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SOLAR DRYING OF SLICED POTATOES.AN EXPERIMENTAL INVESTIGATION

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Abstract

The work presented in this paper was aimed to investigate an indirect solar dryer, locally designed and constructed, In order to adjust appropriate conditions for safe store of sliced potatoes. Throughout this study, by the mean of several experiments performed at Ouargla City in southern Saharan of Algeria. We searched to improve the performance of our solar drying system. An electrical resistance supplied by a variable number of photovoltaic panels was used to enhance the thermal efficiency. On the other hand, we tried to follow the impact of various controlling factors of hybrid solar drying on the quality of dried potato slices. Our present findings showed that the best operating conditions to ensure best efficiency, low duration time and higher product quality were selected as follows:

1- Hybrid drying (solar energy) with improving the delivery of solar panels, drying time and quality of the product. Used operating conditions were: air flow speed 0.51 m/s in duration of 2h 45min through the period between Mai 06th , 2012 and Mai 28th, 2012.
2- Hybrid drying (conventional electric power) using a maximum speed, performed at: 0.5 m/s in duration of 1 h 15min through the period between Mai 13th, 2012 to Mai 18th, 2012.

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Key words: Solar drying, Photovoltaic, forced convection, sliced potato, quality

1. Introduction

Solar energy represents one of the non-polluting and economical energy sources which are more requested worldwide. However this energy remains untapped in the south, mainly in the African countries. In the process of crop production, post harvest treatments are highly requested by thermal means in several food engineering applications. In fact, heat treatments are preferred because they can avoid the side effects of chemical treatments. Generally these thermal methods allow food crops to preserve their quality however they are known to be high cost treatments, especially when a drying process is introduced [1]. So we can consider that solar energy is the best alternative both in industrial applications and scientific research in the Maghreb countries mainly Algeria [2]. According to FAO-STAT, Algerian production of potato reached 3290000 tons in 2010. Much of the production comes from south hot climate oasis areas, so actual practice to save this product is the cold storage. Nevertheless the consumer's appreciations show that potato kept in cold stores presents a short lifetime after which it loses its textural firmness. In this view point,

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drying operations may have an important economical impact. Acording to some previous works [3, 4, 5] good quality criteria with low cost of final product can be obtained by solar drying which will enable food storage [6]. The introduction of solar driers in the countries in the way of development can reduce food loss and improve the quality of dried products in comparison with traditional drying to preserve food crops [7, 8]. Many researches were reported in the literature and studied the different types of solar driers for fruits and vegetables [6 ,7,8,9,10] ; some researchers have been interested in analyzing the passive solar energy drying systems , while others have been studying the passive solar energy drying. Several and different theoretical and experimental [11, 12, 13] studies were carried out. The drying of vegetables is a practice method for food preservation by reducing of the food losses, the potatoes is one of the important vegetables with high nutritional value consumed in large quantities in Algeria. Several experiment and theatrical works were realized and developed for potatoes solar drying [14, 15, 16, 17, 18, 19, 20]. P. Tripathy et al[15, 16, 17, 18, 19] proposed a methodology for the determination of temperature dependent drying parameters namely drying constant and lag factor from the experimental drying kinetic curves of cylindres and slices of potatoes using mixed solar dryer. The results were explained that the comparison of experimental dimensionless moisture contents with those calculated with variable (temperature dependent) and constant values of drying parameters demonstrates that the predicted results from variable parameters can better simulate the experiments. The major part of these studies relates the impact of the drying parameters and geometry of product on different mode of solar drying. Theoretical results of the proposed studies are in good agreement with the experimental ones. M .Azam Khan et al [20] developed the performance of convective solar dryer, by adjustment of the absorber temperature and the air flow rate to find the optimum for the deshydratation of blanched potato ships. S. S. Hobhana et al [21] studied the Development of generalized drying characteristic curve. The results shows that the methodology proposed facilitates to generate single generalized characteristic curve representing 16 drying kinetics and dimensionless parameter called dryer performance index (DPI) characterizing the effectiveness of potato's dryer system.

