International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 3, Issue 5, pp 16-21, May-2019

Development and Evaluation of an Infra-Red Dryer for Grape Drying

[1]Dr.Ahmed M. Matouk, [2]Dr.Mohammed M. El-Khouly, [3]Dr.Ahmed Tharwat, [4]Dr.Samy E. El-Far

[1] Prof. of food process Engineering, Faculty of Agriculture, Dep. of Agric. Eng., Mansoura University, Egypt

[2] Prof. of food process Engineering and Director of Agricultural Engineering Research Institute, Egypt

[3,4]Lecturer of Food Process Engineering, Faculty of Agriculture, Dep. of Agric. Eng., Mansoura University, Egypt

***Abstract* - The main objective of the present work was to develop and evaluate a small scale industrial portable grape dryer using infrared radiation heating mechanism with capacity of 150 kg fresh grapes (type Thompson seedless grapes) suitable for small farms and rural areas. The dryer was developed, manufactured and tested. A standard dip emulsion pretreatment was used, this pretreatment increases drying rate because of cracks developed on the pretreated grape's surface. The quality evaluation tests showed the advantages of the developed dryer in giving high quality raisin based on the Egyptian Standard of dried grapes (Raisins) No., 285/2005 and in the International standard ISO 21527 (2008). The results also show that, drying grapes with infra-red drying method gives raisin with high safety in terms of microbial infection.**

Keywords: Infra-red drying, grape drying, raisins, raisins quality.

I. INTRODUCTION

Application of FIR drying in the food industry is expected to represent a new process for the production of high-quality dried foods at low cost. Far-infrared energy has very little penetration capacity and is almost all converted to heat at the surface of the food. In general, the food substances absorb FIR energy most efficiently through the mechanism of changes in the molecular vibrational state, which can lead to radiative heating. Water and organic compounds such as proteins and starches, which are the main components of food, absorb FIR energy at wavelengths greater than 2.5 urn. Therefore, FIR drying operations have been successfully applied in recent years for drying of fruit and vegetable products such as sweet potatoes [11], onions [7],[12], and apples [8],[13].

Matouk et al [6] conducted an experimental work to test and evaluate the use of infra-red radiation as heat energy source for drying lemon slices. A laboratory scale dryer was developed and tested. The experimental treatments included three different levels of radiation intensity (0.973, 1.093, and1.161 kW/m^2), three different air temperatures (40, 50 and 60°C) and air velocity of 1 m/sec. The results showed that the best level of radiation intensity for drying the whole lemon is 1.093kW/m^2 and for the slices is 0.973 kW/m^2 at air temperature of (50 ^{o}C).

Abdelmotaleb et al. [1] studied infra-red drying of thin layer garlic slices at four different levels of radiation intensity 0.075, 0.15, 0.225 and 0.3 W/cm^2, three levels of air velocity 0.25, 0.75, and 1.25 m/s and constant air temperature of (40 °C). They found an increase in drying rate, thermal efficiency, drying ratio and color difference and a decrease in drying time, specific energy, and the flavor strength with the increase of infra-red intensity and decrease of air velocity.

Kumar et al [5] studied the effect of combined infrared (IR) and hot-air drying of onion slices under different parameters such as drying temperature, slice thickness, air temperature and velocity. The onion slice quality was evaluated based on changes of color and the pyruvic acid content. Drying of thin slices of onion (2 mm) at temperature of (60 ^{o}C) with a moderate air velocity of (2 m/s) and air temperature (40^o C) retained greater flavor and color.

Hebbar et al. [4] developed a continuous combined infra-red and hot air dryer for vegetables drying. The drying system was examined under infra-red, hot air and combined infra- red and hot air mode independently. When processed under combination mode, the synergistic effect of infra-red and hot air rapidly heated the material resulting in a higher rate of mass transfer. The combined mode drying reduced the processing time by (48%), in addition to consuming less energy (63%) for water evaporation compared to hot air drying.

Sharma et al., [12] developed a laboratory scale infrared-convective dryer for single layer drying of onion slices at infra-red power levels of 300, 400 and 500 W, drying air temperatures of 35, 40 and 45 °C and inlet drying air velocities of 1.0, 1.25 and 1.5 m/s. They found that the drying time was reduced by about 2.25 times with increasing of infra-

ISSN (online): 2581-3048
Volume 3, Issue 5, pp 16-21, May-2019

red power from 300 to 500 W, air temperature 35 – 40 °C and air velocity from 1.0 to 1.5 m/s.

