# EVALUATION OF POTATO SLICES DRYING USING SOLAR DRYER

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## ABSTRACT

*The objective of the present study was to investigate the drying characteristic curves and the drying duration when drying potato slices using natural convection solar dryer. For that sake an experimental setup was developed. Measurements of total solar radiation on the plane of the collector, ambient air temperature, drying air temperature and moisture loss in weight were collected. A group of experiments were conducted using potato slices with thickness of 1 mm to study the effect of pretreatments on drying characteristics. The maximum temperature attained in the drying chamber is 52 $^{o}$c at 13:00 and 14:00 pm and the maximum temperature attained in the collector is 75$^{o}$c at 14:00 pm while the corresponding values of solar radiation and ambient temperature were 876.5 W/m$^{2}$and 38$^{o}$c, respectively. The final moisture contents were 7.15 and 4.48 db in B (blanch + calcium chloride) and C (blanch + citric acid) treatments, while in A (blanch), D (blanch + potassium meta sulphate) and E (blanch + acitric acid) were 14.20, 22.35 and 13.73 db. Consequently, citric acid solution and calcium chloride solution were more effective solutions in potato slices drying. The slices treated with citric acid (C), potassium meta sulphite (D) and acetic acid (E) provided better color for drying compared with the slices that treated with blanch only (A) and with calcium chloride (B) under which the colors were brown.* ***.*** *The effective moisture diffusivities of pretreated with treatments (A, B, C, D and E) were ($1.35\times10^{-11}$, $1.39\times10^{-11}$, $1.45\times10^{-11}$ , $1.23\times10^{-11}$and $1.40\times10^{-11}$m$^{2}$/s), respectively. Based on these results, pretreated samples with citric acid solution (C) had the highest effective moisture diffusivity compared with other samples.*

***Keywords****: Drying rate, potato slices, natural convection, solar dryer and drying characteristics.*

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## INTRODUCTION

Potato belongs to the family Solanaceae along with other well-known cultivated plants including chilies, tomatoes, tobacco, pepper and eggplant ***(Miranda and Aguilera 2006).*** Potatoes are the fourth most important vegetable product for human nutrition in the world ***(Aghbashlo et al. 2009).*** The annual world production of potatoes in 2009 was 329,581 million tones. Major producing countries are China, Russian Federation, Indian, Ukraine and the U.S.A. ***(FAO 2011).*** A possible method of storing potatoes and avoiding further deterioration is by drying treatment of the product. Decreasing the moisture content guards against degradative reactions, from both the physicochemical and microbiological points of view ***(Rosselló et al. 1992).*** Drying is a classical method of food preservation, which provides an extension of shelf life, lighter weight for transportation and less space for storage ***(Okos et al. 1992; Teles et al. 2006; Pardeshi et al. 2009).*** The main objective of any drying process is to produce a dried product of desired quality at minimum cost and maximum throughput, and to optimize these factors consistently ***(Teles et al. 2006).*** Drying process improves the food stability, since it reduces considerably the water and microbiological activity of the material and minimizes physical and chemical changes during its storage ***(Hatamipour et al. 2007).*** Sun drying is the most common drying method of agricultural product in the tropical and subtropical countries. This method is cheapest and is successfully employed in various agricultural products. Moreover, it is traditionally practiced because there is negligible cost in processing and work of spreading and turning the crop. However, the long drying time is undesirable for economic reasons and because of the danger of contamination and spoilage of the product exposed to the open environment ***(Sacilik et al. 2006; Adedeji et al. 2008).*** To improve the quality of products, traditional drying techniques should be replaced with the industrial dryers such as freeze and hot air dryers. Freeze-drying is said to be best drying technology regarding product quality of the end product ***(Claussen et al. 2007).*** However, freeze-drying is an expensive method, and the high costs of process limit its application to industrial scale ***(Shishehgarha et al. 2002; Muthukumaran et al.***

