DEVELOPMENT AND EVALUATION OF A PORTABLE GRAPES DRYER

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Abstract

A study was carried out to develop and evaluate a small scale portable grape dryer using butane-gas as heat energy source. The experimental work was conducted at the Dept. of Agric. Eng., Fac. of Agric., Mansoura Univ. Three different levels of drying air temperature (50, 60 and 70 °C) and two different levels of air velocity (1 and 2 m/s) were used for the experimental work. Two different thin layer drying models (simple, and Page) were examined for simulating the drying behavior and predicting the change in grape moisture content during the drying process. Total drying time, thermal efficiency, final quality of the produced raisins and cost estimation of the drying process were also considered. The obtained results showed that, both the examined models could describe and predict the change in grape moisture content during the drying process satisfactory. While the Page model could describe the drying process more than the other model. Meanwhile, the recorded drying time of grape from an initial level of 386 % (d.b.) to an average final moisture content of 19.89 % (d.b.) were 52, 20 and 14 hours for the drying temperature of 50, 60 and 70 °C and air velocity of 1 m/s. The corresponding drying times at 2 m/s air velocity were 52, 20 and 14 hours, respectively.

Also, the higher drying air temperature of 70 °C and air velocity of 2 m/s showed the best organoliptic characteristics of the dried grape and the highest thermal efficiency of 68.20 %. On the other hands, the estimated drying cost at this level of drying air temperature and air velocity was 1.76 LE/kg of fresh grape.

INTRODUCTION

In Egypt, Grapes are the second most important fruit crops. They come after citrus fruits. Average cultivated area with grape vines increased from 84,509 feddans in 1989 to 141,233 feddans in 2000 with an increase of 67 % of the cultivated area. Also the production increased from 606,845 tons in 1989 to 1009,563 tons in 2000, with an increase of 66 % over the same period (MALR, 2000).

The most important local varieties grown in Egypt are Superior, Flame seedless, Thompson seedless and Fiesta as seedless varieties and Early Muscat, Muscat of Alexandria, Roumy Ahmer and Fayomy as seed varieties.

In the north western coastal region and Delta region, the producers of grape have been suffering from the high percentage of fresh commodity losses, which reached up to 50 % especially in summer seasons due to high maturity percentage at the end of the season. (Ibrahiem, 1990). Meanwhile, post-harvest loss in grapes varieties grown in Egypt averaged from 25 % to 30 %.

In Egypt most of dried grapes (raisin) are produced on small farms, in which the fresh grapes are harvested manually at moisture content of 78 to 80 % (w.b.) then, pre-treated by blanching, dipping and sulfuring and spreaded for drying under direct sunlight or indirect sunlight, using transparent plastic films, glass or non-transparent covers. Meanwhile, industrial drying may be carried out in either solar air dryers (Bolin et al., 1978, Bolin and Salunkhe, 1982, Riva and Peri, 1986), or in large scale mechanical dryers heated by burning a gas fuel usually propane gas, butane gas, or fuel oil or combinations of these methods (Akyurt and Seicuk, 1973).

The large scale mechanical dryers are capital intensive and are not suitable for small-scale farms in the Delta area or the majority of grape farms in the newly reclaimed lands. On the other hand, they have several disadvantages mainly high cost of equipment and the cost of light consumed energy (thermal and / or electrical). (Adams and Thamposon, 1985, Karathanos and Belessiotis, 1997). Meanwhile drying with various forms of traditional sun drying has the advantage of small or negligible insolation and energy costs. However the running costs may be high because this method being a slow process due to climatic variation and a labour intensive operation. Several other factors, however, make traditional sun drying less attractive. These factors include product pollution from dust, and animal contamination, large production losses due to inadequate dehydration, or/and product infestation and spoilage due to the large processing times in areas of poor hygienic standards. Another factor of equal importance may be the inclusion of stones and other visual objects such as seeds which increase the cost of sorting the final dried product.

The main objective of the present study was to develop and evaluate a small scale portable fruit dryer using butane gas as heat energy source. This approach will lead to improve the traditional sun drying methods of grape and also overcome the problem of high energy consumption and capital intensive of the large scale industrial grape dryers.