The objectives of this research work were development, test and evaluate a small scale industrial portable grape dryer using infrared radiation heating mechanism with capacity of 150 kg fresh grapes (type Thompson seedless grapes) suitable for small farms and micro-projects in rural areas.

II. MATERIAL AND EXPERIMENTAL PROCEDURE

a) Preliminary Experimental work

This part of activity included laboratory experiments for testing and evaluating different methods of pre-treatments of grapes prior to the drying process. The effect of the studied methods on the drying characteristics using infra-red dryer was evaluated. The evaluation bases included drying rate, and quality changes of the pre-treated samples.

b) Materials

Fresh, ripe hand harvested samples of seedless Thompson (Banaty) were used for the experimental work. It was obtained from local market in August (2015). The initial moisture content of the freshly harvested grape barriers was 74.46%. (wet basis), the total soluble solids (TSS) was 23.60%.

c) Preparation of samples

For ensuring the uniformity of the grapes used for different experimental runs, the berries of each sample were selected from the same bunch and cleaned with tap water to make it free from dust and foreign materials. Then, it was cut into small pieces prior to different studied pre-treatments.

Since, the grapes are a complex product with an outer waxy cuticle and pulpy material inside, the outer waxy cuticle affects the moisture diffusion from the grapes during the drying process. A chemical pre-treatment is generally applied to decrease the skin resistance and hence improving moisture diffusion through the waxy cuticle [9], [3].

The pre-treatments prior to the drying process included immersion in NaOH solution (0.2%) at temperature of 90oC and dipping time of (1 min). After immersion of samples, the samples were taken out from NaOH solution and washed under tap water until full removal of alkaline. Then the washed samples were immersed in 3% sodium meta bi-sulphate solution for 5 min.

d) Considerations taken for the development of the dryer

1. Simple design with capacity of 150 kg pre-treated fresh grape.
2. Locally manufactured with efficient and convenient operation system, capable for long operating life.
3. The drying beds are stainless-steel trays supported vertically inside the dryer frame over side rollers for easy movement.
4. Infra-red is the main source of grapes heating accompanied with heated air supply system for moisture carry out from the dryer
5. Precise control of Infra-red intensity and air temperature.
6. Air movement in parallel stream over the surface of the drying bed.
7. Supplied by radial flow air fans with speed control switches for precise air distribution over the surface of drying trays.
8. Possibility of operating all trays or only one tray during the drying process for energy saving purpose.

e) The dryer frame and drying beds

The dryer frame was constructed of 5.08 cm (2 inch) iron angles with dimensions of 250 cm long, 100 cm wide and 150 cm high. The frame of the dryer was divided into three separate sections for accommodating the drying trays. Each section was provided with Teflon rollers for smooth movement of the drying trays. The frame sides were covered by double sheets of galvanized iron and filled with foam material for precise insulation of the dryer body. The frame was carried out in four rubber wheels with 25 cm diameter for free movement of the dryer.

The drying bed consists of three separate drying shelves. The dimensions of each shelve are 250 cm long and 100 cm wide. Six perforated stainless steel trays (made of stainless steel 304) with tray dimensions of 81 cm long, 50 cm wide and 3 cm high were used for forming the drying bed of each shelf.

The drying trays were arranged in sequences of three trays facing the other three trays at each shelve. For easier charging and discharging the grape trays of each shelve, two doors were assembled in the front and back sides of the dryer. The doors were constructed of iron angles covered by iron sheets and filled with foam material for insulation as shown in figure (1).