***2008).*** Hot air-drying, which is far more rapid, providing uniformity and hygiene, is inevitable for industrial food drying processes ***(Kingsly et al. 2007; Duan et al. 2008)***. Pretreatments of some agricultural foods prior to drying have been reported to help reduce some of undesired changes such as color and textural changes. Potassium and sodium hydroxide, potassium carbonate, potassium meta bisulphate, methyl and ethyl ester emulsions and ascorbic acid are the most common and commercially used for some pretreatments ***(Saravacos et al. 1988; Tarhan et al. 2006; Adedeji et al. 2008; Bingol et al.2008)***.Pretreatments prevent loss of color by inactivating enzymes, reduce the drying time by relaxing tissue structure and yield a good-quality dried product. Blanching of vegetables and fruits is a common pretreatment used prior to thermal processing, freezing and drying ***(Al-Khuseibi et al. 2005).*** The purpose of blanching is to inactivate enzymes responsible for browning and the hydrolysis of lipids, which could lead to the development of off-flavors during storage of the dried product ***(Cunningham et al. 2008).*** Generally, fruits and vegetables are blanched by heating them with steam or hot water ***(Kim et al. 2004; Falade et al. 2007).*** The present work aimed to investigate the drying characteristic curves and the drying duration when drying potato slices using natural convection solar dryer and study the effects of pretreatment and conditions on the quality of potato chips in terms of color and tasty.

## MATERIALS AND METHODS

The effect of pretreatments on drying characteristics of potato slices was investigated in the present study using solar dryer. The experiments were conducted on potato slices with thickness of 1 mm. The solar dryer (figure 1) was constructed at local workshop in Zagazig city, Sharkia governorate (longitude =35° 30° and latitude =31° 31°) in august 2014.The solar dryer consists of two main parts namely; solar collector and drying chamber (Fig.1). The specifications of the solar dryer can be presented as follow:

### The solar collector :

The solar collector was fixed at the front side of the dryer. The collector consists of a wooden frame of 100 x 50 x 20 cm. A corrugated black painted iron sheet 0.5 mm thickness was used to increase the efficiency of energy collection. The slope of the collector was adjusted at 30º with the horizontal level. While, the top surface of the solar collector was covered by a glass 5 mm thickness. The front side was made from a perforated stainless steel sheet as a window for air inlet. The window's dimensions are 50 × 20 cm at the north side. The collector was oriented North-South.

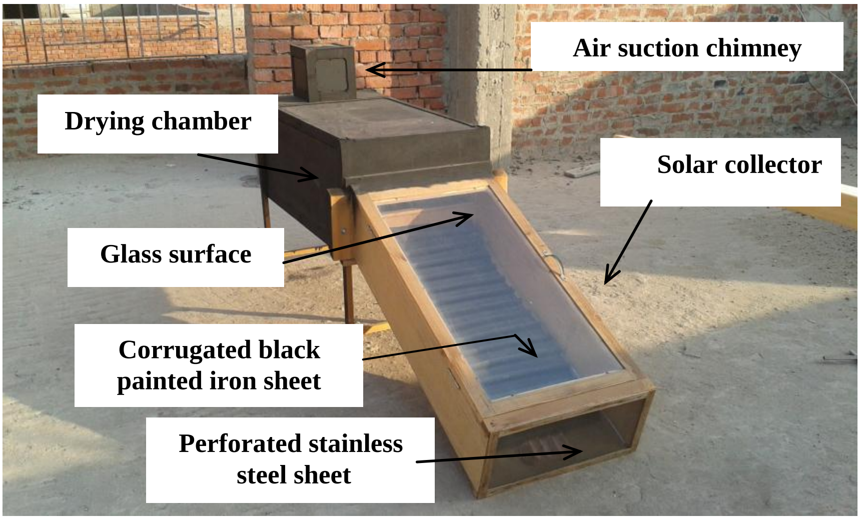

Figure (1): The solar dryer.

