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Full length article

Some engineering factors affecting referactance window drying of guava

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ABSTRACT

In the present work drying kinetics of Guava of initial moisture content 88 ±1 % w.b. using Refractance Window (RW) dryer as affected by three different levels of water basin temperature, namely: 80, 85 and 90 ±1°C and three different puree thickness of approximately 1,2 and 3mm as a parameter. The indicators that used to evaluate this system such as rehydration ratio, color as quality indicators, productivity(kg/h), drying efficiency and costs. The main results showed that drying time was affected by water basin temperatures and puree thickness significantly, the drying time decreases with water basin temperature increases and puree thickness decreases. The puree temperature affected by drying elapsed time and the rehydration ratios increased as water basin temperature decreases. The RW drying method had significant impact on color quality of dried samples. Increasing puree thicknesses, productivity decreases due to its dependence on drying time. The drying efficiencies were ranged from 28 to 65%. Moderate values of drying costs were recorded at 85°C and 2mm thickness.

1. Introduction

Refractance Window (RW) system is a novel drying method for converting liquid foods and other related biomaterials into powders, flakes, or sheets with added value. In this system, purees or juices prepared from fruits, vegetables, or herbs dry in short times, resulting in products with excellent color, vitamin, and antioxidant retention (Nindo and Tang, 2007).

Guava (*Psidium guajava* L.) is known as a "super fruit", for its nutritional importance in terms of vitamins A and C. Also seeds rich in Omega 3, Omega 6, Polyunsaturated acids, Riboflavin, Protein and minerals (Kadam et al., 2012). Due to the high nutritional value, the guava is used in diverse ways. Guava has a very rich taste and fragrance. The use of the juice and other products made from guava is becoming popular due to its nutritious value. In different fruit juices like mango, apple, pear, etc., guava juice is added to enhance taste, flavor, and vitamin C content (Irshad et al., 2020). According to Food and Agriculture Organization (FAO) of the United Nations and the Ministry of Agriculture, Egypt guava production as of 2019 was 2.7 million Mg (FAOSTAT, 2020). Drying is one of the oldest food preservation methods. High amount of water in food is the main reason for spoilage and the main purpose of drying is to lower the moisture content in food to reduce the microbial and enzymatic activities (Grabowski and Marcotte, 2003). The main advantages of drying are extended product shelf life and out-of-season availability, reduced packaging, storage, handling and transportation costs (Moses et al., 2014).

Several works have been reported on RW drying of agricultural products to compare drying characteristics and quality with other drying techniques. These include strawberry and carrot puree (Abony et al., 2002), pumpkin puree (Nindo et al., 2003) tomato puree (Abul-Fadl and Ghanem, 2011), mango puree (Caparino et al., 2013), guava snacks (Leiton et al., 2020). There are many

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factors affecting RW drying including thickness of puree or slices, temperature of water bath and residence time. Frabetti et al. (2018) investigated the effect of pulp layer thickness of 2 and 3 mm on drying rate and temperature of guava pulp. The duration was 6 mins for 2 mm thickness pulp and 14 min for 3 mm thickness pulp. The drying time was 10 min for 2 mm-thick guava pulp and 18 min for 3 mm-thick pulp. Drying rate was 2.1 greater using 2 mm thick-pulp than 3 mm thick-pulp. Leiton et al. (2020) obtained guava snacks by RW drying, the thickness of slices were 2 mm and 35 mm in diameter, water temperature was 90°C, and moisture content of 4% w.b was achieved in 76 min.

Castoldi et al. (2015) observed moisture content reduction of wet samples increases with the increase in circulating water temperature. Jafari et al. (2016) observed that the product temperatures during RW drying process were observed to be 77, 64 and 49 ºC when water bath temperature were 95, 75 and 55 ºC, respectively. At similar drying time (i.e., at 10.74 min; 55, 75, and 95 ºC water temperature) the results were 57.3, 10.7, and 3.8 % w.b respectively (Nindo et al., 2003). Zotarelli et al. (2015) observed that increasing water temperature from 75 to 85 ºC increased drying rate by 1.7 times and increased temperature from75 to 95 ºC increased drying rate 2 times for 2 mm thick pulp layer.

Traditional drying such as Cabinet, bed type, spray, drum, Microwave and infrared dryers adversely affects the taste, color, nutritional qualities and preservation of bioactive compounds due to high temperature exposure of the product. In the present work Guava were selected in the experimental due to their popularity and nutritional value. The present research aims to developed and evaluate Refractance window dryer for determining its optimal operating conditions.

2. Materials and methods

In the present study, a pilot plant Refractance Window (RW) dryer was constructed, designed and tested in Lab. of the Dept. of Ag. Products Processing Eng. Fac. of Ag. Eng., Al-Azhar U. Cairo to be used in this experimental work in July to September 2021.

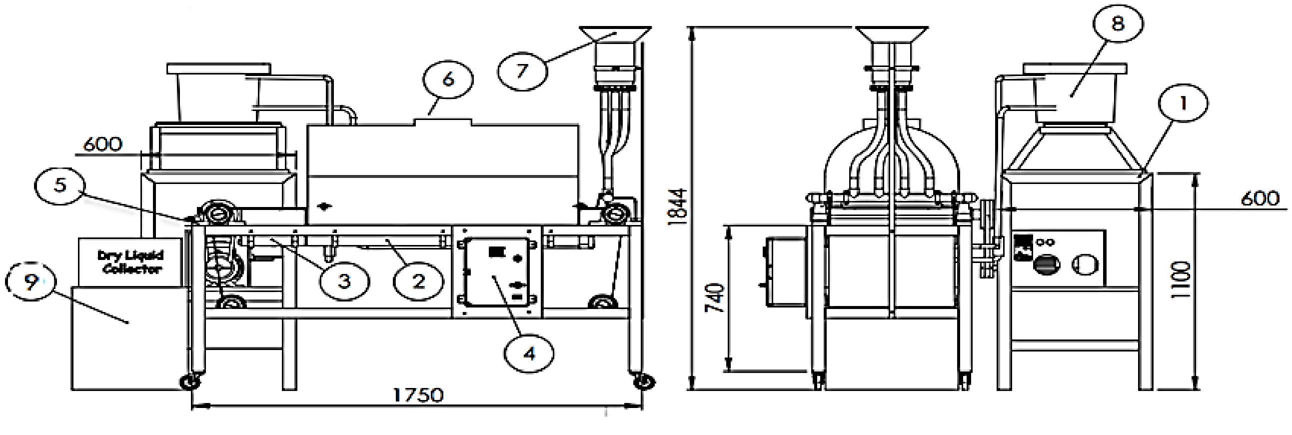
2.1. Materials

2.1.1. Guava Samples

Guava was obtained from a local market in Cairo, Egypt the fruits were selected according to the degree of ripeness by visual inspection, washed, peeled minced by a kitchen blender to be puree of average moisture contents 87 ±1 % w.b. for drying process.