MATERIALS AND METHODS

Materials:

Fresh, ripe hand harvested grape samples of seedless Thomposon (Banaty) were used in this study. It was obtained from Gemmeza Research Station, Gharbia governorate in July (2003). The initial moisture content of the freshly harvested grape berries ranged from 77.3 % to 80.5 % (wet basis) and the sugar content was at Brix value of 23 as measured by the hand refractometer.

Pre-treatment of samples:

The grape samples were blanched by dipping in boiling solution containing 0.1 % NaOH for 10 seconds, and immediately cooled by immersing in running cold water. The blanched grapes were washed with tap water to be free of alkaline.

Following this process, 35 g of sulfur powder was burned in a sulfuring cabinet for 8 hours to sulfur blanched samples. After the pre-treatment, grape samples were stored in plastic bags and kept inside a refrigerator at 5°C until used. Before any experimental run, the grape berries were taken out of the refrigerator and kept in the laboratory to attain room temperature.

Equipment:

1- **The sulfuring cabinet:** The sulfuring cabinet was constructed of wooden chamber with exterior dimensions of 1350 × 700 × 500 mm. The chamber body was covered with plastic sheet (high density polyethylene) in order to prevent up taking of sulfur dioxide gas outside the chamber, consequently maintaining the level of gas concentration through-out the sulfuring process. Four trays made of fiber wire screen, with dimensions of 700 × 500 mm were used for holding grape berries. Each tray held up to 5 kg of blanched grape berries.

2- **The portable dryer**:

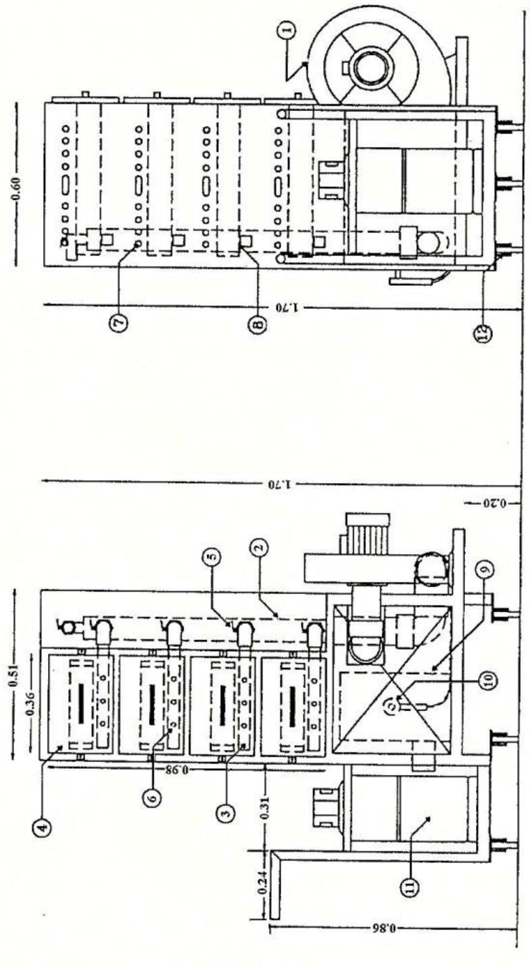
Fig. (1) illustrates elevation and general view of the portable dryer used for the experimental work. The dryer was constructed at the workshop of Agricultural Engineering Department, Faculty of Agriculture, Mansoura University. The dryer consists of the following parts:

A- Main frame:

The dryer main frame was constructed of (50 × 50 mm) iron angles with dimensions of 600 mm long, 600 mm wide and 1750 mm high. The frame was completely covered with 2 mm thick double iron sheets filled with 5 cm thick fiberglass insulation. A small iron frame (810 mm high × 500 mm wide) was attached to the base of the main frame through two iron hinges to accommodate the gas cylinder. Four caster rubber wheels were used for free movement of the dryer.

B- Drying bed:

The drying bed consists of four drying trays with capacity of 5 kg pre-treated grape each. The trays were constructed of iron frames of 540 × 275 × 80 mm (L × W × H) and the sides of each tray were covered with double aluminum sheet, while the base was made of stainless steel wire net. The four drying trays were supported inside the dryer body in vertical sequence forming a plenum chambers of 600 × 70 × 315 mm (L × W × H) between trays. To prevent air leakage through the drying bed, the front face of each tray was sealed with a rubber gasket and a silicone caulking.



