Role of agricultural engineering in environmental and sustainable development for the valley and delta areas: 1879 -1889

DRYING FIGS USING DEVELOPMENT MECHANICAL DRYER

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ABSTRACT

The present work was conducted to study and simulate the drying behavior of whole figs fruits under different drying parameters. The approach led to develop a small scale industrial figs dryer using butane-gas as heat energy source and also describe the change in whole figs moisture content during actual drying process using the proposed dryer. The experimental were carried out using fresh whole figs "Ficus Carica" its local name is "Sultani". Whole figs fruits were treated before drying by treatment (A): the fruits sulfured by dipped in 1.5% aqueous sodium metabisulfit and, treatment (B): the fruits were dipped in 1% sodium hydroxide before treated with solution of 1.5% sodium metabisulfit. Four levels of drying air temperature (55, 65, 75 and 85 °C) and four levels drying air velocity (0.2, 0.4, 0.6 and 1 m/s)

The results showed that, the reduction rate of whole figs moisture content was increased with the increasing of drying air temperature and air velocity in all pretreatment of simple whole figs. On the other hand, the whole figs moisture content reduction rates on the treatment (B) were higher than that in treatment (A) for all the combination of the parameters. The recorded drying time for drying whole figs from an initial moisture content of about 223-400% d.b to a final moisture content of about 18-20% d.b were 35-20hours under different drying parameters. Heating control unit using butane-gas was used to control heat source in drying air temperature with fluctuation of about ±1.7 °C for all levels of drying air temperature. The total capacity of the dryer is about 40 kg of fresh figs producing about 10 kg of dried figs, the calculated operation cost of the dryer approaches about 6.3 LE/kg of dried whole figs fruits. The developed dryer of whole figs fruits showed good mechanical and thermal performance.

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INTRODUCTION

The drying of agricultural products, common method of natural preservation by reducing the moisture content, has always been a sign cant contribution to the income of the agricultural societies. Figs, one of the earliest cultivated fruits, with several varieties dried and stored for later consumption ***(Vinson, 1999)***.

Figs can be dried either by traditional means (open sun or solar drying) or in mechanical dryers utilizing heated air. Nowadays an increasing volume of the total production of figs causes a need for artificial drying using, in heated air mechanical dryers.

The large scale mechanical dryers are capital intensive and are not suitable for small-scale farms in Delta area. On the other hand it has several disadvantages assisted with the cost of equipment and the cost of the consumed energy (thermal and 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 labor intensive operation. Several other factors, however, make traditional sun drying less attractive. These factors include product pollution from dust, and animal contamination, a 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 increases the cost of sorting the final product.

Pangavhane et al., (2000) used a laboratory dryer for drying grapes. They found that the drying air temperature range of (20 to 70 °C) make explicit influence on the drying rate.

Guine, (2008) studied the effect of the drying air temperature from (30 to 50 °C) and air velocity from (0.5 to 1.5 m/s) on the shrinkage of pears fruits. Temperature affected mostly the water loss while the concentration of the solution affected mostly the solids gain.

Stamatios, et al., (2005) studied the drying air characteristics on the drying performance of figs *(Ficus Carica)* several drying tests have been carried out in a laboratory scale tunnel-dryer. The investigation of the drying characteristics has been conducted in the temperature range of (55–85^{o}C) and the air velocity in the range of (0.5–3m/s). An Arrhenius-type equation was used to interpret the influence of the drying air parameters on the effective diffusivity, calculated with the method of slopes in terms of energy of activation, and this was found to be insensitive to air velocity values higher than 2 m/s.

Xanthopoulos et al., (2007) reported that dried whole figs have the color and aroma of produce being dried by heat pumps were better (visually and qualitative) than those being dried by conventional hot air dryers. The main objective of the present study was to develop and to evaluate a small scale mechanical fig dryer suitable for small and medium farms using butane gas as economic heat energy source without environmental pollution. The approach leads to improving the traditional sun drying methods of fruits and also overcome the problem of higher energy consumption and capital intensive of the large scale industrial fruits dryers. The specific objectives were as follows:

1- To develop, test and evaluate a whole figs dryer using butane-gas as heat energy source under four levels of drying air temperature 55, 65, 75, and 85 °C, four levels of air velocity 0.2, 0.4, 0.6 and 1 m/s and two methods of pretreatments,

2-To determine energy consumption, thermal efficiency, drying cost and final quality of the dried whole figs.