2.1.2. System description

The RW dryer as shown in Fig. 1 is consisted of; Water basin, 4 kW electrical water heater, the water temperature was controlled using controller element, contactor and digital temperature interface; Polyethylene terephthalate moving (Sheet) made in China of 0.9 transmissivity coefficient with dimensions of 0.25 mm thickness and 0.6×1.80 m^2; Transmission system constructed of motor 0.75 kW, 60 Hz, 3phase, and 48 rpm, made in Germany. System speed was varied from 0.45 m/min to 0.58 m/min by LS inverter made in Korea (SV008IC5-IF model, single phase, motor rating is 0.75 kW), Pulleys, Teflon drums and bearings.



① Frame. ② Hot water tank. ③ Cold water tank. ④ Temperature controller. ⑤ Scraper.
⑥ Fan. ⑦ Puree inlet. ⑧ Boiler. ⑨ Dry liquid collector.

Fig. 1. Elevation and side view of (RW) dryer structure.

2.1.3. Measuring instrumentations

2.1.3.1. Temperature measurements

In the present study, the Arduino MEGA 2560 was used as A/D input and output for recording temperatures and ambient air conditions through three DHT22 sensors and the liquid temperatures by three DS18B20 sensors. Arduino was programmed to record these parameters every 1min, the recorded data was sent to Coolterm program® that attached with computer.

2.1.3.2. Electrical balance

Initial and final mass changes during drying process of each sample were measured by a digital balance (HR-200, max 210 g of accuracy of 0.0001g, made in Japan) for determining initial and final moisture content.

2.2. Methods

2.2.1. The *experiments procedure*

Several obstacles were presented as controlling film thickness, fixing measuring instrumentations, puree material adhesion and scratching final dried product. To get rid of these obstacles, stationary dryer was used in the present work. Experiments were conducted in batch mode and at laboratory scale for drying Guava puree. The temperature of water bath was set at 80, 85 and 90 ±1ºC and three different puree thickness of approximately 1,2 and 3mm, chosen based on preliminary tests and previous studies. Moisture contents for the products were continuously determined and during the drying, air, sample and sheet temperatures were recorded.

2.2.2. Dryer material balance

The concept of mass balance was used for final mass of dried product, water removed and water evaporated according to Abul-Fadl and Ghanem (2011).

$$M_p\,(t + \Delta t) = \frac{m_p(t)\left(1 - M_{w.b}\,(t)\right)}{\left(1 - M_{w.b}\,(t + \Delta t)\right)} \quad \text{... [1]}$$

$$W\,(t + \Delta t) = m_p(t + \Delta t) \times (M_{w.b}\,(t + \Delta t) \quad \text{... [2]}$$

$$Wwe\,(t + \Delta t) = ww(t) - ww\,(t + \Delta t) \quad \text{... [3]}$$

where: Mp(t) is the mass of product at a time period (t); kg, Mw.b (t) is the moisture content of product at (t) %, mp(t+ Δt) is the mass of product being dried after time (t + Δt) kg, Mw.b(t + Δt) is the moisture content of product after time (t +Δt) %, W (t +Δt) is the Water content of product being dried after time increment of (t + Δt); kg, Wwe (t +Δt) is the water removed after time (t + Δt); kg/min.

2.2.3. Moisture content of samples

Moisture content of samples was evaluated according to the ASAE standard (2002) by oven method at temperature of 105ºC (±1) for 24 hours as follows:

$$m = \frac{W_m}{W_m + W_d} \times 100\ (w.b\%) \quad \text{... [4]}$$

where m is moisture content wet basis (%), wm is mass of moisture in sample (g), W_d is mass of bone-dry material (g).

2.2.4. Moisture Ratio (MR)

The moisture ratio was calculated as follows:

$$MR = \frac{M_t - M_e}{M_i - M_e} \quad \text{... [5]}$$

where MR is moisture ratio (kg $_{water}$/ kg $_{dried\ material}$), M_t is moisture contents after time t (%), M_i is initial moisture content (%), M_e is equilibrium moisture content, assumed M_e is M_f (%) and M_f is final moisture content (%).

2.2.5. Useful drying energy rate (Pu)

$$P_u = (m \cdot c_p \cdot \Delta T + Ww \cdot L) \quad \text{... [6]}$$

where P_u is useful drying energy rate (kJ), m is mass of the sample to be dried (kg), c_p is specific heat of the sample (kJ/kg.ºC), its calculated as function of moisture content from following equation according to Toledo (1991).

$$cp = 4.1868\, m_{w.b} + 0.83736\,.(1 - m_{w.b}) \quad \text{... [7]}$$

ΔT is temperature difference of sample (ºC), Ww is amount of removed water (kg), L is the latent heat of evaporation at sample temperature (kJ/kg).

2.2.6. Average drying efficiency determination

The average drying efficiency evaluated according to Abul-Fadl and Ghanem (2011).

$$E_T = E_{e1} + E_{e2} + \int_t^{t+\Delta t} p_a + \int_t^{t+\Delta t} p_b \quad \text{... [8]}$$

$$\eta_i \frac{(W_{we} \times L) + m\,cp\,\Delta t}{E_{Total}} \quad \text{... [9]}$$

where: E_T is the total energy used for heating, moving drying air and plastic belt during a time period of (t) to (t+Δt); in kJ, E_{e1} is power required to raise the water temperature in the basin to 80, 85 and 90ºC ±1 (kW), E_{e2} is power required for compensating heat losses and drying process (kW), P_a is electrical power required for moving drying air (kW), P_b is electrical power required for moving the plastic belt (kW), m is total mass of water in the dryer basin (kg), Cp is specific heat of water (kJ/kg ºC), W_{we} is the moisture evaporated during time period of (t) to (Δt), in kg, which can be calculated using the mass balance concept, L is the latent heat of vaporization of water at the drying air temperature in kJ/kg.