ISSN (online): 2581-3048
Volume 3, Issue 5, pp 16-21, May-2019

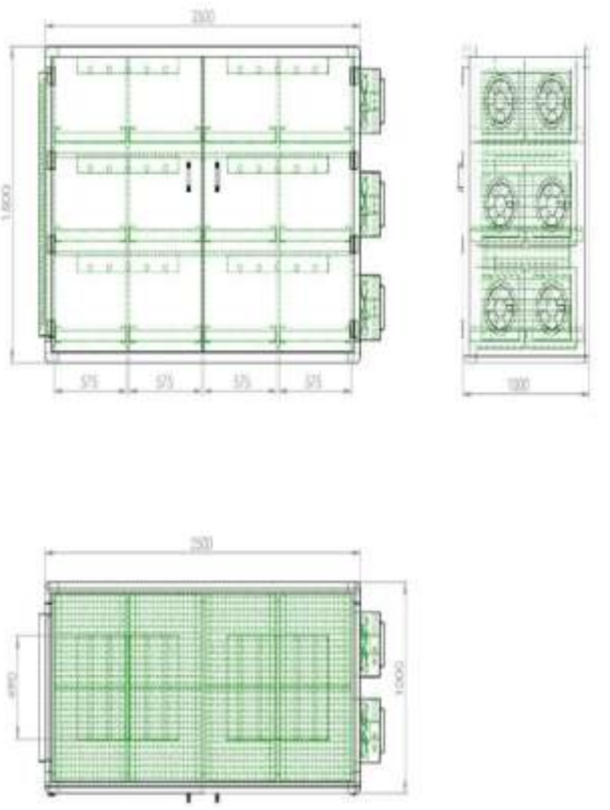

Figure 1: Schematic diagrams for different parts of the infra-red dryer

f) The Infra-red heating system

For infrared heating process, 12 infra-red heaters (800 W/heater) were used to heat each separate drying bed (36 heaters for the three shelves). Each Infra-red heater was fixed over two iron blades and assembled into the ceiling of each drying shelve facing the drying trays at controlled distances from 15 to 24 cm using two screw rods welded to the iron blades as shown in figure (2).

It should be mentioned that, the optimum distance between the infra-red heaters and also the distance between the heaters and the drying trays was assessed after adding and calibrating the intensity control system for the infra- red heaters. This system allows for selecting the proper intensity and the matching distance.

g) Air heating, distribution and temperature control system

Electric heaters were used for heating the supplied air to each drying chamber. The heating circuit of each chamber consists of two 1 kW – electric heaters, fixed over the surface of multiple iron nets in order to increase the area of air contacted with the heating source.

Figure 2: Distribution of the Infra-red heaters

Digital thermostats were used for temperature control of air passed over the drying trays at each drying chamber. Each digital thermostat was connected to the electric circuit for stopping and connecting the electric heaters and keeping the pre-adjusted temperature of the air constant throughout the drying process. A relative humidity sensor with digital display was also provided for measuring the air relative humidity at each separate drying bed.

For air supply and distribution, two identical axial flow fans model OLMO – 22 W – 1300 rpm (250 CFM) were used for suction of the heated air in a parallel direction over the surface of each drying bed. The two fans of each drying bed were assembled in one side of the drying chamber facing the air heaters. The drying air is supplied equally to each drying chamber using a speed control switch for controlling the rpm of each fan. An air filter was assembled at the entrance section of the fresh air to each drying bed for air cleaning and preventing any dust or trashes to enter the dryer.

III. RESULTS AND DISCUSSIONS

a) Infra-red Drying Process

Based on the results obtained from the preliminary experiments for assessment of the optimum operational condition, the field tests of the dryer were conducted under radiation intensity of 0.973 kW/m^2 and inlet air temperature of 70 ^{o}C at air velocity of (2.5 m/s).

Figure (3) illustrates the average change in grape vines moisture content as related to drying time at different location of the dryer trays.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 3, Issue 5, pp 16-21, May-2019