(1) Centrifugal fan (2) Main air duct (3) Air duct branch (4) Drying trays
(5) Air valve (6) Air entrance holes (7) Air discharge holes (8) Plenum chamber
(9) Air heating unit (10) Gas nozzle (11) Gas Cylinder (12) Wheels

Fig. 1: Schematic diagram of the portable dryer.

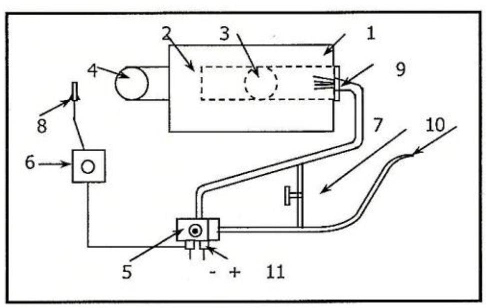
C- Air heating and temperature control system:

A butane gas heating unit was used as heat source for drying air. The heating unit was accommodated inside an insulated iron housing located at the base of the dryer with dimensions of 520 × 185 × 410 mm. The heating circuit consists of stainless-steel cylinder with 90 mm diameter, 450 mm long and 4 mm thick and a gas nozzle fixed at the front side of the stainless-steel cylinder for gas ignition and heating the cylinder surface. The drying air would pass perpendicularly around the stainless-steel heating cylinder until reaching the required level of drying air temperature.

The temperature control system was provided with a precise thermostat connected to a gas solenoid valve for stopping and connecting the gas flow through the ignition nozzle. For re-ignition of the gas nozzle, a small tube branched from the main gas tube was fixed in a position facing the gas nozzle and kept in, continues ignition throughout the drying process. The details of the temperature control system are shown in Fig. (2).

D- Air supply and distribution:

A centrifugal fan model IC 98 ZB was used for air supply. The drying air was supplied equally to each plenum chamber through a main vertical PVC pipe with four side branches. Each branch was accompanied with a control valve to furnish the required amount of air to each plenum chamber. Meanwhile, six holes were opened over the side of each tray to allow air exhaust out of the dryer.



1- Heating unit 2-Heating cylinder 3- Air inlet 4- Air outlet
5- Solenoid valve 6- Thermostat 7- Control valve 8- Sensor
9- Nozzle 10- Gas source 11- Electric source

Fig. 2. Sketch of the temperature control system.

Measuring equipment:

Grape moisture content:

In this study, the moisture content of grapes was determined according to the method recommended by (AOAC, 1995). At this method 5 g of grapes and 2 g dry sands, were mixed and dried in an electric oven at 105 °C for 5 – 7 h. The drying process was repeated if a significant decrease in weight is noted. Weights of samples were determined using an electrical balance with accuracy of ± 0.01 g. The measurement of moisture content was carried out, with three replicates, and all readings were expressed on dry basis.

Air velocity:

The air velocity through the trays was measured using a digital air velocity instrument model (TRI-SENSE 37000 – 62, USA) connected to a velocity probe with measuring range from (0.1 to 10 m/s) and accuracy of (± 0.1 m/s).

Weight of fruits:

Weight of fruit samples was recorded using an electrical digital balance model (MFD – K 1000920, Japan) with a maximum capacity of 6000 g, and ± 0.1 g accuracy.

Air temperature and relative humidity:

A temperature and relative humidity meter was used for measuring both parameters. It has a measuring probe of 1 cm diameter and 17.8 cm length connected to the meter by a 1.5 cm length electrical cable.

Experimental procedure:

Six experiments were conducted to study the drying kinetics of the grapes. The temperature of drying air was adjusted to be approximately constant during every experiment at selective levels of 50, 60 and 70 °C and air velocities 1 and 2 m/s. The centrifugal fan was adjusted to force the hot air from the heating chamber at equal amounts through the four drying chambers. Before each experimental run, the dryer was adjusted for the required drying air temperature using the temperature control electric thermostat and the required air velocity using the air control valves and the air velocity meter. To grantee the dryer stability during the experimental run, all the dryer trays were loaded with dummy samples of 5 kg for each tray and operated for at least one hour. The drying air temperature and air velocity were measured periodically during the stability test until reaching the required levels for each run. After making sure that the dryer working at stable condition, the dryer trays were again loaded with pre-treated grapes and distributed uniformly in a single layer. The first and third trays were employed for measuring the change in grape moisture content at time intervals of 30 min at the beginning of the drying process up to 120 min during the last stage of drying. While the second and fourth trays were used for measuring the initial and final moisture content of the grape. Drying air temperature, relative humidity and air velocity were measured at different points under each tray at adjacent time intervals of measuring moisture content of grape samples. The drying process was stopped when the moisture content of the dried samples reached around 16 to 18 % (d.b).

