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THEME

Assessment of the Thermal Efficiency of an Indirect Solar Drying System in El Oued state

Before the jury composed of : **Directed by:**

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Gratitude and Appreciation

This work was carried out at HAMMA LAKHDAR University in EL-OUED, Faculty of Technology Department of Mechanical Engineering.

Above all, we would like to thank God Almighty for giving us the strength and journey to complete this humble work.

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We thank the members of the jury who have the honor of participating in the discussion.

We thank the entire team for our promotion in mechanical specialization for their family souls during the study cycle.

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We can only think of those who responded to the present and gave us their moral support at the difficult moment and who were on our side to share our moments of joy.

Dedications

I dedicate this modest work:

To my dear parents

To my brothers and sisters

To my whole family

To my supervisors Professor. Aoun Yacine and Dr. Mnasser Nour Eddine

To all my colleagues and friends everywhere

To all students of the Department of Mechanical Engineering

To all those who helped me, even with a word of encouragement and kindness.

To all those who sacrificed their time for science

With my sincere thanks.

Abstract

Traditionally, farmers dry their agricultural products using sunlight outdoors, including peppers, tomatoes, and others. However, this approach exposes the food to harmful changes due to UV radiation, dust pollution, insect attacks, and other factors. Dryers have been developed to overcome these issues and preserve the quality of agricultural products by achieving drying in a controlled environment inside the direct solar dryer.

This study aims to mix heat storage materials with heat transfer materials (salt and aluminum). A mixture of salt and aluminum is used because salt has the ability to store heat while aluminum excels in heat transfer. This improvement was implemented in the indirect solar dryer, consisting of dedicated drying chambers well-insulated to conserve energy. Each chamber is equipped with a fan at the bottom to increase air flow, and an equal amount of salt and aluminum is placed in each chamber. Then, the thermal efficiency and storage capacities of each chamber were compared.

Keywords: direct solar dryer, indirect drying, solar energy, heat-assisted drying, salt, aluminum .

الملخص

تقليديا، يتبع المزارعون عملية الجفيف منتجاتهم الزراعية بواسطة أشعة الشمس في الهواء الطلق، وتشمل هذه العملية الفلفل والطماطم وغيرها، ولكن هذا النهج يعرض الطعام للتغيرات الضارة نتيجة تأثير أشعة فوق البنفسجية، والتلوث بالغبار والهجمات من الحشرات، وغيرها من العوامل تم تطوير المجفف للتغلب على هذه المشاكل والحفاظ على جودة المنتجات الزراعية عن طريق تحقيقها في بيئة محكمة الإغلاق داخل المحقق المباشر.

تهدف هذه الدراسة الى خلط مواد التخزين مع مواد ناقلة للحرارة (الملح والألمنيوم) يتم استخدام خليط من الملح والألمنيوم لأن الملح يمتلك القدرة على تخزين الحرارة بينما يتميز الألمنيوم بقدرته الجيدة على نقل الحرارة تم تطبيق هذا التحسين في المجفف الشمسي غير المباشر الذي يتكون من غرف مخصصة للمختص والتجفيف معزولة بشكل جيد للحفاظ على الطاقة وتم تجهيز كل غرفة بمروحة في الجزء السفلي الزيادة تدفق الهواء الداخل، ويتم وضع كمية متساوية من الملح والالمنيوم في كل غرفة، ثم تمت مقارنة الكفاءة الحرارية وسعات التخزين لكل غرفة.

الكلمات المفتاحية مجفف شمسي مباشر تجفيف غير مباشر طاقة شمسية تجفيف بحمل حراري، ملح، المنيوم.

Contents

General Introduction

General Introduction

Solar energy, originating from sunlight, constitutes the foundational source for energy production across diverse applications. Presently acknowledged as a renewable energy source, it transforms into various usable forms. Predominantly harnessed for the generation of heat and electricity, its utility spans multiple sectors. Solar drying, a methodical approach to leveraging solar energy, stands as a prevalent system for desiccating vegetables, fruits, fish, and meat. This preservation methodology for agricultural and food products entails reducing their moisture content to levels that effectively deter microbial proliferation.

Drying can be carried out either directly by exposing the product to the sun or indirectly by heating the drying air with a solar collector before it enters the drying chamber.

Our primary goal is to develop an indirect solar dryer tailored to the needs of local crops. To achieve this, we have implemented two salt and aluminum receptors, each with a distinct placement method. Our choice of beet as the drying material is based on its unique properties and widespread presence in the region.