2.2.7. Rehydration ratio (RR)

Rehydration capacity is useful to determine how the dried product reacts with the moisture. The rehydration capacity of dried product was evaluated by immersing 5g of dried samples in boiled distilled water. Samples were removed at regular time intervals (each 5 min.) and weighed until difference in successive weightings was insignificant. Rehydration ratio was calculated from the following equation (Gowen et al., 2008):

$$\text{Rehydration ratio (RR)} = \frac{w_t - w_d}{w_t} \quad \text{... [10]}$$

where w_t is the mass of rehydration sample at any time (g), wd is the mass of dried sample (g).

2.2.8. Color evaluation

The surface color of the fresh and dried samples was measured according to RAEI and JAFARI (2013), color of the dried samples was carried out by 10 trained panelists. They were requested to assess sensory attributes of the samples including color and total acceptability on a 5-point scale (1 = very bad, 2 = bad, 3 = mediocre, 4 = good, 5 = very good)

2.2.9. Cost analysis

The current economic study is conducted to determine the costs of drying using RW. The hourly cost of drying can be calculated according to Awady et al. (2003).

$$C = \frac{P}{h}\left[\frac{1}{a} + \frac{i}{2} + t + r\right] + (W.e) + \left(\frac{m}{200}\right) \quad \text{... [11]}$$

$$\text{Cost (L.E./kg}_{\text{dried product}}) = \frac{\text{Dryer hourly cost (L.E./h)}}{\text{Dryer productivity (kg}_{\text{dried product}}/\text{h)}} \quad \text{... [12]}$$

where: C is total cost, L.E. /h, P = price of system, L.E., h = yearly working hours, is assumed in the present work to be:(300 day/year × 2 period/day × 8 h/period = 4800 h/year), a = life expectancy of system, about 10 Years, i = interest rate/Year. (The bank interest in Egypt / year), which was about 11%, t = taxes and overheads ratio, which is assumed to be 20 %, r = repair and maintenance ratio, which is assumed to be 10 %. W = power of dryer (kW), e = hourly cost/kW.h, (1.6 L.E./kW.h), m = the monthly average wage, L.E., (2000L.E) in the present work, impose that there are 10 dryers becomes (200 L.E. /man.dryer.month), 200 = the monthly average working hours.

3. Results and discussions

3.1. Moisture content wet basis, water removed at three different film thickness and three different water basin temperatures

In present work Guava puree films of approximately 1, 2 and 3mm were dried in a Refractance widow dryer designed to study the effect of Guava film thickness, water basin temperature 80, 85 and 90 ±1°C on final moisture content as affected by elapsed drying time. Moisture contents wet basis were average values of three replicates for all experiments.

Fig.2a,b and c showed the relationship of Guava puree moisture content as affected by water basin temperature and drying elapsed time at approximately film thickness 1,2 and 3mm respectively. There is approximately inverse proportional between the puree moisture contents and elapsed drying time for all water basin temperatures and all studied thickness. It also clears that there is inverse proportional between water basin temperatures and the final moisture contents of all studied thickness.

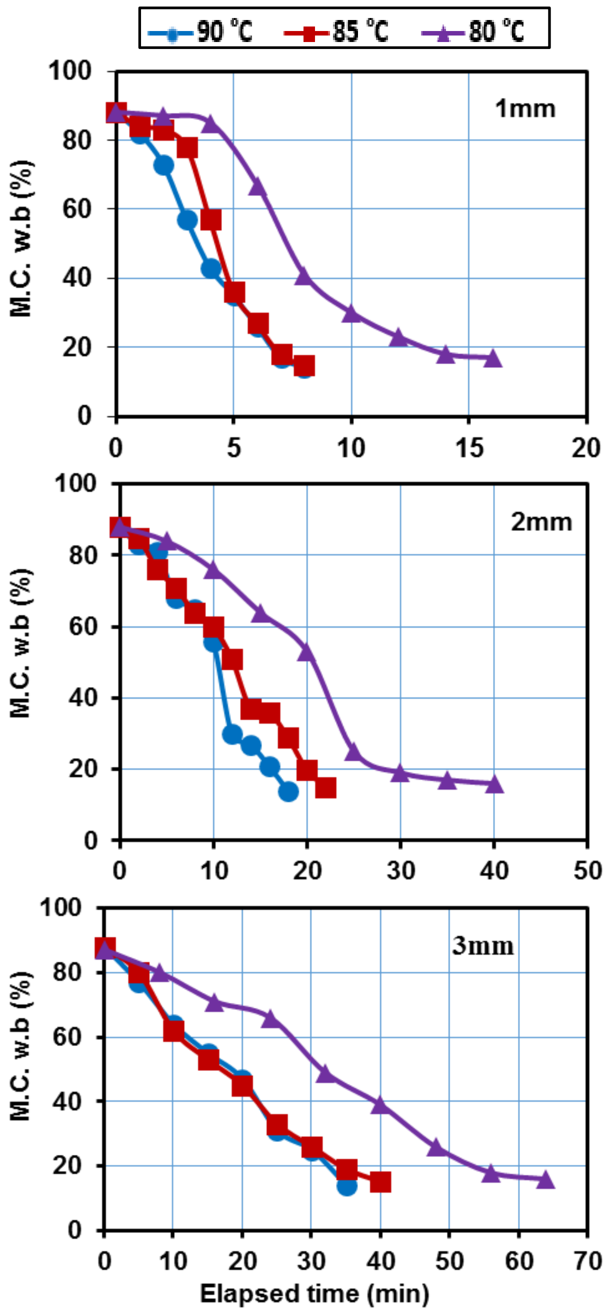


Fig. 2. Moisture contents wet basis (%) of Guava puree as affected by water basin temperature and drying elapsed time at the three different thicknesses studied.

The elapsed drying time for Guava puree to reach approximately the same final moisture content of water basin temperature of 80 °C for 1, 2 and 3mm thickness were (2,2.3), (1.8,2.2) and (1.6,1.8) times that of 85 °C and 90 °C respectively. The final moisture contents were approximately 17%, 15%, 14% and 16%, 15%, 14% and 16%,15%,14% for the three different studied thickness and at 80,85 and 90°C respectively. It is also cleared that when drying is proceeded water removed decreased for all studied temperatures and thickness. It can be also concluded that at fixed drying time the puree moisture contents increased as water basin temperature decreased at same thickness. It is also cleared that the higher the water basin temperature the lower the moisture ratio and the faster the drying is progressed (the lower the elapsed drying time is required), these results agreed with Shende and Datta (2019).