MATERIAL AND METHODS

The experimental were carried out using fresh whole figs were treated before drying by treatment (A): the fruits sulfured by dipped in 1.5% sodium metabisulfit for two minutes and treatment (B): The fruits were dipped in 1% sodium hydroxide to crack the skins at 90^{o}C for one minute before treated with solution of 1.5% sodium metabisulfit for two minutes. Four levels of drying air temperature (55,65,75and85 °C) and four levels drying air velocity (0.2,0.4,0.6and1m/s) the approach led to develop and evaluate a small scale industrial whole figs dryer using butane-gas as heat energy source and also describe and predict the change in whole figs moisture content during actual drying process using the proposed dryer.

Experimental set-up:

Figures (1 and 2) illustrate the elevations and a general view of the artificial dryer used for experimental work the details of the temperature control system .

Moisture content of figs:

The initial moisture content on dry basis, "Mdo" of the fresh fruits was determined by the vacuum oven drying method. Samples of the fruit mass "Wo" were dried in a vacuum oven at 70 ^{o}C until the mass "Wd" of the dried sample became stable, according to ***(A.O.A.C, 1985).***

The instantaneous moisture content on dry basis, "Mt" at any time can be calculated from the following equation as mentioned by ***(El-Sebaii et al., 2002)***:

$$M_t = \left[\frac{(Md_o + 1) \times W_t}{W_o} \right] - 1 \quad \text{...(1)}$$

Where:

Wo = mass of the original fresh fruits, kg.

Wt = mass of dried to dried at any time, kg.

Mass of fruits.

The mass of figs samples was measured using an electrical digital balance model D-type with a maximum capacity of 3000 g and measured to an accuracy of 0.01 g, **Rehydration ratio.**

Rehydration ratio was used to express ability of the dried material to absorb water ***(Lewicki, 1998).*** It was determined by the following equation:

$$\text{Rehydration ratio} = \frac{\text{Mass of water absorbed during rehydration}}{\text{Mass of water removed during drying}} \quad \text{.....(2)}$$

Reducing sugar (g/100g on dry weight basis).

It was determined by the method described in ***(A.O.A.C, 1985).***

Thermal Efficiency of the Dryer

The thermal efficiency was calculated using the following relationship according to ***(Jindal and Reyes, 1987).***

$$\eta_t = \left(W_w \times \frac{Lh}{Q} \right) \times 100 \text{ , \%} \quad \text{……………………. (3)}$$

Where:

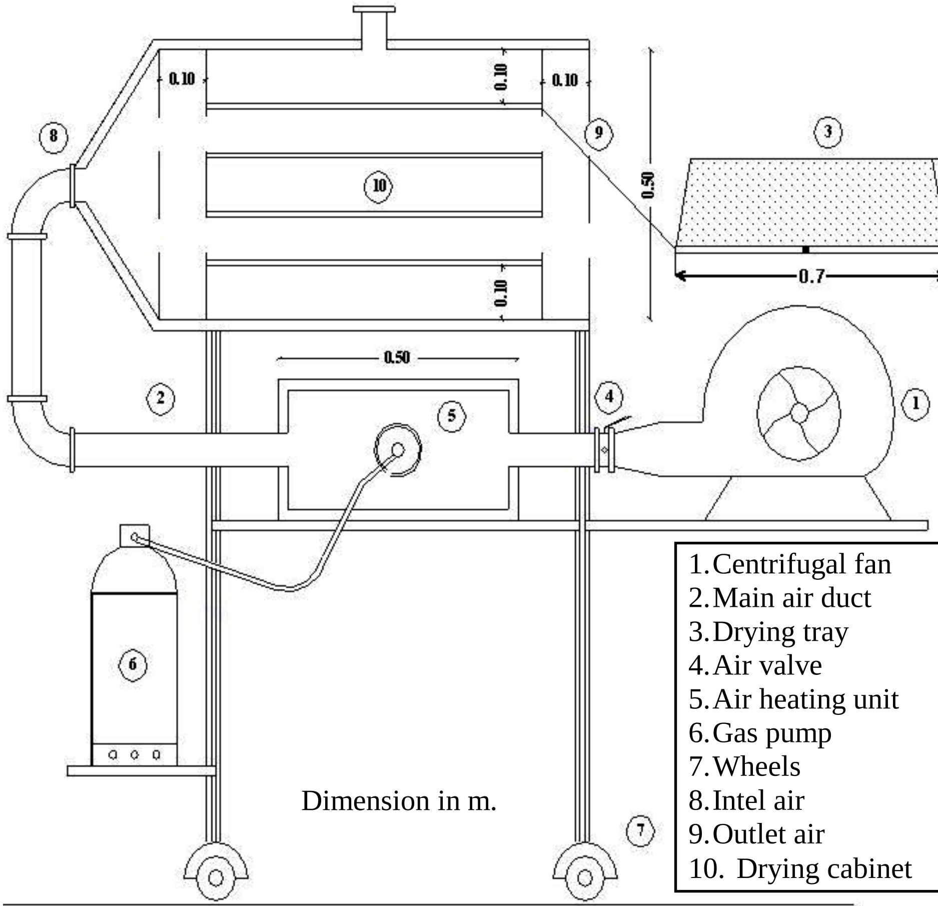
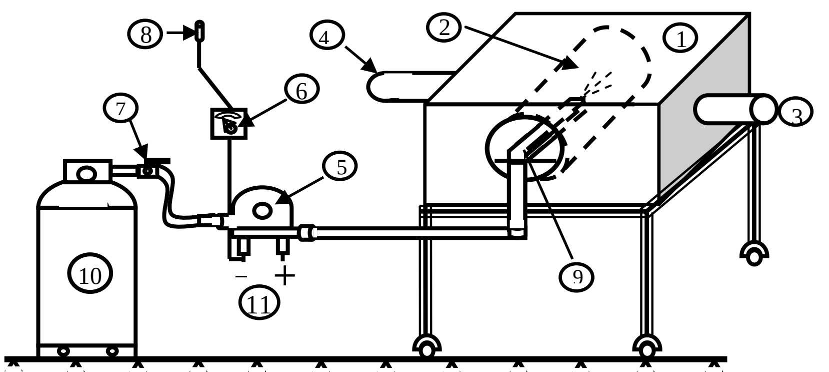


Fig. (1): Schematic of the dryer.



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 pump	11- Electric source	

Fig. (2): Sketch of air heating unit and temperature control system.

η_t = thermal efficiency, % W_w = water evaporated from figs, kg.
Lh = latent heat of water evaporation. KJ/kg.
Q = total energy consumption, kJ.

RESULTS AND DISCUSSION

The Characteristics of Fig Fruits:

The diameter of the local figs variety "Sultani" ranges from (2.6 to 5.2 mm), and its weight ranges from (26 to 60 gram). The selected fruits were taken to be 48 mm (± 2 mm) in diameter. The mass of one fruit of this size is about 45 gram.

The Ability of the Dryer in Heating Control Unit.

The heat control circuit of the dryer could control the drying air temperature with average fluctuation range of ±1.7 °C for all levels of drying air temperature. The above mentioned results revealed that, the heating control unit of the dryer could preciously control the drying air temperature, within reasonable fluctuation range.

Influence of Drying Air Parameters on the Drying Curves.

The change in moisture content of fig as relate to drying time for different pretreatment of samples, different levels of drying air temperature and air velocity are illustrated in figure (3). As shown in the figures the reduction rate of fig moisture content was increased with the increase of drying air temperature and air velocity in all pretreatment of simple figs. On the other hand the fig moisture content reduction rates on the treatment (B) were higher in comparison with treatment (A) for all the combinations of the parameters tested. Figures (4) show the variation of drying rate with the change in fig moisture content. As shown in figures, drying rate of fig was decreased continuously with the increase of drying time due to the reduction in fig moisture content.

Effect of Different Dehydration Methods on Quality of Dried Fig.