After a comprehensive preamble, the thesis is delineated as follows:

The inaugural chapter will delve into an examination of the sun, encompassing an analysis of its inherent attributes and irradiance, coupled with an exploration of pertinent climatic factors such as temperature, and wind patterns specific to the El Oued locale.

In the subsequent chapter, we provide an exposition on solar drying methodologies, with a particular focus on indirect solar drying. This method encompasses a constellation of pivotal components operating synergistically to facilitate the optimal execution of the drying procedure. Noteworthy is its discerning design, which enables adept accommodation of diverse drying requisites.

rigorously assesses the thermal efficiency and the thermal storage capacity inherent in each configuration of the solar collectors.

In the forthcoming third chapter, a comprehensive exposition will be provided on the constituent elements of the solar dryer, alongside a detailed elucidation of its construction and testing methodologies. Furthermore, the operational intricacies of the drying process facilitated by this apparatus will be explicated, with specific reference to a sugar beet drying experiment conducted to assess its real-world effectiveness and efficiency.

Subsequently, in the ensuing fourth chapter, the conclusive findings derived from the final data series of the indirect solar dryer will be presented. This segment will focus on evaluating the thermal efficiency and performance of the collectors utilized. A meticulous analysis will be conducted to scrutinize the efficacy of various collector configurations, thereby enhancing our comprehension of the factors influencing the device's performance.

Finally, the thesis will culminate with a comprehensive concluding section, encapsulating the primary research findings and providing insights into prospective avenues for further exploration.

Chapter I:

General Information on solar Energy and it's Applications.

I.1 Introduction

Solar energy is the basis of biological and climate cycles, as well as fossil energy resources such as coal, oil and gas, and renewable energy resources such as biomass, hydro and wind. As a result, it has been indirectly exploited for millennia to feed and heat living beings.

However, the widespread use of fossil fuels and hydrocarbon energy sources in the 20th century led to significant emissions of carbon dioxide and other greenhouse gases. Evidence to date clearly indicates that climate change due to human activity is still in its infancy. If we are to mitigate the potential catastrophic consequences of major climate change, it is imperative that we act now. This implies a drastic reduction in emissions from the combustion of hydrocarbons.

This reduction can be achieved in two main ways:

- A major overhaul to create a society that is significantly less energy dependent.
- A major overhaul to create a society that uses energy intensively but efficiently.

By drawing a significant share of its energy from renewable and alternative sources.

Over the years, the use of solar energy has gained popularity, allowing it to play an increasingly important role today in terms of economic and environmental sustainability, which gave it a huge impact in various domains.

In this chapter we will provide information about the sun starting with the definition of the sun moving by its origin, Special characters and radiation also about Soil albedo, duration of sunstroke, Geographical coordinates of the sun.

I.2 Solar energy information

The solar field refers to the energy transmitted in the form of solar radiation. The sun is the main driver of all major natural resources.

I.2.1 The sun

The Sun, the only star in our solar system and the closest to Earth, takes about 8 minutes for its light to reach us. The next closest star, Proxima Centauri, is 4.23 light-years from our Sun. However, the great distance that separates us from this star means that the Sun is the only star on Earth conducive to life. [1] [2]

From a human point of view, the Sun is of paramount importance. It is the source of energy that allows the existence of life on Earth, promoting the existence of liquid water and feeding the process of photosynthesis of plants. In addition, solar radiation plays a crucial role in the creation of climatic and meteorological phenomena. [1]

I.2.2 Solar energy

I.2.2.1 Origin

In the core of the Sun, conditions favor the interaction of hydrogen atoms, thus triggering a thermonuclear fusion reaction. This process involves the fusion of four hydrogen nuclei to form a helium nucleus, releasing energy in the form of gamma rays and X-rays.

Every second, about 564 million tons of hydrogen are converted into about 560 million tons of helium. This difference, of the order of 4 million tons per second, corresponds to the differential bonding energy between hydrogen protons and helium nuclei. This energy difference manifests as radiation, producing about 3.7 x 10 26 joules of energy per second. [3]

I.2.2.2 Special characters

Solar energy is the only external source of energy for the Earth and has the following characteristics: [4]

- Universal: Available everywhere, with a maximum power density of 1 kW/m² at noon when the sky is clear.
- Diffusion: Due to the low power density received at ground level (1 kW/m²), it is used in a diffuse manner.
- Abundance: The Earth receives nearly 104 times more solar energy than humanity consumes.
- Variability: Intermittent and variable due to the day-night cycle and seasonal and daily variations in sunlight.
- Energy losses: Due to energy losses in the conductive, convective and radiative modes, a given area cannot fully recover the captured solar energy.
- Clean: It is a clean energy source, producing no pollutants when converted to electricity.