3.2. Effect of water basin temperature and puree thickness on Guava puree drying curves

Fig. 3 indicated the relationships of moisture ratio and drying time as affected by water basin temperature and puree thickness. It's clear that the higher the water temperature and the lower puree thickness the lower moisture ratio and total drying time. It is found that the least drying time was 7 min with puree thickness of 1mm and water basin temperature 85 °C, while the highest drying time was 96 min with puree thickness of 3mm and water basin temperature 80°C.

Fig. 4 illustrated the relationships of drying rate and drying time as affected by water basin temperature and puree thickness. It's clear that as the water temperature increases and puree thickness deceases the drying rate increases. The results were in agreements with Badr (2012) and Eissa (2021). It's also clear that increasing water temperature from 80 °C to 85 °C increased drying rate by 1.1 times and increased water temperature from 80 °C to 90 °C increased drying rate by 1.3 times, the average drying rates were 0.014, 0.03 and 0.031 for 80, 85 and 90 °C for 2mm of Guava puree thickness respectively.

3.3. Water basin, Sheet and puree temperatures as affected by drying elapsed time

Figs. 5, 6 and 7 cleared water basin, Sheet and puree temperatures as affected by drying elapsed time for guava puree for all studied basin temperatures and all thicknesses. It clears that for all purees studied, the puree temperature started at 22°C and increased to maximum temperature of approximately 70°C, the average puree temperatures as drying proceeds were observed to be 58, 56 and 54°C when the water basin temperatures were 90, 85 and 80°C respectively. It is clear that in all cases the puree temperature does not reach the heating water temperature.

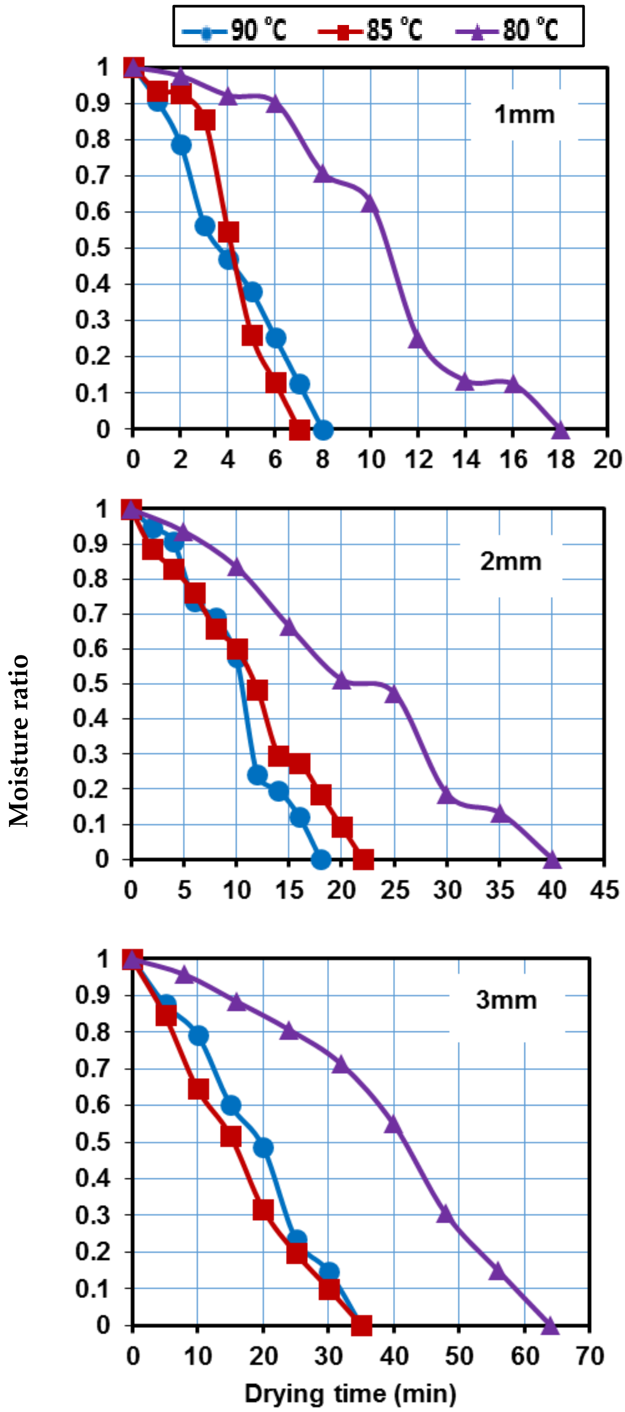


Fig. 3. Moisture ratio of Guava puree as affected by water basin temperature and drying elapsed time at the three different thicknesses studied.

Despite this fact that the RW drying process yields better quality products with help of high-water temperatures resulting in both rapid dehydration and quit low product temperatures. These results in agreement with that reported by Nindo and Tang (2007), when the actual product temperatures which is usually below 70°C, this may be attributed to resistance to heat transfer and cooling that accompanies intense evaporation Abonyi et al. (2002) and Nindo et al. (2003).