The present work is aimed to study the physical behavious and quality evolution of sliced potato treated by a convective indirect solar drier. The process of drying is operated through a hybrid solar drier with forced convection via photovoltaic and electric network. The objective of the performed experiments was to reach the final output of water content for safe storage, on one hand. On the other hand our work tried to predict the impact of the drying process on the quality of sliced potatoes by determining of the colour evolution.

Nomenclature

M	product weight
Tair	air temperature (°C)
T p	product temperature (°C)
V	air velocity (m/s)
X_f	final water content (kg w/kg d m)
ΔE	color distance

2. Materials and methods

2.1. Description of the Drying System

In this study we used an indirect solar dryer with forced convection (figure1) designed and realized by the energy conversion research group at LENREZA laboratory, Kasdi Merbah University in southern of Algeria. The used drying apparatus has been object of some improvements particularly the connection of the system with solar panels to increase the temperature of the drying room.

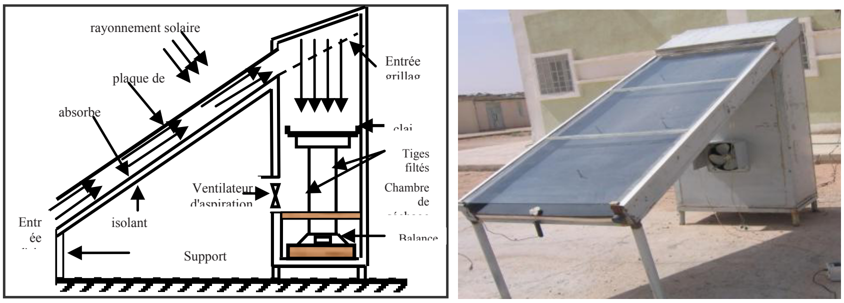

Fig.1. Schematic description of the drying system

The characteristics of photovoltaic panels are:
Maximal power :75w
Power tension :17v
Maximal electric current : 4.4 A
The main components of the drying system are mentioned as follows.

Production unit of hot air

Hot air production system is composed of solar collector with simple circulation and ordinary glass with area of 2.5m^2 inclined by 31°C (Ouargla city altitude, Algeria) The absorbing galvanized sheet iron is painted in black. The thermal isolation which is of 50mm thick is made of polyester.

Drying room

The drying room is parallelipedic form of 1.6 m high, 0.7 m long and 0.6 m large. The exterior walls are made of galvanized iron sheet with an interior isolation made of polyester inside the drying room. Electric resistances are placed and powered to 1500 W and driven by a thermostat. Air circulation and air exit are aspired by a fan (trade mark KFA – 30 A ; at a speed of 1400 rotation /mm). A rectangular galvanized grid is used as a support for the product.

2.2 Experimental measures

The experiment consists of:

- Global radiation captured by digital solarmeter
- Temperature is measured by thermocouples
- Inner humidité measurement with solar drying and outside measurement with hygrométere fixed to apparatus of type testo 645
- Weighing the dried product with a précise scale of 0.01g at equal intervals

2.3. Vegetal product

The sample of potatoes used in the experiment with an initial water content of equal too 5.4kg of water/kg dm .The preparation of these samples before experiments in draying consists of 3steps

a) Selection : eliminate all crushed potatoes or darkoues
b) Peeling of potatoes
c) Sliced of peeling potatoes in rounded forms of 2mm thick
   The selected potatoes are scattered on the grid of the drying room. The average total for drying products is of 100g on the grid for each experiment

2.4 Experimental procedure

Check in for drying is done each 15minutes using precise scale. The timing for drying the product should be respected equal or inferior to (76°C) to obtain a desired result. The water content is about 0.13kg of water /kg dry matter [6]. The measurement of temperatures, solar radiation and air speed is done each 15mn. Average production of dried product is done daily from 9:00 A.M. The operation is stopped when the desired final water content is reached.