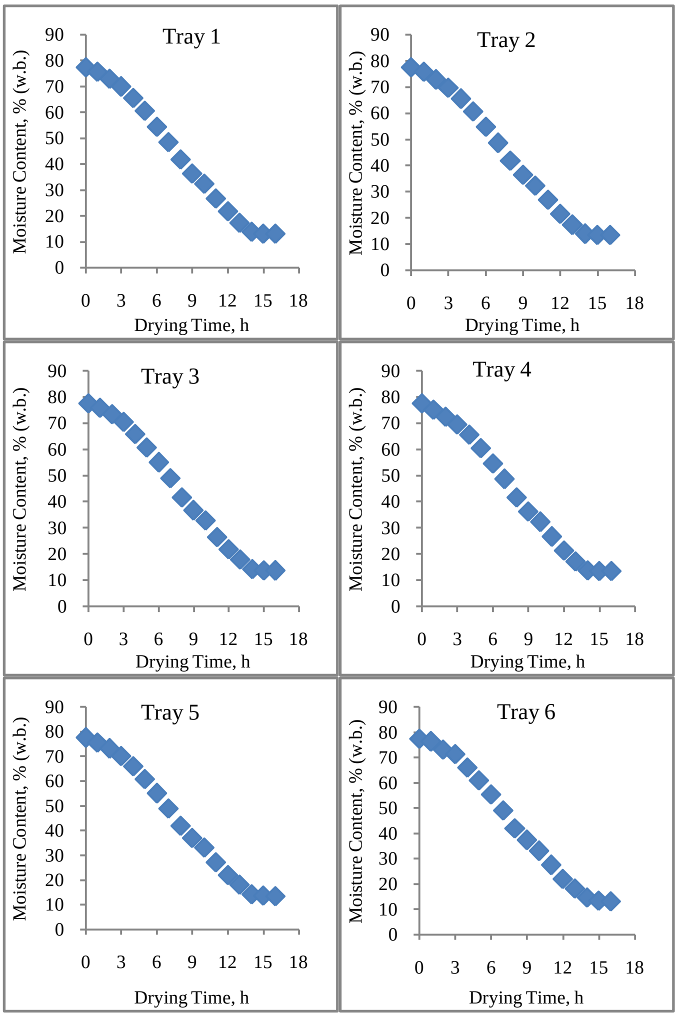

Figure 3: Changes in the moisture content of grapes (w.b.) with drying time at six different drying trays inside the infra-red dryer

As shown in the figure, the average initial moisture contents of grapes were about 77.56% (w.b.) and the reduction in moisture content of grape vines was higher during the early stage of the drying process and starts to decline with time until reaching the final level of about 13.414% w.b.

Meanwhile, the average bulk temperature of grape seeds was about 57.8 ^{o}C and the required drying time for approaching the safe level of moisture content (13.414% w.b.) was about 16 hours.

The figure also shows that, the moisture reduction rate and the corresponding moisture content of grape vines was nearly similar in different locations of the dryer trays which means homogeneous drying of grapes. This was a reflection of homogeneous distribution of air temperature, and air velocity over the trays surfaces.

In general, the infra-red dryer shows an acceptable performance in terms of the required drying time, homogeneity of grape moisture content and final quality of the dried grapes.

b) Quality assessment of the produced raisin

Results in table (1) show that the principal of chemical analysis of fresh grapes and dried grapes (Raisins) for infra-red drying method.

TABLE - 1
Chemical analysis of fresh grapes and dried grapes (Raisins) for the infra-red drying method

Sample	*Test methods	Test results%			
		Moisture, %(w.b)	T.S.S, %	Total sugars, g/100g	So$_2$, ppm
Fresh grape	[2], [10]	77.56	23	19.46	ND
IR dried raisin		13.414	74.60	70.38	314.1

Data in table (1) indicated that the moisture content, T.S.S. and total sugars of fresh grape were 77.56 %, 23% and 19.46 %, respectively on fresh weight basis. These results mean that the grapes were harvested at the optimum time for collection and production of raisins, since total soluble solids must be not less than 22%.

The results also show that the sugar content of fresh grapes was higher than 19%, which indicated a good level for high quality dried grapes in terms of color changes during the drying process. Meanwhile, after the drying process, the results in table (1) also showed that the moisture content of dried grapes with infrared drying method was 13.414 %,(w.b.). This level of moisture content represents an optimum level of dried grapes (raisins) which usually not over than 18% (w.b.) according to the Egyptian Standard of dried grapes (Raisins) No., 285/2005.

From the same data in table (1) the results of dried grape showed that the total soluble solids (T.S.S.) were higher than 66% and total sugars represent 85% of T.S.S. values. This means that, the predominate of solids in the dried grapes were sugars. Also, these high total sugars content of raisins maintain shelf life and keep high quality of the product.

ISSN (online): 2581-3048
Volume 3, Issue 5, pp 16-21, May-2019

The use of sulfur dioxide during drying of grapes to maintain the color of grape is not exceeding the limits allowed in the standard specifications. Sulfur dioxide of dried grapes produced from infra-red drying method was 314.1 ppm.

Generally, the amount of sulfur dioxide did not exceed the allowable level of 1500 ppm as recommended by The Egyptian standard of dried grapes (Raisins) No.,285/2005.

c) Microbiological Evaluation

One of the most important signs of product safety is that it is free of pathogenic microbes. This was evident in the examined drying method (infra-red drying method). From table (2) the yeast and molds were not found in the dried raisin samples.

TABLE – 2
Microbiological examination of fresh grapes and dried grapes (Raisins) for solar and infra-red drying methods

Test item	*Test method	IR dried raisins
Total Bacterial count	ISO 4833	N.D
Yeast & Moulds	ISO 21527	N.D

The results in table (2) also show that bacterial colonies were detected in the samples dried by the infra-red dryer. The counts of microorganism of dried grapes were less than the level allowed for dried grapes as indicated in the Egyptian standard of dried grapes (Raisins) No., 285/2005 and in the International standard ISO 21527 (2008). In general, drying grapes with infra-red drying method gives high quality product with high safety in terms of microbial infection.