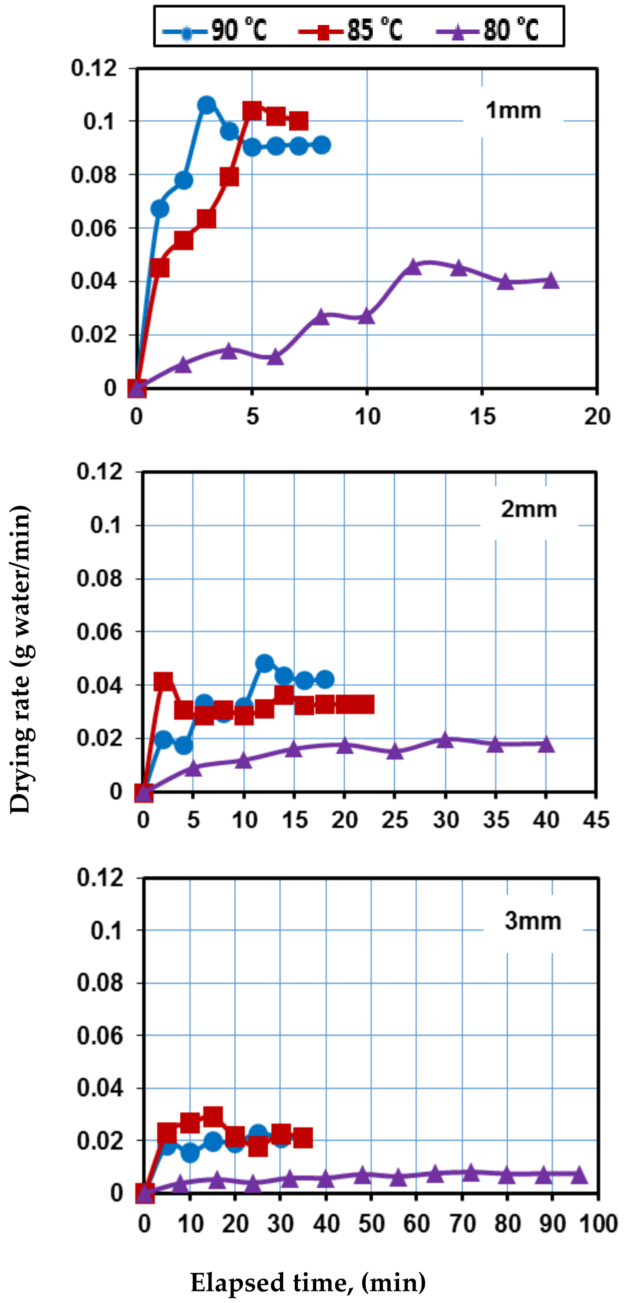


Fig. 4. Drying rate of Guava puree as affected by water basin temperature and drying elapsed time at the three different thicknesses studied.

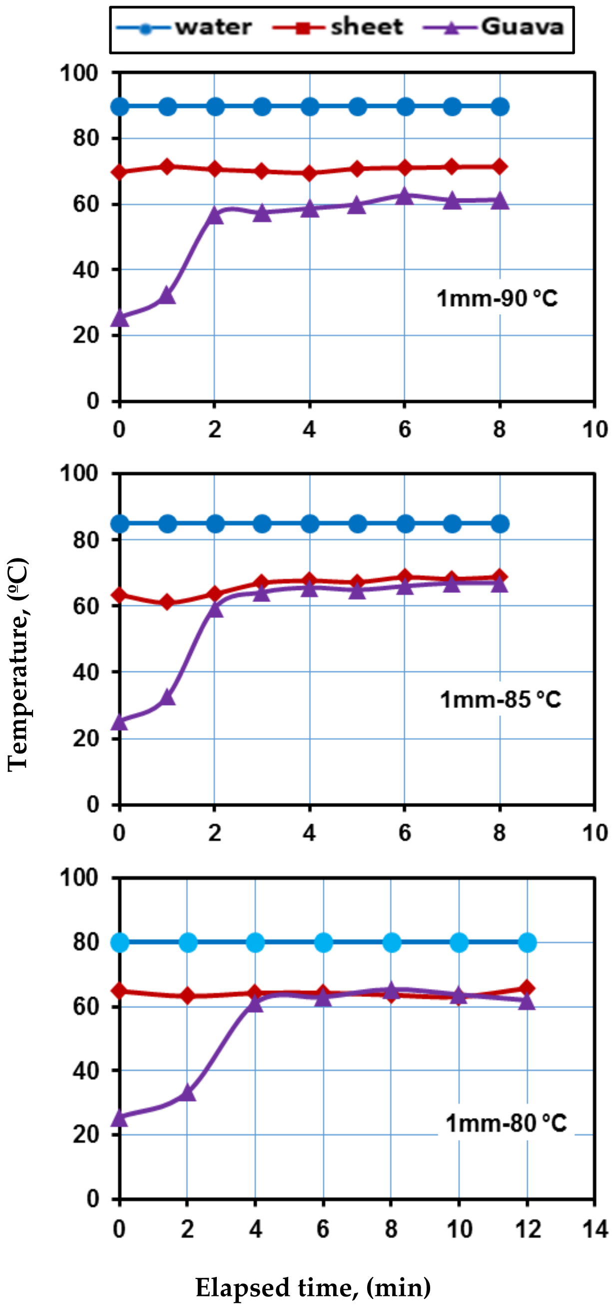


Fig. 5. Water, Sheet and Guava puree temperatures as affected by elapsed time at 1mm thickness.

3.4. Drying efficiency

Average drying efficiencies were evaluated according to Abul-Fadl and Ghanem (2011), based on measurements of electrical power required for heating water basin, operating belt, air fan and water pump in kW.

Fig. 8 explaine that the average drying efficiencies of Guava increased as drying temperature increases and decreased as puree thickness decreases. In present study the drying efficiencies were 28-65%, these results agreed with that reported by Nindo et al. (2003), that the drying efficiency for pilot and commercial scale of RW dryers ranged between 28-48% and 52-70% respectively.

3.5. Productivity

The RW dryer productivity were evaluated for moving belt dryer as a function of water basin temperatures and puree thickness of Guava. Fig. 9 showed that the dried Guava productivity increases as water basin temperature increases. Due to dependence of water basin temperature, time and thickness, the productivity of one mm has the highest productivity of all studied thickness, and as the puree thickness increases the productivity decreases due to its dependence on drying time. The average productivity of 1, 2, and 3mm at 85°C were 0.49, 0.36, 0.29 kg powder/h.