2.5 Experiments

The present experimental investigation can be detailed in three parts:
1-The study of solar drying (with or without the use of additional energy (date of experiment March 13th, 2012 to April 28th, 2012)
2-The second step is based on the improvement of solar drying process via electric and photovoltaic network. In this case experiments were performed from Mai 06th, 2012 to Mai 25th, 2012 with the use of photovoltaic panels (2 panels – one panel) in count other experiments of solar drying in constant regime with a surplus of energy speed (v=0.31m/s, v=0.4m/s , v=0.51m/s)
3-In order to study the impact of hybrid drying on the quality of sliced potatoes, we have studied the colour parameters (L-a-b) with a colorimeter Minolta type CR400

3. Results and discussions

3.1 Solar drying process without products (solar drying with auxiliary heating submitted to variable conditions)

Effect of the use of auxiliary heating on drying air temperature

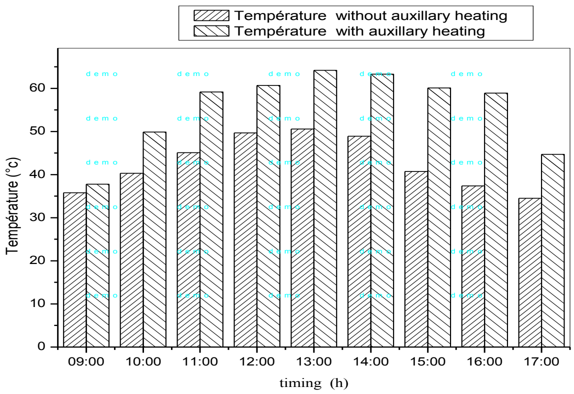

Fig.2. Comparison between the temperature of the drying air for a solar dryer with and without auxiliary heating

The Figure 2 shows that it is very important to use solar drying with auxiliary heating in comparison with the one without it. These results show that the air temperature in drying without using auxiliary heating has not reached the highest level in drying the product. However, the use of auxiliary heating in drying enables to reach the desired product with 20°C gained, It reduced also the timing in drying considerably.

3.2. Impact of the use of various panels on the drying air temperature

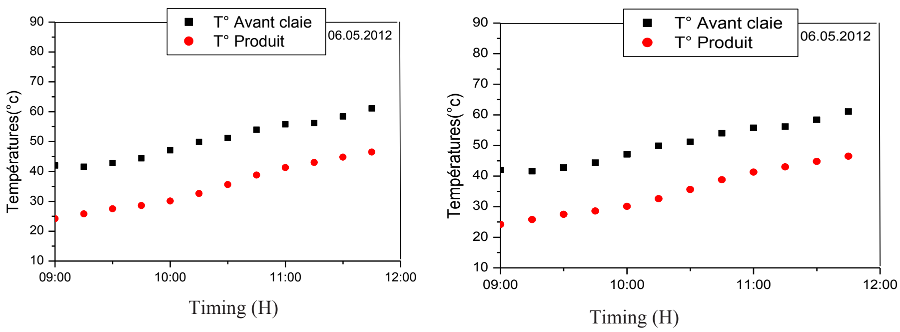

Fig. 3 .Variation in temperature in accordance with timing at the level of the drying room

(a) Associated with 1pannel ;(b) associated with 2panels

Temperature evolution of the drying air and potato slices, according to time for the different trials according to the number of the used solar panels is represented by the figure 3. The daily overage values trend of the air temperature at the entrance of the grid and that of the product is displayed in the table 1

Table1. Minimal/Maximal values and average temperatures trends at the entrance of the drying room

	T_{air}^{max}	T_{air}^{min}	$T_{air}^{average}$	$T_{product}^{max}$	$T_{product}^{min}$	$T_{product}^{max}$
1 panel	*57.8°C*	*39.4°C*	*50.1°C*	*48.4°C*	*28.1°C*	*43.7°C*
2 panels	*61.1°C*	*41.6°C*	*51.2°C*	*46.5°C*	*24.2°C*	*35.6°C*

The previous results shows that the energy supply of the resistance by the solar panels contributes to the increase of the temperature before the grid. This increase grows proportionally to the number of the number of panels associated in parallel it increases the electric current intensity and the increase of the temperature in the room according to the produced joule effect. This increase has consequences on the dried products. With the use of one single panel the difference in temperature (air/product) at the beginning of the drying start quit high (7°C-10°C) this difference reduces with time and remain steady up to the end of the drying (5°C - 6°C). This decrease is due to the evaporation of an important quantity of water at the beginning of the drying, the product being still rich in humidity.

