content :

Figure (9) illustrates the changes in thiosulphinates content of onion slices at different levels of infrared radiation intensity, drying air temperature and slices thickness. As shown in the figure the thiosulphinates content of onion slices ranged from 0.411 to 0.744 µmol/g. However, the onion samples dried at 0.861 kW/m^2, air temperature of 50 ^{o}C and slices thickness of 4mm recorded the highest thiosulphinates content of 0.744 µmol/g.

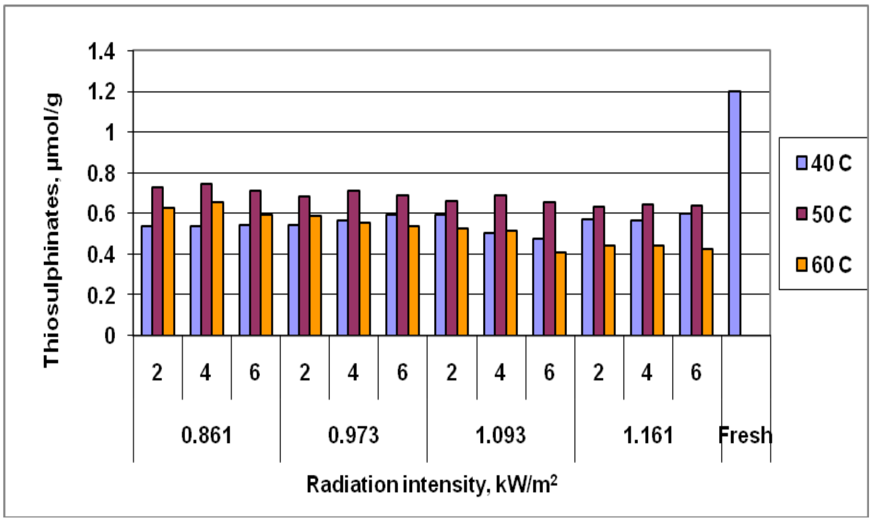


Fig. (9) The changes in thiosulphinates content of onion slices at different levels of the studied parameters.

Anthocyanin :

Figure (10) illustrates the changes in anthocyanin content of onion slices at different levels of infra-red radiation intensity ,drying air temperature and slices thickness . As shown in the figure, the anthocyanin content of onion slices ranged from 12.7 to 36.7 mg/100g and the onion samples dried at 0.861 kW/m^2, air temperature of 50 ^{o}C and slices thickness of 4 and 6mm recorded the highest thiosulphinates contents of 36.49 and 36.7 mg/100g respectively.

Rehydration ratio:

Figure (11) illustrates the change in rehydration ratio of onion slices at different levels of infra-red radiation intensity, drying air temperature and slices thickness. As shown in the figure the percentage of rehydration ratio ranged from 4.17 to 5.88 for the onion slices. In general the recorded rehydration ratios of all treatments combinations were in the acceptable levels mentioned by Sharma et al., (2004).

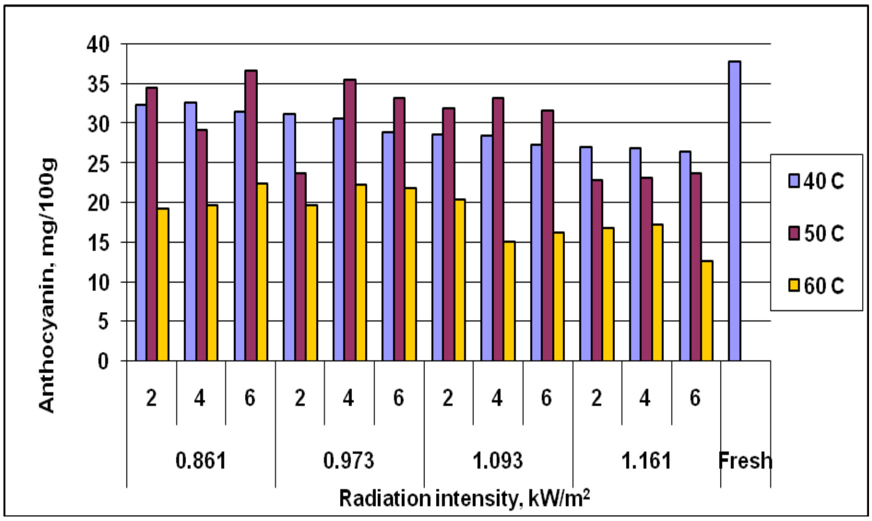


Fig.(10) The changes in anthocyanin content of onion slices at different levels of the studied parameters.