The results show treatment (B) of figs was the best pretreatment which ranks 70-90 degree of overall acceptability for all dehydration methods. This may be due to the fact that it needs short drying time and characterized by low dehydration ratio and high rehydration ratio. Dried fig produced by this pretreatment was also distinguished for light-color and gummy texture. Moreover, it rehydrated faster on contact with water. These results are agreed with those reported by ***(Gabas et al, 1999 and Abd EL-Aal, 1998).***

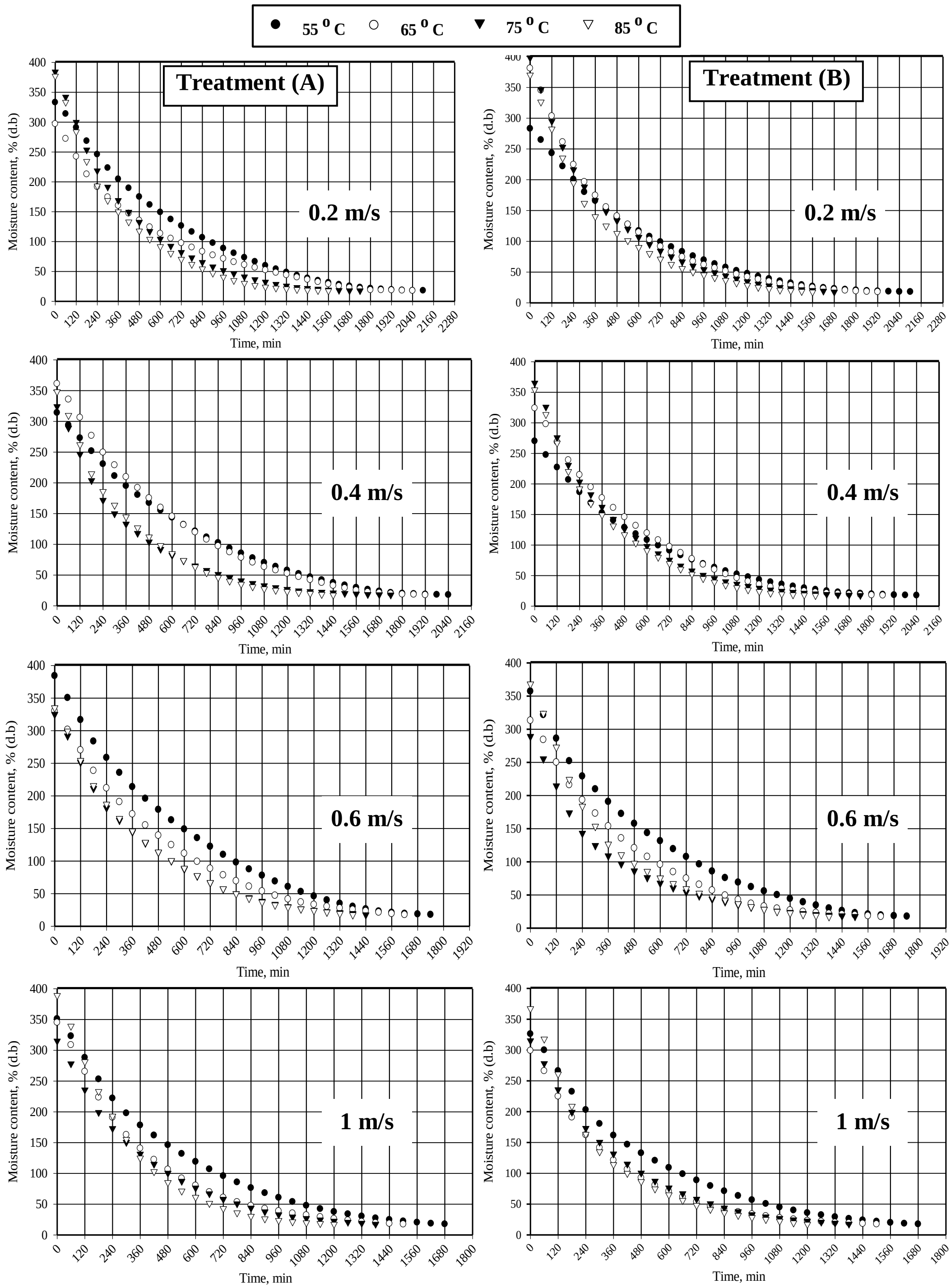


Fig. (3): Change in moisture content of fig as related to drying time at different drying air temperature, air velocity at different treatment of figs.