I.2.2.3 Solar radiation

Also called thermal radiation, is a form of natural electromagnetic radiation emitted in all directions by any object whose temperature is above 0 degrees Celsius. The energy of this radiation is transported by photons that move at the speed of light in space. Each photon carries an energy represented by the formula E= hv, where h is the Planck constant, equal to 6.624 x 10 -34 J.s.

The solar constant refers to the total energy received from the Sun by the Earth's atmosphere on an area of 1 square meter, perpendicular to radiation. In other words, it represents the density of the solar energy flux. Its average value is 1350 W/m², and this constant is independent of weather conditions.

• It is defined by: [5]

$$\boldsymbol{I_{SC} = \sigma T^4 (R_s \,/\, D_{ST})} \qquad \text{(I.1)}$$

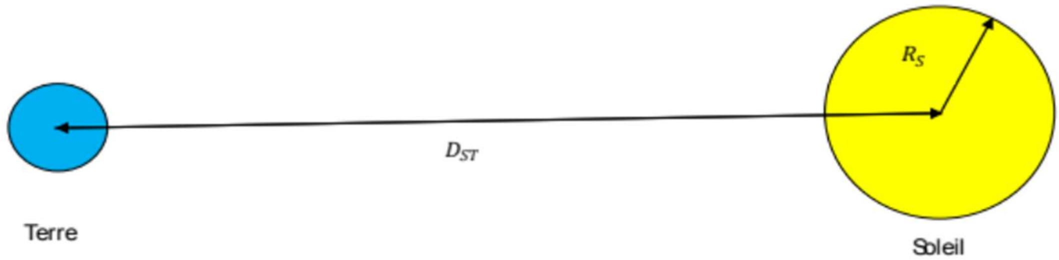


Figure I.1: The earth-sun distance.

$\boldsymbol{D_{ST}}$: The earth-sun distance (m).

$\boldsymbol{R_s}$: The sunlight (m).

$\boldsymbol{\sigma}$: Stéphane-Boltzmann's constant : $5,67.10^{-8} W \,/\, m^2 K^4$

$\boldsymbol{T}$: Temperature at the surface of the sun (K)

Even before the rays arrive on earth, they meet on their way several.

Factors that condition and mitigate their intensity, the latter is also dependent on the latitude and climatic conditions.

The following layers make up the atmosphere:

1 .A lower layer (stratosphere) 10-15 km thick.

2 .An intermediate layer 15 to 100 km thick (the mesosphere).

3 .An upper layer (ionosphere) with a range of 100 to 800 km.

When passing through the atmosphere, solar radiation is altered by the following phenomena: [6]

- Diffusion of molecules and suspended particles.
- Selective absorption of oxygen, ozone, (CO_2) and water vapour.
- Diffraction by dust and suspended droplets.
- Reflection of the clouds.

I.2.2.4 Types of solar radiation

- Direct solar radiation:

Direct radiation is the incident radiation on a given plane from a small solid angle centered on the solar disk, it reaches in a straight line and in clear weather. [7]

The state of the sky is defined by two coefficients, a and b which symbolize the atmospheric disturbance of the place where the solar collector is located (table I.1).

The total transmissivity of the atmosphere for direct incident solar flux is given by [8]:

$$\boldsymbol{\tau}\mathbf{dir} = \mathbf{a} \times [\mathbf{exp}(-\mathbf{p} \times \mathbf{b})/(\mathbf{1000} \times \mathbf{sin}(\mathbf{h}))] \qquad (I.2)$$

Where:

a, b: coefficients reflecting atmospheric disturbances.

h: height of the sun.

P: atmospheric pressure of the place.

Table (I.1): Atmospheric disturbance coefficient values [9]

	clear sky	normal conditions	industrial zones
a	0,87	0,88	0,91
b	0,17	0,26	0,43

The direct radiation received on a horizontal plane is given by [10]:

$$\mathbf{Gdirh} = \mathbf{C} * \times \boldsymbol{\tau}\mathbf{dir} \qquad \text{(I.3)}$$

Gdirh: direct energy illumination received on a horizontal plane.