## The drying chamber:

The gross dimensions of the drying chamber were 100×50×30 cm. The base of the drying chamber consists of: 1- body made from plywood. 2- a chimney for air suction was stetted at the top of the dryer, the dimensions of the air chimney were 20x20 cm, covered by perforated stainless steel. 3- tray consists of a frame made from wood bars covered with perforated stainless steel sheet that net surface area was (0.5) $m^2$. 4- four legs 40 cm height were connected at the corners of the bottom of the dryer to raise its body.

## Sample Preparation

The samples of fresh potatoes were stored in a refrigerator at about 8 $^oC$ for experiments. Before drying the potatoes were cleaned, peeled and sliced automatically by thickness of 1mm. Then, the samples were pretreated with different solutions for inactivation of enzymes. Samples are spread over the shelf of the chamber in a single layer and weighed every an hour until they reach a state of equilibrium. Simultaneously, the temperatures were recorded above the bed. Before placing the product in the dryer, the installation was left to stabilize for an hour.

**Pretreatment;**

Table (1) represent pretreatments investigated in this study.

**Table 1. List of pretreatments.**

| CODE | DESCRIPTION |
|---|---|
| (A) blanch | All samples were blanched by immersing in hot water at 90 $^{o}$c for 1 min. After blanching, the samples were cooled to room temperature, under running cold water. and then blotted with tissue paper to remove superficial water. |
| (B) blanch + calcium chloride | Samples were pretreated with solution of calcium chloride (1:25, w/w) for 3 min. After pretreatment, the samples were blotted with tissue paper. |
| (C) blanch + citric acid | Samples were pretreated with solution of citric acid (1:25, w/w) for 3 min. After pretreatment, the samples were blotted with tissue paper. |
| (D) blanch + potassium meta sulphite | Samples were pretreated with solution of Potassium meta sulphite (1:25, w/w) for 3 min. After pretreatment, the samples were washed under running cold water then blotted with tissue paper. |
| (E) blanch +acetic acid ($CH_3COOH$) | Samples were pretreated with solution of citric acid (1:25, w/w) for 3 min. After pretreatment, the samples were blotted with tissue paper. |

**Measurements**

mass of samples was measured using electric balance (accuracy 0.1 g and maximum weight 2000 g). Solar radiation and temperature of ambient air were measured by "Watchdog" weather station model 900 ET. The weather station measured the following: temperature (-30° :

100° c), relative humidity (20-100% ± 3%) and solar radiation (1-1250 W/m$^2$). Air temperature inside the dryer was recorded using thermometers with accuracy of 1°c with maximum of 100°c and with calibrated thermocouples connected to a multi channel digital display with an accuracy of 0.05°c. Moisture content was measured using the electric oven . Air velocity was measured using the anemometer model made in China, the range for air velocity from (0 to 45 m/s) with accuracy of (±0.3 m/s).

**Moisture content (MC):** $\boldsymbol{MC = \left(M_i - M_f\right) / M_i}$ **,%**

Where $M_i$: mass of sample before drying (g) and $M_f$: mass of sample after drying (g).

**Average drying rate (DR):** $\boldsymbol{DR = \frac{M_{t-dt} - M_t}{dt}}$, g /h

Where :$M_{t-dt}$ and $M_t$ are the moisture contents (db%), at t-dt and t , respectively, and dt is the drying time period (h).

**Determination of effective moisture diffusivity:**

It has been generally accepted that the drying phenomenon of biological materials is controlled by the mechanism of moisture diffusion during the falling rate period. The experimental drying data for the determination of diffusivity coefficients were interpreted by using Fick’s second diffusion model, as shown in this equation, has been frequently used to describe the internal moisture transfer during drying process.

$$\frac{\partial M}{\partial t} = D_{eff} \nabla^2 M$$

The solution of diffusion equation for slab geometry is solved by ***Crank (1975)*** and supposed uniform initial moisture distribution, negligible external resistance, constant diffusivity and negligible shrinkage:

$$MR = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left( - \frac{(2n+1)^2 \pi^2 D_{eff}\, t}{4L^2} \right)$$

where $D_{eff}$ is the effective moisture diffusivity (m$^2$/s), *t* is the time (s), *L* is the half thickness of samples (m) and *n* is a positive integer. For long drying times, a limiting of this equation is obtained and expressed in a logarithmic form ***(Madamba 2003):***

$$\ln MR = \ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff}\, t}{4L^2}$$

The effective diffusivity is typically calculated by plotting experimental drying data in terms of ln(MR) versus time.