Drying models used for simulating the drying data

An application of the two most commonly used drying models was conducted to examine their applicability in fitting and predicting the drying data. The examined drying models included:

1- The simple exponential model:

$$MR = \frac{M - M_e}{M_0 - M_e} = \exp(-kt) \qquad \text{.......................(1)}$$

Where:

MR: Moisture ratio, dimensionless

M : Material moisture content, (d.b) kg water / kg dry solid.

M_e : Material moisture content in equilibrium with the drying air.

t : Time, min

k : The drying rate constant, min^{-1}

2- Page's model: ....(2)

$$MR = \exp(-kt^u)$$

Where

u : Experimental constant, dimensionless

Thermal efficiency:

The thermal efficiency was calculated using the following relationship according to Reys and Jindal (1987)

$$\eta = (W_w \times \frac{Lh}{Q}) \times 100 \qquad \text{...................(3)}$$

Where

η : Thermal efficiency, %

W_w : Water evaporated from grapes, kg

Lh : Latent heat of evaporation of water, kJ/kg

Q : Total energy consumption, kJ

Total energy consumption was calculated according to the following formula:

$$Q = C.V \times qc \qquad \text{...................(4)}$$

Where

C.V : Calorific value, kJ/kg

qc : Gas consumption, kg

The latent heat of water vaporization was taken to be 2382.7, 2358.5 and 2333.0 kJ/kg at 50, 60 and 70 °C, respectively according to Franzo and William, (1968). Also calorific value and density of butane gas were taken to be 45600 kJ/kg and 2.7 kg/m^3 respectively according to El-Kholy (1998).

Cost Estimation

In order to evaluate the applicability of the dryer in commercial scale, a cost estimation was carried out to determine the drying cost in LE/kg fresh grape.

Tests to evaluate raisins quality:

Physical tests:

Organoleptic tests: These tests included color and taste of the dried grape (raisins). These characteristics were judged by a group of agricultural engineers (from 5 – 10 panelists), according to Winkeler et al. (1974).

Chemical tests:

Re-hydration (reconstitution) test:

This test was determined by soaking 10 g of raisins in water at room temperature for 20 min. After that, samples were reweighed every 5 min. until nearly a steady weight was reached. The re-constitution was determined according to Ranganna (1977) as follows:

$$\text{Reconstitution} = \frac{\text{Increase in raisins weight}}{\text{Original rasins weight}}$$

RESULTS AND DISCUSSION

The ability of the dryer in controlling the drying air temperature

The ability of heating control circuit in controlling the drying air temperature was examined for different levels of drying air temperature and air velocity. As shown in Fig. (3), the heat control circuit could control the drying air temperature with average fluctuation range of ±1.6737 °C. At air velocity of 1 m/s the recorded average drying air temperature for 50, 60 and 70 °C were 51.83, 60.55 and 71.89 °C with a corresponding relative humidity of 23.62, 17.26 and 13.90 %, respectively.

Moisture content and drying time:

The change in moisture content of grape as related to the drying time for different air temperature and air velocity are illustrated in Figs (4 and 5) respectively. As shown in the Figs. the drying rate was higher during the early stage of drying and starts to decline with the progress of drying process due to lower diffusion rate of moisture from the interior layers to the surface layer. The recorded drying time of grape from an average initial moisture content of 386 % (d.b) to an average final moisture content of 19.89 % (d.b) were 54, 26 and 16 hours for the air velocity of 1 m/s, drying air temperature of 51.08, 60.55 and 71.25 °C and air relative humidity of 23.62, 17.25 and 13.9 %, respectively. The corresponding drying time for the air velocity of 2 m/s were 52, 20 and 14 hours respectively. This means that the drying time of grape was affected by both drying air temperature and relative humidity, while, the drying air velocity has the lowest effect.