3.3 Water content variation according to the drying period under different operating conditions

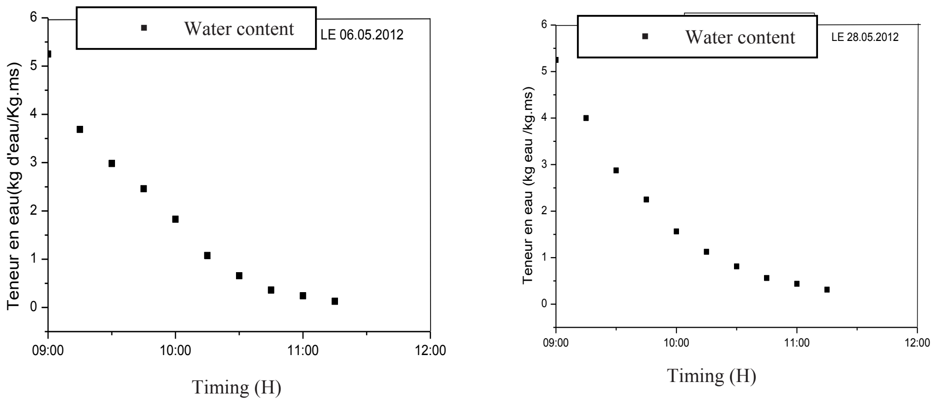

Fig . 4. Variation of water content as function of time
(a) Associated with 1 panel ; (b) associated with 2 panels

The figure 4 shows the water content variation according to the drying period. The differences in initial and final water content for the different testing conditions is presented in the following table

Table2. Variation of water content during the various operating conditions

	1 panel	2 panels
X_i (kg w / kg d.m)	5.22	5.25
X_f (kg w / kg d.m)	0.13	0.13
timing of drying (H)	3H	2H45min

The Drying time to have final water content X_f=0 .13 kg w /kg d m varies according to the varying operating conditions in the drying room. With the use of one single solar panel, the drying time to get a final water content X_f=0 .13kg w /kg d m 3hours with an air drying speed equal to 0 .4m/s. The drying operating for the first hour presents an important decrease of the water content (5 .2213kg w /kg dm to 1.5613kg w /kg dm) during the two hours ; that explains the evaporation of an important water quantity from potato slices. With the use of 2 solar panels the potatoes drying period length is reduced of one quarter an hour (15mn) meaning 2h45mn. We deduce that the evolution of the product water content according to time and the drying conditions depends on the number of associated panels. The influence of air temperature seems to be logical in the curves. It can be increased by the increase of the joule effect in the drying room. The more the temperature is high, the more the drying period is reduced.

3.4 Choice of the appropriate number of panels.

3.4.1 *Optimization of the air drying temperature according to the number of used solar panels.*