The Gdir energy illuminance received on an inclined plane is given by [8]:

$$\mathbf{Gdir} = \mathbf{Gdirh} \times \mathbf{cos}\,\boldsymbol{\theta} \qquad \text{(I.4)}$$

θ: angle of incidence of solar rays.

- Diffuse Solar radiation:

The diffraction of light by atmospheric molecules and its refraction by the earth cause a diffuse radiation that allows to see the entire celestial vault.

Direct and diffuse stream transmissions have the following relationship:

$$\boldsymbol{\tau}\mathbf{dif} = \mathbf{0.271} - \mathbf{0.2939} \times \boldsymbol{\tau}\mathbf{dir} \qquad \text{(I.5)}$$

The diffuse flow received on a horizontal plane is defined by [7]:

$$\mathbf{Gdifh} = \mathbf{C} * \times \ \mathbf{sinh} \ \times \boldsymbol{\tau}\mathbf{dif} \qquad \text{(I.6)}$$

The diffuse flow received on an inclined plane is defined by [8]:

$$\mathbf{Gdif} = \mathbf{Gdif1} + \mathbf{Gdif2} \qquad \text{(I.7)}$$

$$\mathbf{Gdif1} = \mathbf{Gdifh} \times \frac{\mathbf{1+cos(i)}}{\mathbf{2}} \qquad \text{(I.8)}$$

$$\mathbf{Gdif2} = \mathbf{alb} \times \frac{\mathbf{1+cos(i)}}{\mathbf{2}} \times \mathbf{Gdifh} \times \mathbf{sinh} + \mathbf{Gdifh} \qquad \text{(I.9)}$$

Gdif1, Gdif2: radiation from the sky and from the ground respectively.

AB: Soil albedo.

I: angle of inclination of the sensor plane relative to the horizontal.

- Overall radiation:

Global radiation (G) is the sum of diffuse and direct radiation [7]:

$$G = Gdir + Gdif \qquad \text{(I.10)}$$

I.2.3 Soil albedo

In reality, the Earth is not a black body; part of the incident solar radiation is reflected by the atmosphere, mainly by clouds, as well as by the Earth's surface. This amount is called the albedo flux. Albedo is generally defined as the ratio of solar energy reflected from a surface to the incident solar energy. A graduated scale of 0 to 1 is used for albedo, where 0 corresponds to absolute black (no reflection) and 1 corresponds to a perfect mirror (diffusion in all directions without absorption of visible radiation received). Table (I.2) shows the albedo values for different surfaces:

Table (I.2): Typical albedo coefficients [11]

Type of surface	Albedo (ρ)
Lake area	0.02 to 0.04
Coniferous forest	0.05 to 0.15
Tropical forest	0.12
Green grass	0.25
Light and dry Sand	0.25 to 0.45
Dark soil	0.05 to 0.15
Ice	0.30 to 0.40
Warm sea	0.05
Cold sea	0.15
Packed snow	0.60
Fresh snow	0.85
Cloud	0.86
Glass with glass	0.10

I.2.4 Duration of sunstroke

The duration of sunstroke is the number of hours in the day, between sunrise and sunset, where the sun is clearly visible. The reading is made by the Campbell Stokes heliograph in which a crystal sphere concentrates the rays of the sun on a paper it burns as it moves. So, only the moments, when the sun is clearly visible and is recorded. This is known as the actual exposure time or effective and it depends on whether the rising sun is visible from the observation point or hidden by clouds. In the absence of the heliograph, it is possible to start from the calculation of the relative astronomical movement of the sun and earth and assess the theoretical duration of the day; that is, that which there would be if the clouds did not hide the sun [12].

I.2.5 Geographical coordinates of the sun

Any point on the Earth's surface is identified by its geographical coordinates; longitude and latitude, as well as its altitude (figure (I.2).