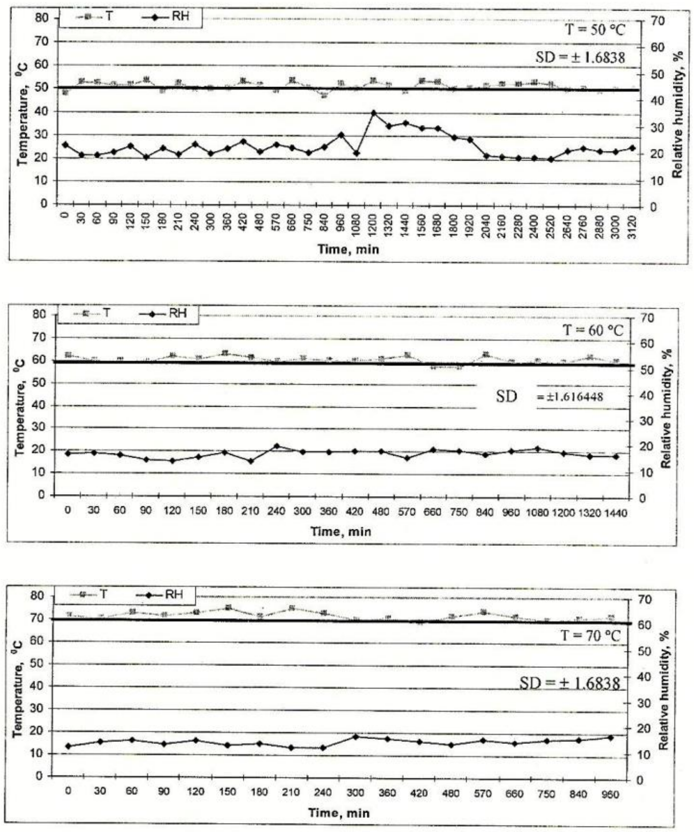


Fig. 3. Fluctuation of air temperature and relative humidity during drying time for different drying air temperatures.

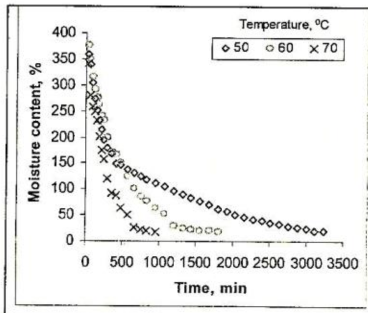


Fig. 4. The change in moisture content of grape as related to drying time at air velocity of 1 m/s.

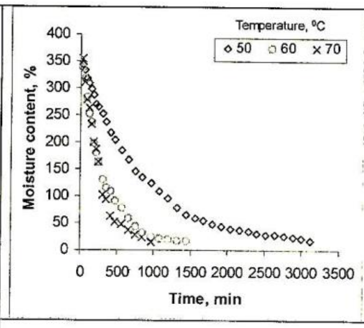


Fig. 5. The change in moisture content of grape as related to drying time at air velocity of 2 m/s.

The applicability of drying models in predicting grape moisture content:

A validation process was conducted to examine and compare the applicability of the two drying models (simple and Page) in predicting the change in grape moisture content during the drying process. The calculations were proceeded using two different forms of moisture ratio considering the terms final moisture content (M_f) and equilibrium moisture content (M_e).

As shown in Table (1) and Figs (6 through 11) both the examined models could describe and predict the change in grape moisture content with drying time satisfactory as indicated from the high values of correlation coefficients which ranged from (0.94 to 0.99), (0.93 to 0.99) and (0.87 to 0.98) for simple and Page's models, respectively. Also the use of (M_e) values for calculating the moisture ratio showed better prediction of moisture content in comparison with (M_f) value for both models.

In general, the results revealed that, the Page model may be considered the most appropriate model for predicting the change in moisture content of grape during the drying process. These results are in agreement with those obtained by Doymaz and Pala (2002).