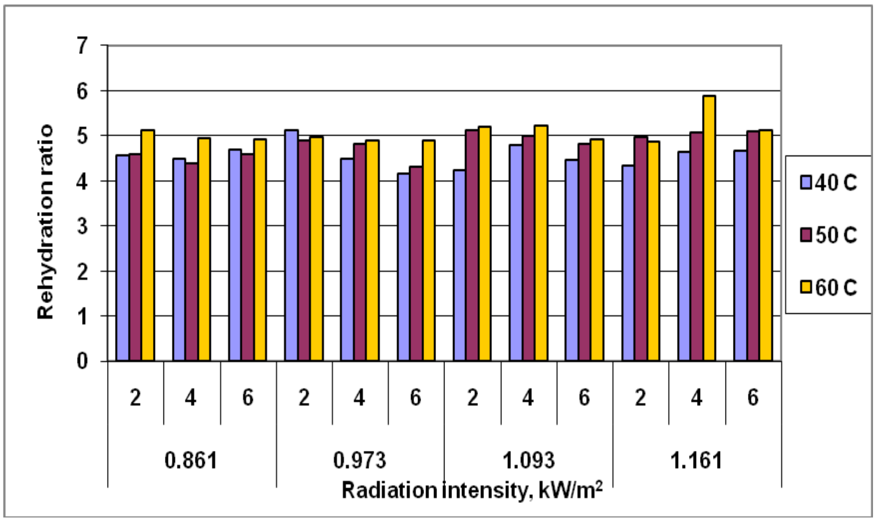


Fig. (11) The changes in rehydration ratio of onion slices at different levels of the studied parameters.

CONCLUSIONS

1-The reduction in moisture ratio of onion slices varied with the experimental treatments and it was increased with the increase of radiation intensity, and drying air temperature. While, it was decreased with the increase of slices thickness.

2-The drying constant (k_L) of lewis's model increased with the increase of drying air temperature and the radiation intensity but it was decreased with the increase of slices thickness.

3-The drying constants (k_h) and (A) of Henderson and Pabis's model were increased with the increase of drying air temperature and the radiation intensity. However, they were decreased with the increase of slices thickness.

4-Both studied models could describe the drying behavior of onion slices satisfactory however Lewis's model could be considered more proper for describing the drying behavior of onion slices and predicting the change in moisture content during infra-red drying process due to more simplicity of calculations.

5-The onion slices dried at radiation intensity of 0.861 kW/m^2, air temperature of 50 ^{o}C and slices thickness of 4 mm recorded the highest quality in terms of higher thiosulphinates and anthocyanin contents and the best rehydration ratio.

REFERENCES

A.O.A.C., (1995). "Official method of analysis, of the association of official analytical chemists". 14th Ed. Published by the Association of Official Analytical Chemists, Arlington, Virginia, 22209 USA. .

Abdelmotaleb, I. A.; M. M. El-Kholy; N. H. Abou-El-Hanaand M. A.Younis, (2009). Thin layer drying of garlic slices using infrared. Misr J. Ag. Eng., 26(1): 282- 305.

Agricultural Statistics, (2006). Statistical Report Egypt, Ministry of Agriculture and Land Reclamation. Economic Affairs Sector. (1): 57-62.

Anonymous, (2002). Anonymous, Export Statistics for Agro and Food Products, Agricultural and Processed Food Products Export Development Authority (APEDA), India (2002) pp. 295–297.

Bonaccorsi. P; C. Caristi, C. Gargiulli and U. Leuzzi, (2008). Flavonol glucosides in Allium species: A comparative study by means of HPLC–DAD–ESI-MS–MS, Food Chemistry 107 (2008), pp. 1668–1673.

Corzo-Martínez,M; N. Corzo and M. Villamiel, (2007) Biological properties of onions and garlic, Trends in Food Science & Technology 18 (2007), pp. 609–625.

FAO, (2009). Food and Agricultural Organization, 2009. www.fao.org. Area and production data.

Fossen, T., O.M Anderson, D.O Ovstedal, A.T Pederson and Raknes, (1996). Characteristic anthocyanin pattern from onions and other Allium sp. J. Food Sci., 61:703-711.

Freeman, G.G.(1974): Flavour Changes in dry bulb onions during overwinter storage at ambient temperature, J. of the Sci. of Food and Agric., 25 (5) 517-520.

Gennaro, L., C.Leonardi, F. Esposito, M.Salucci, G.Maiani, G .Quaglia and V.Fogliano,(2002). Flavonoid and carbohydrate contents in Tropea red onions: Effects of homelike peeling and storage. J.Agric. Food Chem., 50:1904-1911.

Hareedy, L.A.(2000). Technological, Bilogical and Microbiological Studies on some Vegetables and Fruits Cultivars. Un published ph.d Thesis. Fac of agric.Cairo Univ.