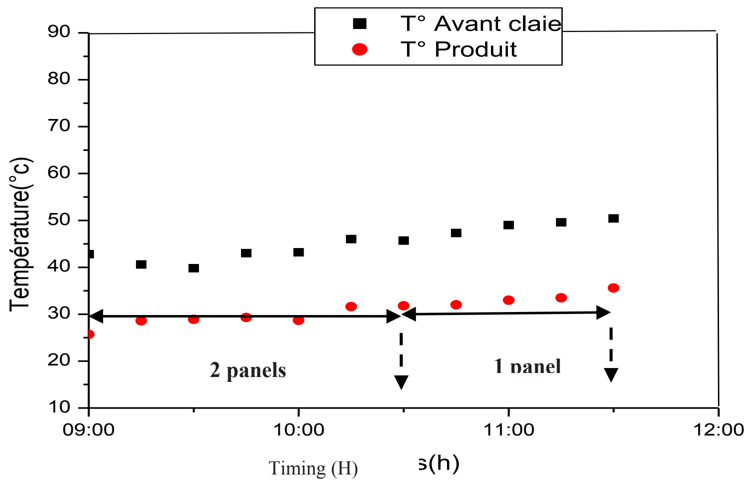

Fig . 5. Temperature evolution in the drying room

The figure 5 represents the temperature variation according to time in the drying room for an optimization test of the temperature with the use a varying number of panels to see the influence of the panels number regarding the drying air temperature and the drying duration period of the sliced potatoes. It can be seen on these given curves a little interval of temperature change which may have good impact on quality criteria.

Table 3 . Influence of the number of solar panels on the temperature

Panels number	**2 panels**	**1 panel**
Duration (h)	10H30 to11H30 min	9H à 10H30min
T (air) min (°C)	45.7	42.8
T(air) max (°C)	50.4	46

Our chosen solar panel number allowed us to control the temperature according to dried products, by limitation of the solar drying period during the experience day.

-to get a temperature between 42.8°C to 50.4°C we almost use 2panels during 1h 30mn of drying (from 9 :00to10 :30mn) -

to obtain a temperature between 45.7°C to 50.4°C we almost use 1panel during 1h of drying (from 10 :30 to 11 :30)

3.4.2 Optimization of the number of solar panels in parallel for the hybrid drying of the potatoes slices

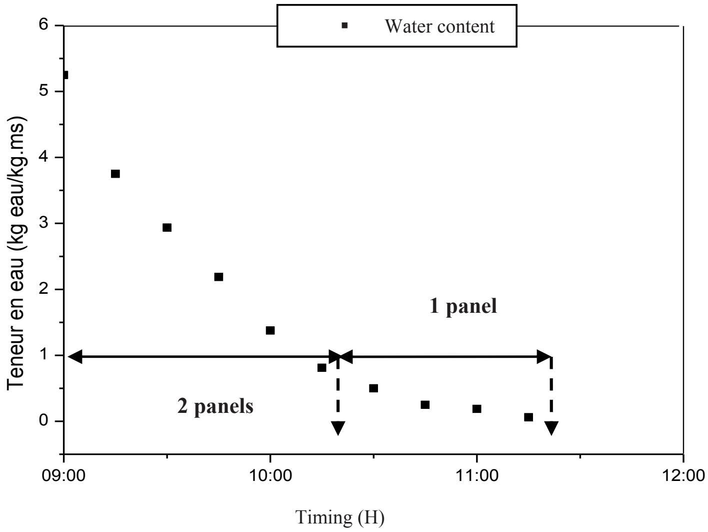

Fig 6. Water content variation according to drying time

The figure 6 shows the water content variation according to time by the optimization of the drying operation. The duration of the operation equal to 2h30mn; this length is limited by the number of solar panels

Table 4. Influence of the number of solar panel on the water content

Panels number used	Water content	(kg w /kg d m)
	X initial	X final
2 panels	5.25	0.5
1panels	0.5	0.13

With the use of 2panels the water content variation is from 5.25 to 0.5 kg w /kg d m during 1 :30mn With the use of 1panels the water content variation is from 0.5 to 0.13 kg w /kg d m during 1h Influence of the temperature on the duration of hybrid solar drying in constant regime

3.5. Influence of the temperature on the solar drying length

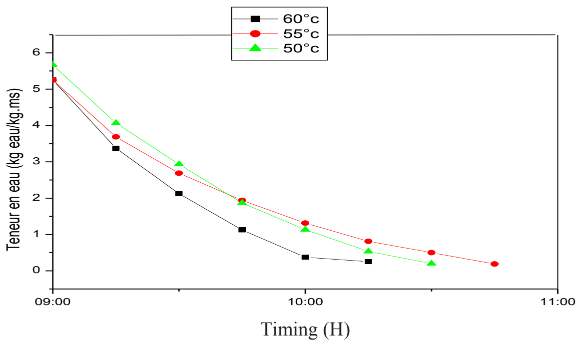

Fig 7. Variation of the water content according to different temperatures as function of the time

The figure7 shows the evolution of water content of the product according to the time of drying for the temperatures from 50°C to 60°C. The influence of the air temperature seems to be as physically expected. The more the temperature is high the more the drying duration is reduced.