## RESULTS AND DISCUSSION

### Influence of solar radiation and ambient temperature on drying chamber and collector temperatures:

Figure (2) shows the variation of the drying chamber temperatures, the collector temperatures and the ambient temperatures and solar radiation intensity during the day. The maximum temperature attained in the drying chamber is 52 $^{o}$c at 13:00 and 14:00 pm and the maximum temperature attained in the collector is 75 $^{o}$c at 14:00 pm while the corresponding values of solar radiation and ambient temperature were 876.5 W/m$^{2}$ and 38 $^{o}$c, respectively.

### Influence of drying pretreatments on final moisture content:

According to the results in figure (3), pretreatments are very important parameter that affects drying time and final moisture content. The samples in treatments (B) and (C) were found to have a lower moisture contents compared with (A),(D) and (E) in the same drying time. The final moisture contents (7.15and 4.48 db) were recorded in (B) and (C) while in(A),(D) and (E) were (14.20,22.35 and 13.73 db). Consequently, citric acid solution and Calcium Chloride solution were more effective solutions in potato slices drying. For potato slices blanched in hot water, the moisture content was lower than the corresponding to potassium meta sulphite and acetic acid. This behavior was probably due to softening by the blanching treatment, which facilitated the water removed. Similar findings were reported in drying of potatoes by ***Severini et al. (2005).***

### Influence of drying pretreatments on drying rate:

Figures (4 and 5) show the changes in drying rate as a function of drying time and moisture content, respectively. It is apparent that drying rate decreases continuously with drying time and with moisture content in all treatments. A constant-rate period was not detected in the drying experiments. Therefore, the entire drying process for potato slices occurs in the range of the falling-rate period. Similar results were obtained by other authors working on drying of various agricultural products drying (***Akpinar et al. 2003; Sacilik et al. 2006; Kingsly et al. 2007; Lee and Kim2009***).

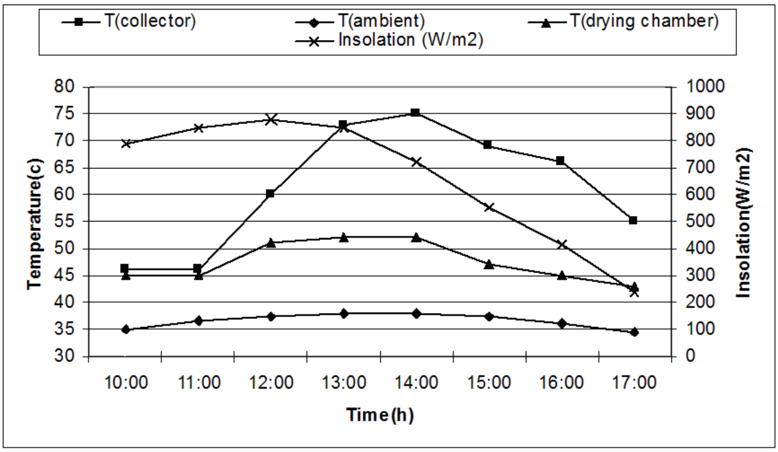

Figure (2): The variation of temperature in the collector, drying chamber, ambient temperature and solar radiation intensity during (15 / 8 / 2014)

**Appearance and color:**

Color is a major quality attribute in dried food products. In order to facilitate the comparison of color and appearances of the samples, a digital picture was taken from each dried sample. The slices treated with citric acid (C), potassium meta sulphite (D) and acetic acid (E) provided better color for drying compared with the slices that treated with blanch only (A) and with Calcium Chloride (B) under which the colors were brown.