Henderson, S.M. and S. Pabis,(1961) Grain drying theory. I. Temperature effect on drying coefficient, Journal of Agriculture Engineering Research 6 (1961), pp. 169–174.

Kim, M. H. and R.T. Toledo,(1987). Effect of osmotic dehydration and high temperature fluidized bed drying on properties of dehydrated rebbit eye blueberries,Journal of Food Science 52 (4) pp. 480-489.

Lewis, W. K., (1921). The rate of drying of solid materials. Journal of Industrial Engineering Chemistry, 13, (5), 427-432 .

Matouk, A.M.; M.M. El-Kholy; A. Tharwat and S.M. Shabban.(2014b). Infra-red Drying and Sterilization of High Moisture Rough Rice. Journal Of Soil Sciences And Agricultural Engineering,Mansoura University .

Matouk, A.M.; M.M. El-Kholy; A. Tharwat and W.M. Abdelrahman.(2014a). Infrared Drying Of Lemon Slices. Journal Of Soil Sciences And Agricultural Engineering,Mansoura University .

Ratti, C. and A.S. Mujumdar, (1995). Infrared drying. In: S.M. Arun, Editor, Handbook of industrial drying (2nd ed ed.),, Marcel Dekker, Inc, New York, pp. 567–588.

Samaniego C.M.; L.F. Boag, and G.L. Robertson, (1991): Kinetics of quality deterioration in dried onions and green beans as a function of temperature and water activity. Lebensm. Wiss. U. Technol., 24-53 .

Sharma G.P., R.C. Verma and P.B. Pathare, (2004) Thin-layer infrared radiation drying of onion slices. Journal of Food Engineering vol. (67).pp. 361–366.

The Hindu Survey, (2007). The Hindu Survey of Indian Agriculture, 2007.

USDA, (2007). USDA, U.S. Department of Agriculture, Agricultural Research Service, USDA National Nutrient Database for Standard Reference, Release 20. Nutrient Data Laboratory Home Page http://www.ars.usda.gov/ba/bhnrc/ndl.

تجفيف شرائح البصل بإستخدام الأشعه تحت الحمراء

أحمد محمود معتوق[١] ، محمد مصطفي الخولي[٢] ، أحمد ثروت [٣] و آلاء محمود عنتر[٤]
١ -قسم الهندسة الزراعية- كلية الزراعة - جامعة المنصورة.
٢ -معهد بحوث الهندسة الزراعية .
٣ -قسم الهندسة الزراعية- كلية الزراعة - جامعة المنصورة.
٤ -كلية الزراعة – جامعة المنصورة.

أجريت دراسه لاختبار وتقييم استخدام الاشعه تحت الحمراء كمصدر للتسخين الحراري في تجفيف شرائح البصل باستخدام مجفف معملي يعمل بالاشعه تحت الحمراء خلال موسم٢٠١٤م وشملت المتغيرات التجريبيه ٤ مستويات للاشعه تحت الحمراء (٠.٨٦١ ، ٠.٩٧٣ ، ١.٠٩٣ ، ١.١٦١ كيلووات/م^{٢}) و ٣ مستويات لدرجة حرارة الهواء الحامل للرطوبه (٤٠ ، ٥٠ ، ٦٠ ^{o}م) و٣ مستويات لسمك شرائح البصل (٢، ٤ ، ٦مم) . وقد تم اختبار كل من النموذج الرياضي البسيط Lewis’s model والنموذج الرياضي المعدل Henderson and Pabis’s model في وصف عملية التجفيف والتنبؤ بالتغير في المحتوي الرطوبي لشرائح البصل اثناء عملية التجفيف تحت الظروف التجريبيه موضوع الدراسه .

وقد أظهرت النتائج المتحصل عليها ما يلي :

١ -زاد معدل التجفيف لشرائح البصل بزياده كل من شده الاشعه تحت الحمراء ، درجه حرارة الهواء الحامل للرطوبه بينما انخفضت بزيادة سمك شرائح البصل المستخدمه .

٢ -كلا من النموذج الرياضي البسيط والمعدل وصفا عمليه التجفيف لشرائح البصل بصوره جيده الا أن النموذج البسيط يعتبر الاكثر ملائمه لسهوله إجراء الحسابات الخاصه بالتنبؤ بالتغير في المحتوي الرطوبي لشرائح البصل تحت المتغيرات التجريبيه موضوع الدراسه .

٣ -أعطت شرائح البصل المجفف عند شده اشعاع (٠.٨٦١ كيلو وات / م^{٢}) ودرجه حراره الهواء ٥٠ ^{o}م وسمك شرائح ٤ مم أعلي درجات الجوده للشرائح المجففه من حيث محتوي الشرائح المجففه من الأنثوثيانين ، الثيوسلفانات ونسبه إعاده التشرب .