IV. CONCLUSION

1. The average bulk temperature of grape seeds was about 57.8 ^{o}C and the required drying time for approaching the safe level of moisture content (13.414% w.b.) was about 16 hours.
2. The infra-red dryer shows an acceptable performance in terms of the required drying time, homogeneity of grape moisture content and final quality of the dried grapes.
3. Drying grapes with the developed infra-red dryer gives high quality product with high safety in terms of microbial infection.

ACKNOWLEDGEMENT

The authors of this research would like to express their sincere thanks and most appreciation for the Science and Technology Development Fund (STDF) for financial support, follow-up of the current research work which has been extracted from the project of “Design and manufacture of grape dryers suitable for medium and small scale farms”.

REFERENCES

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

[2] AOAC (2007). Official Methods of the Analysis of AOAC. Published by *AOAC International Maryland*: USA.

[3] Doymaz. I., M. Pala (2002). The effect of dipping pretreatment on air drying rates of the seedless grapes. *Journal of food engineering*, 52, 413-417.

[4] Hebbar, H. U.; K. H. Vishwanathan and M. N. Ramesh, (2004). Development of combined infrared and hot air dryer for vegetables. *Journal of Food Engineering* 65, 557–563.

[5] Kumar, D.G. Praveen.; H. Umesh Hebbar.; D. Sukumar and M.N. Ramesh. (2005).Infrared and hot-air drying of onions. *Journal of Food Processing and Preservation* 29 (2005) 132–150.

[6] Matouk, A. M.; M. M. El-Kholy; A. Tharwat and W. M. Abdelrahman (2014a). Infra- Red Drying of Lemon Slices. *J. Soil Sci. and Agric. Eng., Mansoura Univ.*, Vol. 5 (4): 569-581

[7] Mongpraneet, S.; T. Abe and T. Tsurusaki, (2002). Accelerated drying of welsh onion by far infrared radiation under vacuum conditions. *Journal of Food Engineering*, 55, 147–156.

[8] Nowak, D. and P. P. Lewicki, (2004). Infrared drying of apple slices. *Food Science and Emerging Technologies* 5, 353– 360.

[9] Pangavhane, D.R.; R.L. Sawhney and P.N. Sarsavadia (1999). Effect of various dipping pretreatment on drying kinetics of Thompson seedless grapes. *J. of food engineering*, 39: 211-216.

[10] Ranganna S. (1977). Manual of Analysis of fruit and vegetable products. *Tata McGraw-Hill Publishing Company* Limited, New Delhi.

[11] Sawai, J.; T. Nakai; A. Hashimoto and M. Shimizu, (2004). A comparison of the hydrolysis of sweet potato starch with b-amylase and infrared radiation allows prediction of reducing sugar production. *Int J Food Sci Technol* 39:967–74

[12] Sharma, G.P.; R.C. Verma and P.B. Pathare (2005). Mathematical modeling of infrared radiation thin layer drying of onion slices. *Journal of Food Engineering*, 71, 282 - 286.

ISSN (online): 2581-3048

Volume 3, Issue 5, pp 16-21, May-2019

[13] Togrul, H. (2005). Simple modeling of infrared drying of fresh apple slices. *J. of Food Eng.* 71:311–23.

[14] International standard ISO 21527 (2008). Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of yeasts and molds. *ISO copyright office Case postale* 56 • CH-1211 Geneva 20.

[15] International standard ISO 4833-1 (2013). Microbiology of the food chain — Horizontal method for the enumeration of microorganisms. *ISO copyright office Case postale* 56 • CH-1211 Geneva 20.

AUTHOR'S BIOGRAPHIES

Prof. Dr. Ahmed M. Matouk
Prof. of food process Engineering, Faculty of Agriculture, Dep. of Agric. Eng., Mansoura University, Egypt

Prof. Dr. Mohammed M. El-Khouly
Prof. of food process Engineering and Director of Agricultural Engineering Research Institute, Egypt

Dr. Ahmed Tharwat
Lecturer of Food Process Engineering, Faculty of Agriculture, Dep. of Agric. Eng. Mansoura University, Egypt

Dr. Samy E. El-Far
Lecturer of Food Process Engineering, Faculty of Agriculture, Dep. of Agric. Eng. Mansoura University, Egypt

Citation of this article:

Dr.Ahmed M. Matouk, Dr.Mohammed M. El-Khouly, Dr.Ahmed Tharwat, Dr.Samy E. El-Far, "Development and Evaluation of an Infra-Red Dryer for Grape Drying" Published in *International Research Journal of Innovations in Engineering and Technology (IRJIET)*, Volume 3, Issue 5, pp 16-21, May 2019.

****