Tests to evaluate raisins quality:

1- Color and taste of raisins:

The results of sensory tests show that, a relatively gummy and sticky surface was obtained for the raisins dried at lower drying air temperature and air velocity. Also, the color of raisins produced at lower drying air temperature and air velocity was not uniform and darker in comparison with the raisins dried at higher levels of air temperature and velocity. These results are in agreement with Radwan (2002).

Table 1. Average values of correlation coefficients between the observed and predicted grape moisture content using the studied models.

Drying models	Equilibrium moisture content (d.b)	Air temperature, °C	51.08		60.55		71.89	
		Relative humidity, %	23.62		17.25		13.90	
		Air velocity, m/s	1	2	1	2	1	2
Simple	M_r	SE	29.836	20.119	25.268	8.457	24.857	24.228
		R^2	0.9452	0.9678	0.9541	0.9946	0.9519	0.9540
	Me	SE	31.286	16.767	22.481	7.451	19.927	21.345
		R^2	0.9412	0.9785	0.9650	0.9959	0.9699	0.9650
Page	M_r	SE	18.402	22.183	26.253	12.458	33.946	37.286
		R^2	0.9738	0.9506	0.9413	0.9861	0.8978	0.8749
	M_e	SE	18.572	20.685	25.370	11.741	32.799	36.460
		R^2	0.9733	0.9575	0.9454	0.9876	0.9500	0.8806

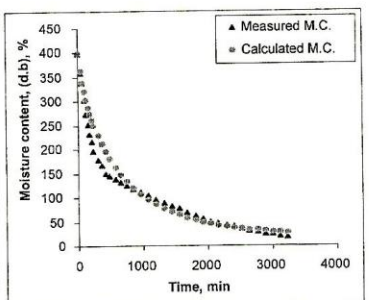


Figure 6. Measured and predicted values of grape moisture content using Page's equation at (T) 50°C using the term (Me) for proto-type dryer at air velocity of 1 m/s.

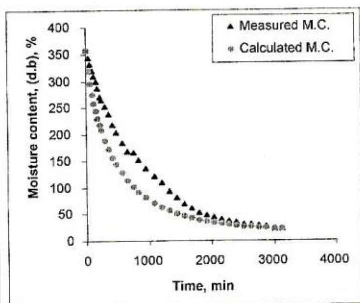


Figure 7. Measured and predicted values of grape moisture content using Page's equation at (T) 50°C using the term (Me) for proto-type dryer at air velocity of 2 m/s.

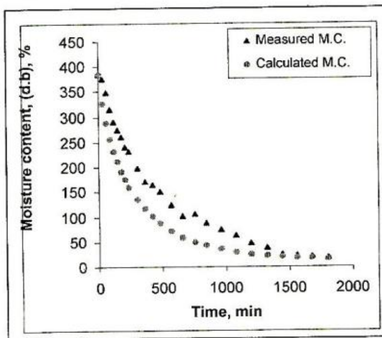


Figure 8. Measured and predicted values of grape moisture content using Page's equation at (T) 60°C using the term (Me) for proto-type dryer at air velocity of 1 m/s.

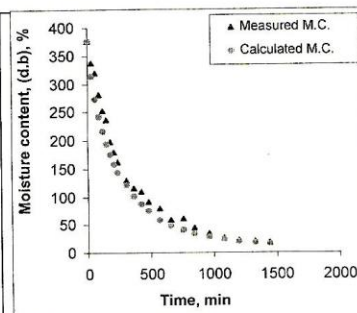


Figure 9. Measured and predicted values of grape moisture content using Page's equation at (T) 60°C using the term (Me) for proto-type dryer at air velocity of 2 m/s.

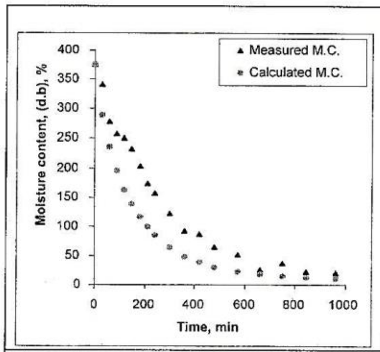


Figure 10. Measured and predicted values of grape moisture content using Page's equation at (T) 70°C using the term (Me) for proto-type dryer at air velocity of 1 m/s.