**The effective moisture diffusivities:**

From figure (6) the effective moisture diffusivities of pretreated were calculated. The effective moisture diffusivities of pretreated with treatments (A,B,C,D and E) were ($1.35\times10^{-11}$, $1.39\times10^{-11}$, $1.45\times10^{-11}$ , $1.23\times10^{-11}$and $1.40\times10^{-11} m^2/s$), respectively. Based on these results, pretreated samples with citric acid solution (C) had the highest effective moisture diffusivity compared with other samples. The pretreatment solution has probably affected the internal mass transfer during drying.

The values of $D_{eff}$ obtained from this study lie within in general range $10^{-12}$ to $10^{-8}$ m$^2$/s for drying of food materials ***(Zogzas et al. 1996).*** These values are comparable with $4.56\times10^{-10}$ to $8.5\times10^{-10}$ m$^2$/s for air-drying of okra at 70 $^o$C ***(Adedeji et al. 2008)***, $1.25\times10^{-9}$ to $2.20\times10^{-9}$ m$^2$/s for carrot at 35 – 55 $^o$C ***(Kaya et al. 2009)***, $6.92\times10^{-9}$ to $14.59\times10^{-9}$ m$^2$/s for white radish at 40 – 60 $^o$C ***(Lee and Kim 2009)***, $1.55\times10^{-9}$ to $16.5\times10^{-9}$ m$^2$/s for mushroom at 50 – 60 $^o$C ***(Arumuganathan et al. 2009)***, $1.92\times10^{-10}$ to $3.55\times10^{-10}$ m$^2$/s for potato at 40 – 85 $^o$C ***(Hassini et al. 2007)*** and $6.36\times10^{-11}$ to $9.75\times10^{-9}$ m$^2$/s for sweet potato at 50–80C ***(Falade and Solademi 2010)***. These values are consistent with the present estimated $D_{eff}$ values for potato slices.

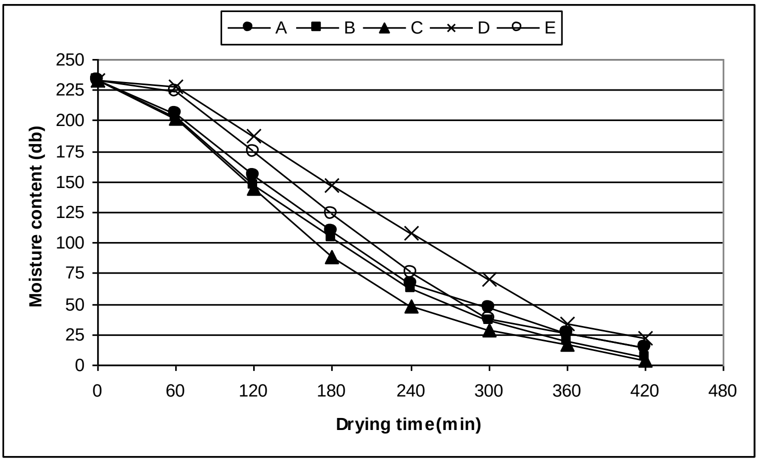

Figure (3): Variation of moisture content with drying time of sliced potato samples pretreatments

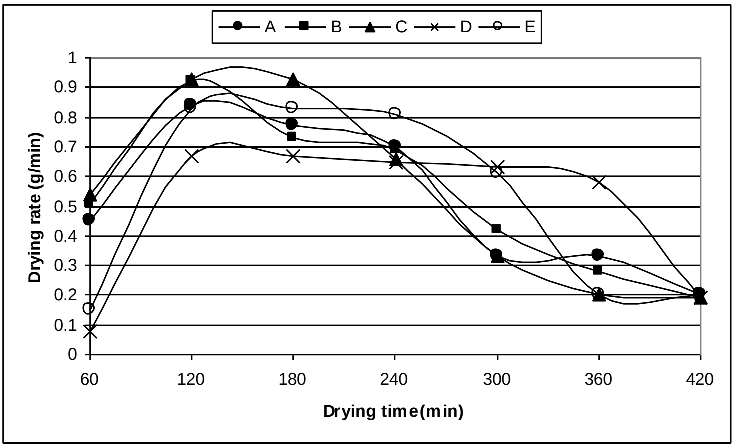

Figure (4): Variation of drying rate as a function of drying time.