Table 5. Drying duration to obtain X_f =0.13kg w /kg d m

Temperatures (°C)	60°C	55°C	50°C
Duration (H)	1.5	2	1.75

The table 5 shows that time of the drying to obtain a final content X_f=0.13kg w/kg d m is shorter when the temperature increases consequently the drying kinetics increases this is on the one hand due to the heat flux increase brought by the air to the product and on the other hand to the acceleration of the internal migration of water [10]. The choice of a suitable drying temperature in case of industrial process remains linked to the quality parameters of the final product. We should pay attention to the browning phenomenon of the product.

3.6. Influence of heat treatment by hybrid drying on the improvement of the final quality of the sliced potatoes

The quantification of the treated samples colour changes was determined by using a colorimeter CR400 which allows the automated acquisition of the parameters L, a ,b in the hunter L ,a ,b system in which L represents the scale parameter black /white , a the red / green scale parameters and b the yellow /blue scale parameter. For each sample the surface colour parameters of 5 different potato slices have been measured and averaged. The global colour change is expressed by the quantity Δ_E Called colour distance. It is a simple value which takes into account the L, a and b differences between the tested sample and a reference sample considered as the best choice. ΔE is calculated by using the equation (1) where L_0 , a_0 , b_0 refer to the measured colour values of a fresh sample

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \qquad (1)$$

The calculated values for ΔE are reported in the following graph

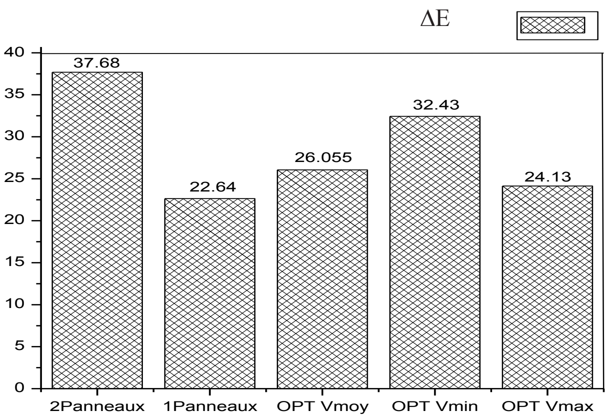

Fig. 8.Quality index variation for different dried slices

We notice that this ΔE colour variation depends on several factors such as the temperature to which the samples are directly exposed, the temperature of the drying air and the duration of the operation. The largest colour difference ΔE=37.68 was obtained when we used 2 panels. The smallest difference ΔE =22.64 was obtained with a sample dried with the help of one panel during 3 hours for ΔE=24.13 the drying time equals 2h 45mn therefore we may conclude that the hybrid solar drying of the potatoes slices with panel induces a considerable colour changes in all tested cases. Any decision to make in the way of defining eventual good criteria must refer to consumer preference and industrial post treatment of the dried product.

Fig . 9. Visual quality appearance of the dried potato of the Desiree variety

4. Conclusion

In this work we studied the solar hybrid drying of sliced potatoes by forced convection in indirect solar dryer using extra energy via a heater by joule effect generated by photovoltaic modules connected in parallel. The main results show that:

With the use of one solar panel to reach the final water content of the potato (x_f= 0.13kg w /kg d m) the drying time obtained was 3H. In case of two panels this time was found 2H45mn

The operating condition ensuring a better result was found as mentioned bellow:

by hybrid (solar, photovoltaic) with an optimization of the number of connected solar panels /drying duration /quality at a maximal circulating drying air speed of 0.51m /s 2h45mn

by Hybrid drying (conventional electric power) using a maximum speed, performed at: 0.5 m/s in duration of 1 h 15min through the period between Mai 13th, 2012 to Mai 18th, 2012.

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