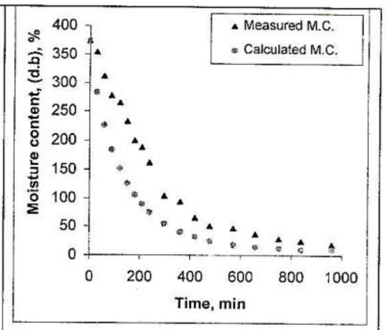


Figure 11. Measured and predicted values of grape moisture content using Page's equation at (T) 70°C using the term (Me) for proto-type dryer at air velocity of 2 m/s.

2- Re-hydration test of raisins:

As shown in Table (2), the re-hydration ratio and the corresponding final moisture content of the dried grape (raisins) increased with the increase of drying air temperature and velocity. At air velocity of 1 m/s and drying air temperature of 50, 60 and 70 °C the recorded re-hydration ratios were 2.163, 2.570 and 2.303 %. While the corresponding values for the higher air velocity of 2 m/s were 2.196, 2.462 and 2.500 %, respectively. On the other hand, the recorded moisture content for the re-hydrated samples of the grape dried at 1 m/s air velocity and drying air temperature of 50, 60 and 70 °C were 148.385, 166.525 and 185.368 % (d.b.), respectively. While the corresponding moisture content for the dried sample at 2 m/s were 145.278, 170.051 and 186.533 % (d.b.), respectively.

Table 2. Re-hydration characteristics of the dried grape (raisins) at different levels of drying air temperature and velocity.

Drying air temperature, °C	Re-hydration ratio		Moisture content of the re-hydrated sample, % (d.b)	
	V1	V2	V1	V2
50	2.163	2.196	148.385	145.278
60	2.257	2.462	166.525	170.051
70	2.303	2.500	185.368	186.533

Thermal efficiency of the dryer:

As shown in Table (3), the dryer thermal efficiency increased with the increase of drying air temperature and air velocity. For the lower air velocity of 1 m/s and drying air temperature of 50, 60 and 70 °C the calculated thermal efficiencies were 37.00, 47.88 and 66.33 % respectively. While, the corresponding values at air velocity of 2 m/s were 41.60, 54.00 and 68.20 % respectively. This means that, the required energy for water evaporation decreased with the increase of drying air temperature due to the fact that, the required latent heat of evaporation is decreased (Moustafa, et al., 1992) in Arabic.

In general, the thermal efficiency of the proposed dryer may be considered satisfactory for general use.

Table 3. Thermal efficiency of the dryer at different drying air temperature and velocity.

Air velocity, m/s	Temperature, °C	Final grape Mc, % (w.b)	Loss of water, kg	Required energy for water evaporation, kJ	Input energy, kJ	Thermal Eff., %
1	50	16.666	12.140	2382.7	78174.55	37.00
	60	16.507	12.000	2358.5	59108.00	47.88
	70	15.820	11.990	2333.8	42220.00	66.33
2	50	16.660	11.770	2382.7	67552.00	41.60
	60	17.287	11.763	2358.5	50,664.00	54.00
	70	18.690	11.845	2333.8	40,531.20	68.20

Cost estimation for the dryer:

The assumptions used in cost estimation and the obtained results are presented in Table (4). As shown in the table, the estimated total cost of grape drying using the portable dryer was 2.35 LE/hr, while the drying cost/kg of fresh grape was 1.766 LE. Since, the total capacity of the dryer is about 20 kg of fresh grape producing about 6 kg of raisin, the calculated operation cost of the dryer approaches about 5.875 LE/kg of raisin.

Table 4. Cost estimation for the portable dryer*.

No.	Assumptions:	
1	Price of the dryer (LE)	2200
2	Dryer capacity fresh grape (kg)	20
3	Drying time (hr)	15
4	Operation hours per year	1350
5	Operation life of the dryer (year)	10
6	Total weight of fresh grape (kg/year)	1800
7	Number of drying runs (run/year)	90
8	Drying ratio, dry/fresh grape	0.30
	A- Fixed costs:	1.1108
	B- Variable costs:	1.16148
	C- Total cost	
	(LE/hr)	2.35
	(LE/kg) fresh grape	1.76
	(LE/kg) raisin	5.87
	LE/run	34.78

* Drying air temperature 70 °C, air velocity 2 m/s.