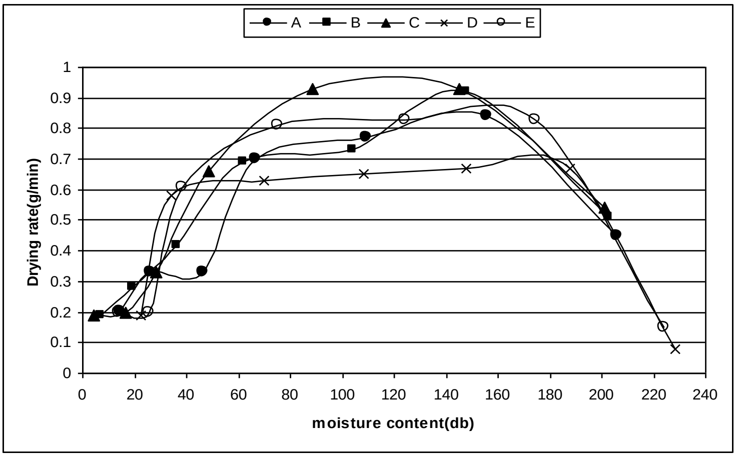

Figure (5): Variation of drying rate as a function of moisture content.

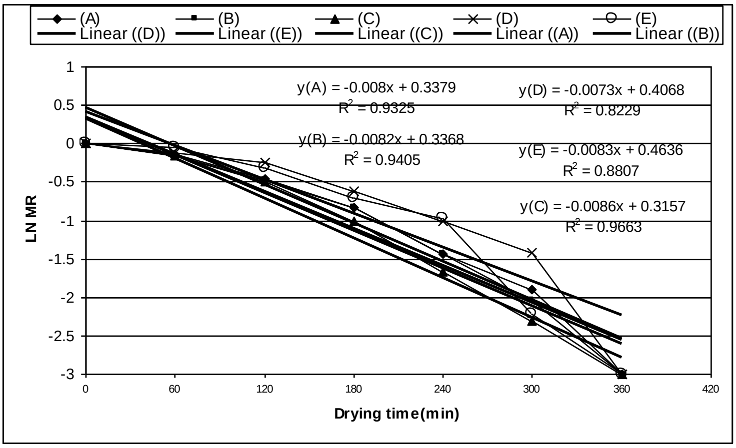

Figure (6): ln(*MR*) versus time for treatments.

## CONCLUSION

The effect of pretreatments on drying characteristics of potato slices was investigated in this study using solar dryer. The experiments were conducted on potato slices with thickness of 1 mm.

From the analysis of the results:

1- The maximum temperature attained in the drying chamber is 52 $^{o}$c at 13:00 and 14:00 pm and the maximum temperature attained in the collector is 75 $^{o}$c at 14:00 pm while the corresponding values of solar radiation and ambient temperature were 876.5 W/m$^2$ and 38 $^o$c, respectively.

2- The final moisture contents (7.15and 4.48 db) were obtained in (B) and (C) while in (A),(D) and (E) final moisture contents were (14.20,22.35 and 13.73 db). Consequently, citric acid solution and Calcium Chloride solution were more effective solutions in potato slices drying.

3- The slices treated with citric acid (C), potassium meta sulphite (D) and acetic acid (E) provided better color for drying compared with the slices that treated with blanch only(A) and with Calcium Chloride (B) under which the colors were brown **.**

4- The effective moisture diffusivities of pretreated with treatments (A,B,C,D and E) were ($1.35\times10^{-11}$, $1.39\times10^{-11}$, $1.45\times10^{-11}$ , $1.23\times10^{-11}$and $1.40\times10^{-11}$m$^2$/s), respectively. Based on these results, pretreated samples with citric acid solution (C) had the highest effective moisture diffusivity compared with other samples.