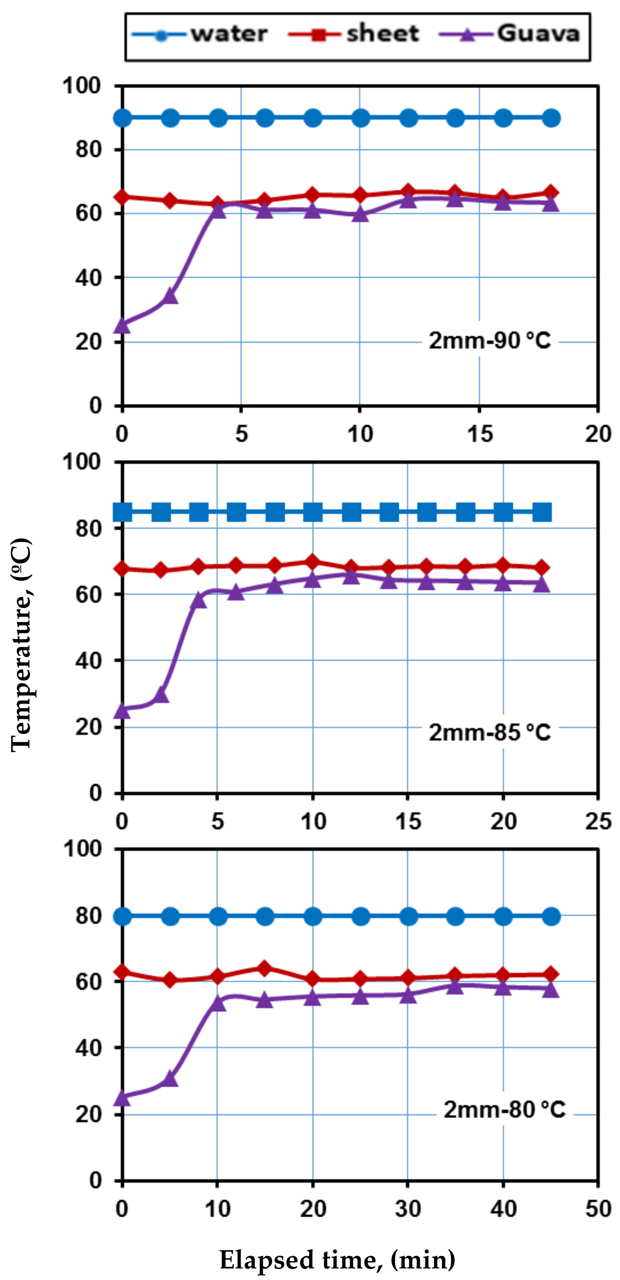


Fig. 6. Water, Sheet and Guava puree temperatures as affected by elapsed time at 2mm thickness.

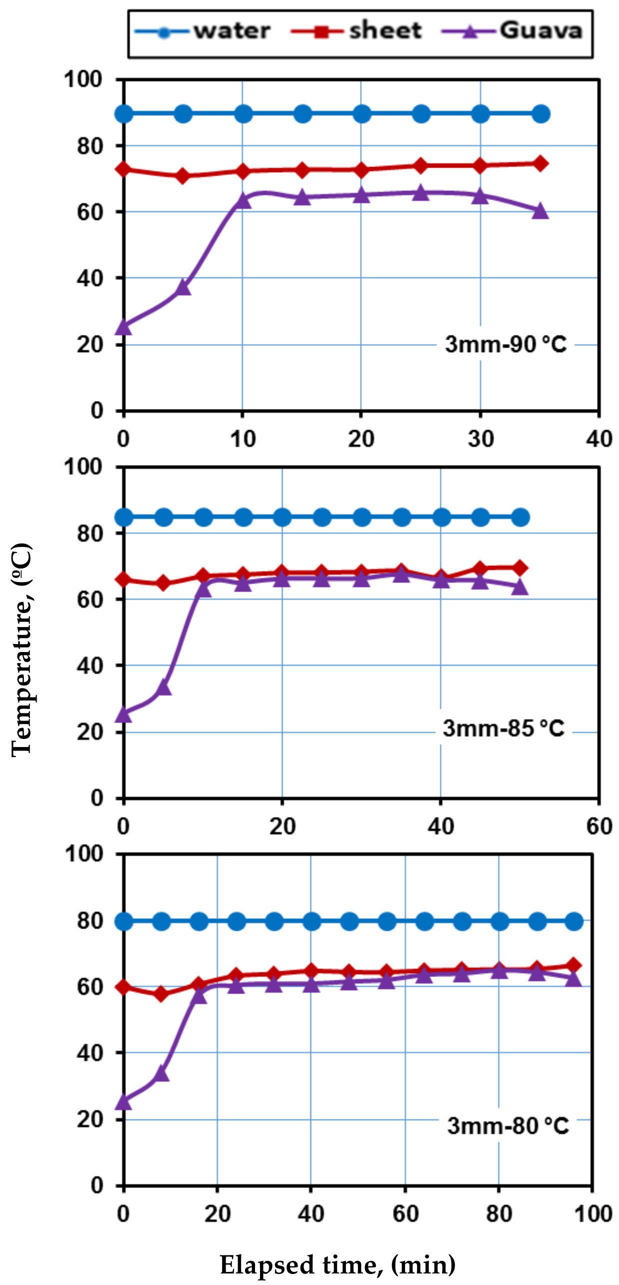


Fig. 7. Water, Sheet and Guava puree temperatures as affected by elapsed time at 3mm thickness.

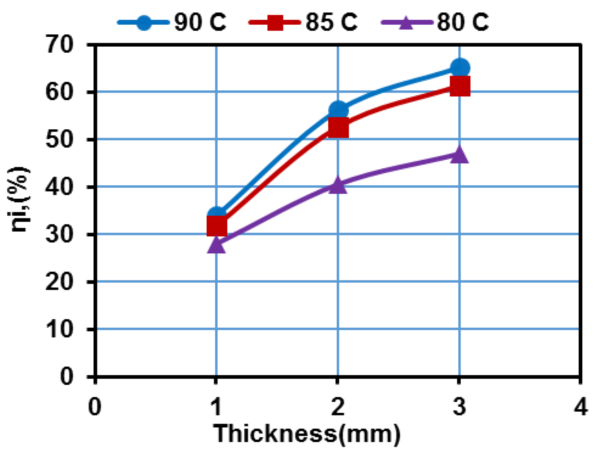


Fig. 8. Drying efficiencies of Guava puree as affected by puree thickness, water basin temperatures.

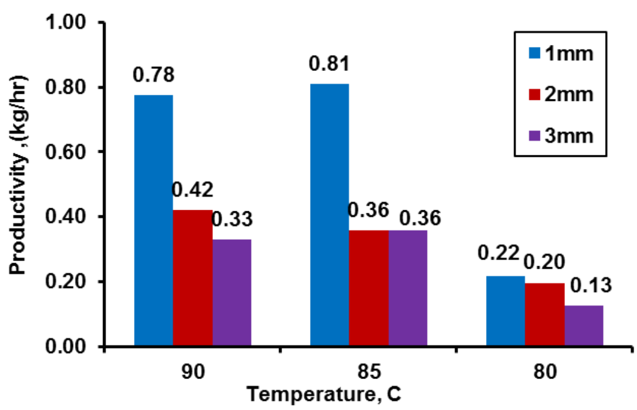


Fig. 9. Productivity (kg/h) of Guava dried as affected by water basin temperatures and puree thickness for all drying experiments.