CONCLUSION

1- The heat control circuit of the dryer could control the drying air temperature with average fluctuation range of ±1.6737 °C.

2- The recorded drying time of grapes were 54, 26 and 16 hours for the air velocity of 1 m/s, and drying air temperature of 51.08, 60.55 and 71.25 °C, respectively. While the corresponding drying time for the air velocity of 2 m/s were 52, 20 and 14 hours, respectively.

3- Both the examined models could describe the change in grape moisture content satisfactorly. While the, Page's model could predict the change in moisture content of grape more adequately than the simple models.

4- The results of sensory tests show that, the color of raisins produced at lower drying air temperature and air velocity was not uniform and darker in comparison with the raisins dried at higher levels of air temperature and velocity. Also, the re-hydration ratio and the corresponding final moisture content of the dried grape (raisins) increased with the increase of drying air temperature and velocity.

5- The dryer thermal efficiency increased with the increase of drying air temperature and air velocity. Also, the estimated drying cost of grape using the portable dryer was 2.35 LE/h while the drying cost/kg of fresh grape was 1.766 LE/kg.

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تطوير وتقييم مجفف متنقل لتجفيف العنب

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أجريت هذه الدراسة لتطوير وتصنيع مجفف متنقل لتجفيف العنب يعمل بغاز البوتاجاز كمصدر للطاقة الحرارية يناسب المزارع الصغير كبديل للطرق التقليدية التى تؤثر بصورة مباشرة على جودة المنتج النهائى وكذلك المجففات الصناعية ذات السعات الكبيرة والتى تحتاج إلى إستثمارات عالية. وقد تم إجراء مجموعة من التجارب لتصميم المجفف المقترح وذلك عند مستويات مختلفة من درجة الحرارة (٥٠، ٦٠، ٧٠ °م) وسرعات مختلفة لهواء التجفيف (١، ٢ م/ث). كما تم أيضاً إختبار ومقارنة نموذجين رياضيين لتجفيف العنب فى طبقات رقيقة شملت (المعادلة البسيطة، معادلة Page) وذلك من حيث وصفها لمنحنيات التجفيف وكذلك إمكانية تطبيقها للتنبؤ بالمحتوى الرطوبى للعنب أثناء عملية التجفيف. وقد شملت أسس تقييم المجفف الزمن الكلى لعملية التجفيف، الكفاءة الحرارية، جودة المنتج النهائى وكذلك التكلفة الكلية لعملية التجفيف. وقد أظهرت النتائج المتحصل عليها ما يلى:

١- أمكن لدائرة التحكم فى درجة حرارة هواء التجفيف بإستخدام غاز البوتاجاز التحكم الدقيق فى درجة حرارة الهواء حيث كان مدى التذبذب فى درجة الحرارة يعادل ± ١,٦٧٣ °م.
٢- وصلت مدة التجفيف إلى حوالى ٥٤، ٣٦، ١٦ ساعة فى حالة سرعة الهواء ١ م/ث ودرجة حرارة ٥٠، ٦٠، ٧٠ °م على التوالى، بينما كانت القيم المقابلة فى حالة سرعة الهواء ٢ م/ث تعادل ٥٢، ٢٠، ١٤ ساعة على التوالى.
٣- أمكن للنموذجين الذين تم إختبارهما وصف سلوك التجفيف والتنبؤ بالمحتوى الرطوبى للعنب بصورة جيدة، بينما أعطت معادلة Page دقة أعلى فى التنبؤ وذلك فى حالة إستخدام المحتوى الرطوبى المتوازن (M_e) فى حساب نسبة الرطوبة (M_f).
٤- أعطت درجة حرارة التجفيف ٧٠ °م عند سرعة هواء ٢ م/ث أعلى خصائص جودة للزبيب المنتج من حيث درجة اللدونة، لزوجة السطح، اللون، وكذلك نسبة التشرب.
٥- أعطى التجفيف كفاءة حرارية مناسبة للإستخدام على المستوى التجارى حيث تراوحت من ٣٧,٠٠ – ٦٨,٢٠ %، بينما وصلت التكلفة الكلية لعملية التجفيف إلى حوالى ٢,٣٥ جنيه/ساعة أو ١,٧٦ جنيه/كج من العنب.