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## الملخص العربي

# تقييم تجفيف شرائح البطاطس باستخدام مجفف شمسى

**منى محمود عبد العزيز حسن***

يهدف البحث إلى تجفيف شرائح البطاطس بواسطة مجفف شمسي ذو حمل طبيعي تحت معاملات مختلفة للشرائح قبل التجفيف و دراسة تأثير هذة المعاملات على زمن التجفيف و لون المنتج النهائى. أجريت التجارب في اغسطس (٢٠١٤)، تم تصنيع المجفف الشمسي في ورشة محلية في مدينة الزقازيق محافظة الشرقية.

يتكون المجفف الشمسي من:

١- مجمع شمسي والتي صنعت جوانبه من الخشب وتم تثبيته في الجانب الأمامي من المجفف، وكانت أبعاده هي ٢٠ × ٥٠ × ١٠٠ سم ويميل على الافقي بزاوية ٣٠° ، استخدم الصاج الأسود المموج أو المتعرج بسمك ٠.٥ مم لزيادة كفاءة تجميع الطاقة، كما تمت تغطية السطح العلوي للمجمع الشمسي بواسطة لوح من الزجاج بسمك ٥ مم . وضع على الجانب الأمامي شبك سلك مقاوم للصدأ كإطار لنافذة دخول الهواء ، أبعاد هذه النافذة كانت ٢٠ × ٥٠ سم، والمجمع كان موجها ناحية الجنوب الشرقي.

**٢-** غرفة التجفيف أبعادها ٣٠×٥٠× ١٠٠ سم، و مصنوعة من الخشب محمولة على أربعة أرجل بارتفاع ٤٠ سم، يوجد اعلاها غرفة للتهوية وخروج الهواء الساخن المحمل ببخار الماء وأبعادها ٢٠×٢٠ ×٢٠ سم. بداخل غرفة التجفيف توجد صينية التجفيف وهى عبارة عن اطار من الخشب وقاعه من شبك سلك مقاوم للصدأ ومساحتها ٠.٥ م$^{٢}$ . تم عمل معاملات ما قبل التجفيف لشرائح البطاطس. شرائح البطاطس توضع على صينية التجفيف كطبقة واحدة.

**النتائج المتحصل عليها يمكن تلخيصها على النحو التالي:**

### ١- تأثير شدة الاشعاع الشمسى و درجة حرارة الجو على درجة حرارة كلا من المجمع و المجفف:

أن متوسط أعلى درجة حرارة تم رصدها فى المجمع والمجفف كانت ٧٥ و ٥٢ درجة مئوية على التوالى وكانت بين الساعة الواحدة و الثانية ظهرا فى حين كانت درجة حرارة الجو ٣٨ درجة مئوية وكان متوسط الاشعاع الشمسى ٨٦٧.٥ وات/م$^{٢}$.

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**[*] أستاذ مساعد – قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر.**

### ٢- تأثير معاملات ما قبل التجفيف على المحتوى الرطوبي النهائى:

كان اقل محتوى رطوبى نهائى مع المعاملات (B),(C) وهما على التوالى (٧.١٥)، (٤.٤٨)%على أساس جاف.أما باقى المعاملات فكانت نسب الرطوبة النهائية اعلى من المطلوب.

### ٣- تأثير معاملات ما قبل التجفيف على لون المنتج النهائى:

المعاملات (C)، (D) و (E)اعطت افضل لون للمنتج النهائى اما باقى المعاملات فكان اللون بنى غامق (غير مقبول).

### ٤- تأثير انتشار الرطوبة على المعاملات:

كان تأثير انتشار الرطوبة على المعاملات (A,B,C,D and E):

$(1.35\times10^{-11}, 1.39\times10^{-11}, 1.45\times10^{-11}, 1.23\times10^{-11}$ and $1.40\times10^{-11} m^2/s)$

على التوالى.