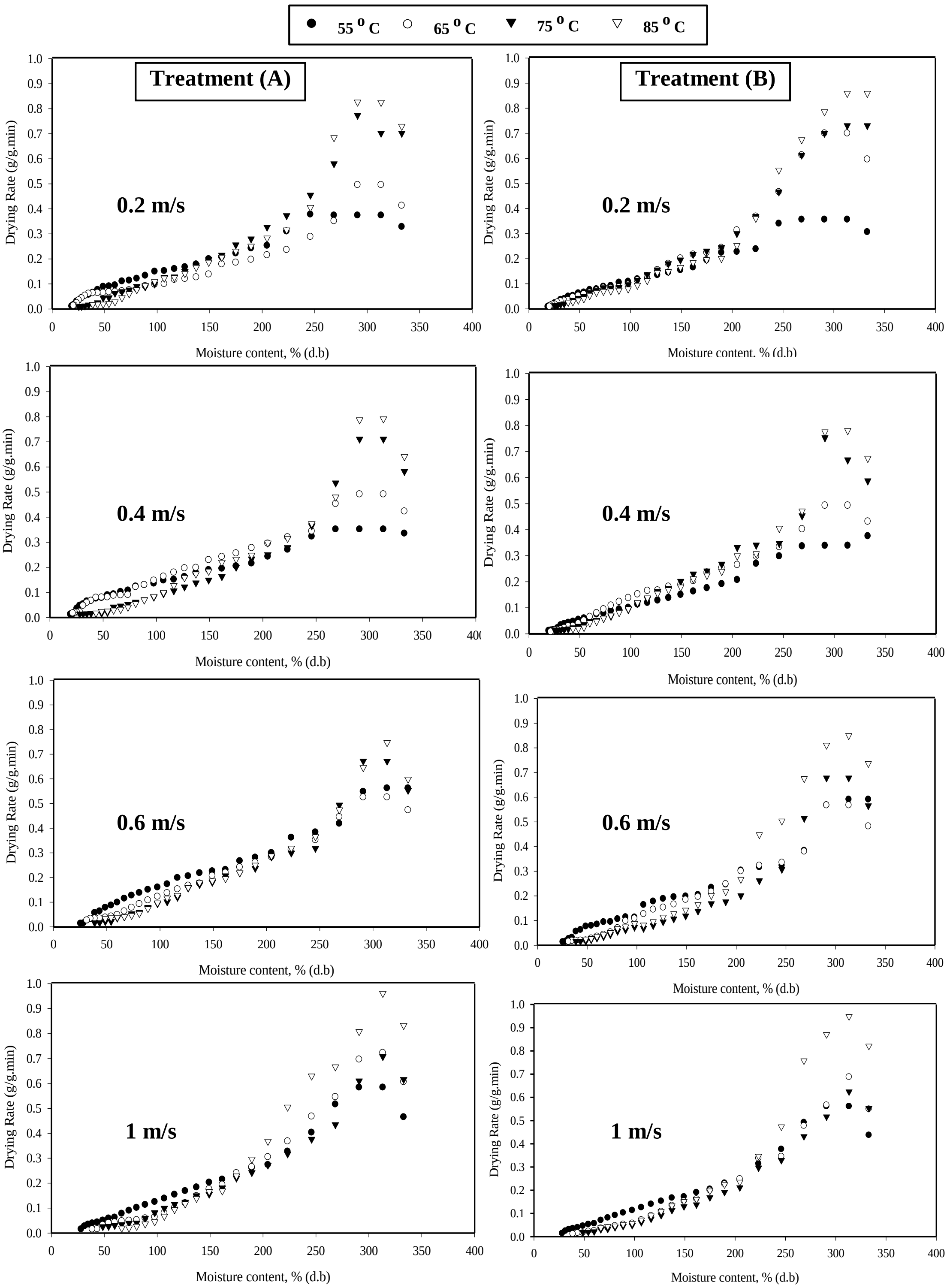


Fig. (4): Change in drying rate of fig as related to drying time at different drying air temperature, air velocity at different treatment of figs.

Thermal Efficiency of the Fig Dryer.

The results show the dryer thermal efficiency was increased with the increasing of drying air temperature and air velocity. This means that, the required energy for water evaporation was decreased with the increasing of drying air temperature due to the fact that, with increasing the heating temperature of the product, the required latent heat of evaporation for this product is decreased ***(Moustafa, et al., 1992)***.