3.6. Quality Considerations

The optimization of drying kinetics was proposed according to apparent color and rehydration capacity. Quality evaluations were carried out on the optimized samples to investigate the effect of film thickness, water basin temperature 80, 85 and 90 ±1°C as affected by elapsed drying time on dried puree color. A panel of 10 evaluators were formed from among graduate students and researchers in Agri. Products Process Eng. Dep., Fac. of Agri. Eng., Al-Azhar Uni., Cairo.

3.6.1. Color Evaluation

Fig. 10 showed that the average points of dried Guava were evaluated by panelist groups. It is clears that as the water basin temperature increases, the color closeness increases. The results indicated that the RW drying method had significant influence on color evaluation of dried samples. On the other hand, the average color scores of Guava were higher than 6, mostly between 7and 8 i.e., between good and very good, indicating panelists' consents of the color. Lower total color changes happened when temperature of water basin decreased that was confirmed by panelist groups results which agreed with Jafari et al. 2016. Finally, average values of different samples, relating to a specific attribute, were compared with each other.

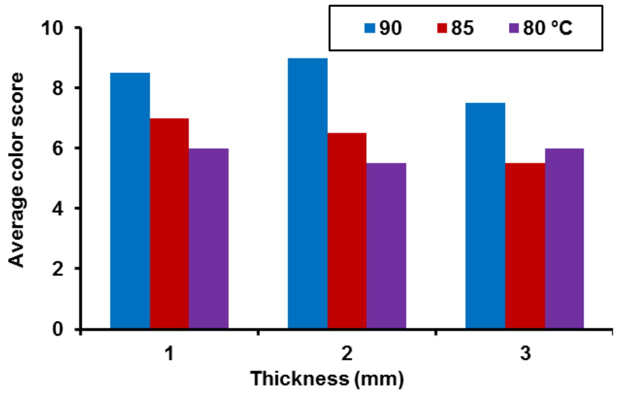


Fig. 10. Average color score of Guava dried as affected by water basin temperatures and puree thickness for all drying experiments.

3.6.2. Rehydration ratio

Rehydration is evaluated in present study for dried products as quality criteria because it is valuable parameter for changing the dried products to juice or mixing it to other food stuffs and may be added to bakeries. Rehydration characteristics of a dried product are used as a quality index and they could indicate physical and chemical changes during drying as influenced by processing conditions. Fig. 11 shows that rehydration ratios reached its maximum value at 85°C of water basin temperature. Increasing water basin temperature to 90°C causing poor rehydration capacity that may be attributed to the collapse of cellular structure or decrease of porosity. These results agreed with Azizi et al. (2017).

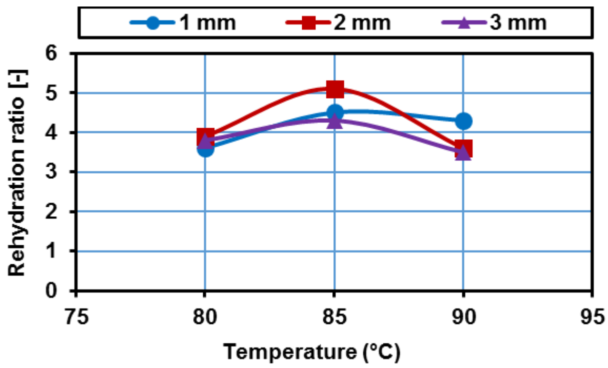


Fig. 11. Rehydration ratio for drying Guava at all drying conditions studied.

3.6.3. Cost Analysis

The production cost (L.E./kg) was evaluated in present work for identifying the economical evaluation of Refractance window dryer at three different film thickness and water basin temperature. As previously mentioned, the operating cost (L.E./h) for the RW dryer and the costs of kilogram dried product (L.E./kg) for Guava pulp were calculated according to Awady et al. (2003).

Fig. 12 showed that the operating costs per kilogram powder of Guava increases as puree thickness increases and also with increasing the water basin temperatures. Moderate values were recorded for 85°C of all studied thickness. Also, one mm puree thickness is the least costs of all studied thickness of Guava dried puree, it has lower rehydration ration and in turn lower quality. The 3mm puree thickness is refused due to larger cost per kg powder, so 2mm thickness is selected as the optimal puree thickness and moderate costs for dried Guava puree. Dollar exchange rate at the time of experimental work was equal to 18 L.E.

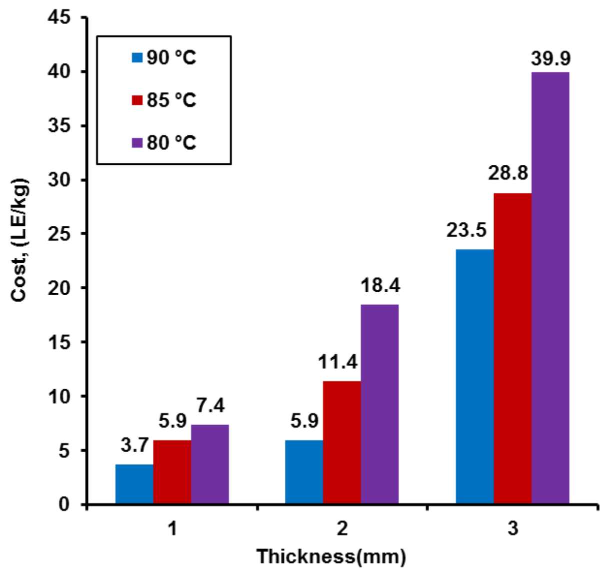


Fig. 12. Operating costs per kilogram powder of Guava.

4. Conclusions

The present work aims to study drying kinetics of Guava using Refractance Window (RW) dryer as affected by namely: three different levels of water basin temperatures (80, 85 and 90 ±1°C), and three different puree thickness (1,2 and 3mm). Quality indicators (i.e., rehydration ratio and color), productivity, drying efficiency and cost analysis were studied.

Results can be concluded in to:

1. Evaluating the behavior of RW drying:
   a. The optimal elapsed time of dried puree at water basin temperature of 85 °C was 22 min at puree thickness of 2 mm.
   b. The final moisture contents were 17%, 15%, 14% and 16%, 15%, 14% and 16%,15%,14% for the three different studied thickness and at 80,85 and 90°C respectively. It is also cleared that when drying is proceeded water removed decreased for all studied temperatures and thickness. It can be concluded that at fixed drying time the puree moisture contents increased as water basin temperature decreased at same thickness. It is also cleared that the higher the water basin temperature the lower the moisture ratio and the faster the drying is progressed (i.e., the lower the elapsed drying time is required).
2. It is found that in all cases the puree temperature does not reach the heating water temperatures. Despite this fact that the RW drying process yields better quality products due to higher water temperatures resulting in both rapid dehydration and quit low product temperatures.
3. Drying efficiencies increases as drying temperature increase and decreases as puree thickness decreases. The drying efficiencies were 28-65%.
4. Quality was evaluated via rehydration ratio and the results were:
   a. Increasing water basin temperature to 90°C causing poor rehydration capacity that may be attributed to the collapse of cellular structure or decrease of porosity.
   b. The higher rehydration ratios were recorded at 85°C for all studied puree thickness. The optimal rehydration ratio was at 85°C and 2mm thickness.
5. The RW dryer productivity increases as water basin temperature increases, due to dependence of water basin temperature, elapsed time and thickness, the productivity of 1 mm has the highest productivity of all studied thickness.
6. The operating costs were recorded for 85°C of all studied thickness as moderate value. 1 mm puree thickness is the least costs of all studied thickness of dried puree, it has lower rehydration ration and in turn lower quality. Puree thickness of 2 mm is the optimal of moderate cost per kg 11.39 L.E./kg$_{\text{dried Guava}}$ at water basin temperature of 85°C.

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بعض العوامل الهندسية المؤثرة على تجفيف الجوافة بالنوافذ الانعكاسية

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الملخص العربي

تعتبر جودة وسرعة عملية تجفيف المنتج الزراعي أو الغذائي للوصول إلى المحتوى الرطوبي الآمن والمحافظة على المنتج من الفساد مقياس هام لتقييم عملية التجفيف والتفرقة بين طرق التجفيف المختلفة. أحد اهم طرق التجفيف الحديثة هي طريقة النوافذ الانعكاسية والتي تعتمد على نفاذ الأشعة الحرارية تحت الحمراء خلال جزيئات الماء مما يسرع من عملية التجفيف وكذلك يعتمد أيضا على انتقال الحرارة بطريقة (التوصيل والاشعاع والحمل) كمصدر أساسي في عملية التجفيف مما يؤدي إلى الحصول على منتج عالي الجودة.

تهدف هذه الدراسة إلى تطوير وتقييم مجفف النافذة الانعكاسية RW ودراسة بعض العوامل الهندسية المؤثرة على عملية تجفيف هريس الجوافة، وتقييم جودة المنتج المجفف من خلال بعض الاختبارات مثل اختبار التشرب واللون.

تم دراسة تأثير درجات حرارة المياه عند مستويات (٨٠ ، ٨٥ ، ٩٠ °م) وسمك الهريس عند مستويات (١، ٢ ، ٣ مم) على كل من المحتوي الرطوبي وزمن التجفيف والانتاجية والتكلفة وكفاءة التجفيف ومؤشرات الجودة (مثل درجة التشرب واللون).

ويمكن تلخيص أهم النتائج التي تم التوصل إليها على النحو التالي:

١. بدراسة تأثير درجات حرارة المياه وسمك المنتج على المحتوى الرطوبي وزمن التجفيف تبين أنه يوجد علاقة عكسية بين المحتوى الرطوبي وزمن التجفيف لجميع درجات حرارة المياه والسمك.

- كان المحتوى الرطوبي النهائي (١٦%، ١٥%، ٨%) و (١٨% ، ١٧% ، ١٤%) و (١٦% ، ١٥% ، ١٤%) للمستويات الثلاثة من سمك الهريس ودرجات حرارة ٨٠ و ٨٥ و ٩٠° م على الترتيب, والتي توضح أنه مع تقدم عملية التجفيف وزيادة درجة حرارة المياه يقل المحتوى الرطوبي, كذلك عند زمن تجفيف ثابت يزداد المحتوى الرطوبي بانخفاض درجات حرارة المياه لنفس السمك.
- كذلك زاد زمن التجفيف عند درجة حراة ٨٠° م للوصول تقريباً إلى نفس المحتوى الرطوبي بمقدار (٢ و٢,٣) و (١,٨ و٢,٢) و (١,٦ و١,٨) مرة عن درجة حرارة ٨٥°م و٩٠°م لكل من سمك الهريس ١ ، ٢ ، ٣ مم على الترتيب.
- كذلك أوضحت النتائج أن ارتفاع درجة حرارة المياه يقلل المحتوى الرطوبي ويسرع عملية التجفيف أي (يحتاج وقت تجفيف أقل).

٢. أوضحت النتائج أنه في جميع الحالات لم تصل درجة حرارة المنتج إلى درجة حرارة المياه، وبالتالي الحصول على منتج عالي في القيمة الغذائية.

٣. أوضحت النتائج أن كفاءة التجفيف تزداد بزيادة درجة حرارة المياه، وتقل عندما ينخفض سمك الهريس، وكانت كفاءة التجفيف تتراوح بين (٢٨-٦٥ %).

٤. تم تقييم جودة المنتج المجفف بدراسة نسبة إعادة التشرب واللون، **وقد أظهرت النتائج الآتي:**

- زيادة درجة الحرارة إلى ٩٠°م تسبب انخفاض نسبة إعادة التشرب وقد يعزو ذلك إلى انهيار تركيب الجزيئات أو انخفاض المسامية.
- تم تسجيل أفضل نسبة تشرب عند ٨٥°م و٢مم سمك وكذلك أفضل درجة للون عند ٩٠°م لنفس السمك.

٥. أوضحت النتائج أن الإنتاجية تزداد بزيادة درجة حرارة المياه، بسبب الاعتماد على درجة الحرارة وزمن التجفيف والسمك وكانت أعلى إنتاجية عند ١مم، وتنخفض الإنتاجية بزيادة سمك الهريس وذلك لاعتمادها على زمن التجفيف.

٦. أوضحت النتائج أن متوسط تكلفة تشغيل الكيلوجرام الجاف من الجوافة كانت عند درجة حرارة ٨٥°م، كان سمك الهريس ٢مم ذات قيمه متوسطة في نسبة التشرب وفى الجودة، كانت أعلى تكلفة عند سمك هريس ٣مم وكان متوسط تكلفة الكيلوجرام الجاف ١١,٣٩ جنيهاً مصرياً عند (٨٥ °م و ٢مم) وكان سعر الدولار وقت التجارب ١٨ جنيهاً مصرياً.