Cost Estimation for the Fig Dryer.

The estimated total cost of fig drying using the dryer was 3 LE/h while the drying cost/kg of fresh figs was 1.57 LE. Since, the total capacity of the dryer is of about 40 kg of fresh figs producing of about 10 kg of dried figs, the calculated operation cost of the dryer approaches of about 6.3 LE/kg of dried figs.

CONCLUSION

The obtained results could be summarized as follow:

1. The results assured that, increasing drying air temperature decreased the drying time, and increased the drying rate of whole figs fruits and also show that increasing air velocity decreased to very limited value the drying time and increased to a very little limited value drying rate of whole figs.
2. The results showed that, the recorded drying time for drying fig from an initial moisture content of about 223-400 % d.b to a final moisture content of about 18-20 % d.b were 35, 32, 28 and 26 hours for air velocity 0.2 m/s and air temperature of 55, 65, 75 and 85 ^{o}C respectively. The corresponded drying time for air velocity 0.4 m/s were 34, 31, 29 and 25 hours respectively. The recorded drying time for 0.6 m/s were 29, 27, 25 and 23 hours respectively. While the drying time for air velocity 1 m/s were 28, 25, 23 and 20 hours respectively.
3. The results assured that, treatment (B) of whole figs was the best treatment which ranks 70-90 degree of overall acceptability for all dehydration methods.
4. The estimated total cost of fig drying using the dryer was 3 LE/h while the drying cost/kg of fresh whole figs was 1.57 LE. Since, the total capacity of the dryer is about 40 kg of fresh whole figs producing about 10 kg of dried figs, the calculated operation cost of the dryer approaches about 6.3 LE/kg of dried whole figs.

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المراجع العربية:

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الملخص العربي

تجفيف التين بأستخدام مجفف ميكانيكى مطور

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أجريت هذه الدراسة لغرض تطوير وتصنيع مجفف ميكانيكي لتجفيف محصول التين السلطاني كأحد منتجات الفاكهة بسعة ٤٠ كيلو جرام يعمل بغاز البتوجاز كمصدر للطاقة الحرارية يتميز بسهولة تصنيعه وانخفاض تكلفته حيث تضمن المجفف بنظام للتحكم في درجة حرارة هواء التجفيف كما ذود الجهاز بمروحة لدفع الهواء داخل المجفف للحصول على سرعة الهواء المطلوبة في عملية التجفيف. حيث أجريت هذه الدراسة بقسم الهندسة الزراعية - كلية الزراعة - جامعة كفر الشيخ.

فقد تم تجفيف التين السلطاني فى طبقة رقيقة باستخدام المجفف المقترح باستخدام أربع مستويات مختلفة من درجة حرارة هواء التجفيف وهى (٥٥-٦٥-٧٥-٨٥ °م) وأربع مستويات مختلفة من سرعة هواء التجفيف وهى (٠,٢-٠,٤-٠,٦-١ م/ث) وذلك بمعاملة ثمار التين السلطاني بمعاملات أولية مختلفة قبل عملية التجفيف ومنها:

أ- الغمر في محلول ميتابيسلفات الصوديوم بتركيز ١,٥ **%**.

ب- الغمر في محلول هيدروكسيد الصوديوم بتركيز ١ **%** ثم محلول ميتابيسلفات الصوديوم بتركيز ١,٥ **%**.

أظهرت النتائج المتحصل عليها أن درجة حرارة هواء التجفيف (٧٥ ٥م) عند سرعة هواء التجفيف (١ م/ث) أعطت أعلى خصائص جودة لتين السلطاني المنتج وذلك من حيث اللون والطعم وكذلك نسبة التشرب. كانت أفضل معاملة لتجفيف التين هي المعاملة بالغمر في محلول هيدروكسيد الصوديوم بتركيز ١ ٪ ثم الغمر في محلول ميتابيسلفات الصوديوم بتركيز ١,٥ ٪ حيث أنها تتطلب اقل زمن تجفيف للوصل إلى أفضل محتوى رطوبى متوازن وامن للتخزين.

اظهر المجفف المقترح خواص ميكانيكية وحرارية مقبولة من الناحية العملية. أيضا حقق المجفف وسعته ٤٠ كجم صافى ربح يعادل ٦,٣ جنيه/كجم من التين المجفف.

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