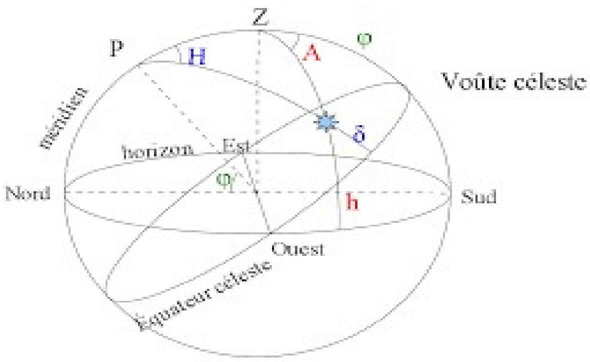


Figure I.2: Geometric coordinates [13]**.**

I.2.6 Longitude (l)

Corresponds to the angle made by the plane passing through the meridian of the point in question with the plane passing through the original meridian, that is, the meridian of Greenwich 0° (United Kingdom). The longitude therefore defines the east/west position of a point. By conversion, the sign (+) the meridians east of that meridian, and sign (–) the meridians east of that meridian the West. The longitude will be designated here by the land (l), it can be between -180° and +180° [14] .

I.2.7 Latitude (φ)

The latitude of a place corresponds to the angle formed by the radius joining the center of the Earth at this place and equatorial plane. Thus, the terrestrial equator is characterized by a latitude equal to 0°, the north pole by +90°, and the south pole by latitude of -90°. In accordance with this convention, places in the northern hemisphere are marked positively (+), while those in the southern hemisphere are negatively marked (-). Latitude is denoted here by the letter (φ) and can range from -90° to +90°. [14]

I.2.8 Altitude

From a point corresponds to the measured according to the vertical of the place, which separates this point from a reference surface called geoid. The geoid is the average surface of the oceans. In General, it is expressed per meter [14]

I.3 The solar field in Algeria:

The solar field is a set of statistics describing the evolution of solar radiation accessible over time. It allows to model the operation of a solar system and to determine the most accurate sizing possible taking into account the demand to be met [15].

Due to its geographical location, Algeria has a huge solar deposit as shown in Figure (I.3):

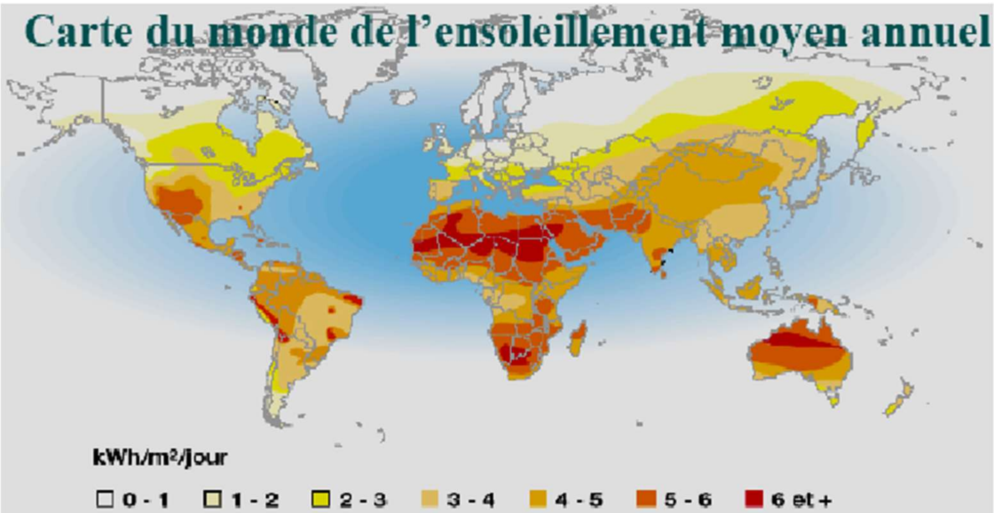


Figure I.3: World map of annual average sunshine [16].

The German Space Agency (ASA) said after a satellite assessment that Algeria has the largest solar potential in the Mediterranean basin, with 169,000 TWh/year for solar thermal and 13.9 TWh/year for solar photovoltaic. Algeria's solar potential is the equivalent of ten huge natural gas discoveries identified at Hassi R'Mel. Table I.3 shows the distribution of solar potential by climate zone at the national level in Algeria, according to the sunshine received annually [16]:

Table (I-3): Sunshine received in Algeria by climatic regions.

Regions	Coastal regions	High plateaus	Sahara
Surface (%)	4	10	86
Average duration of sunshine (h/an)	2650	3000	3500
Average energy received (kWh/m2/year)	1700	1900	2650

The duration of insolation in the Algerian Sahara is of the order of 3500h/ year, the largest in the world, it is always more than 8h/ day and can arrive until 12h/ day during the summer except the extreme south where it decreases until 6h/ day in summer [16].

The Adrar region is particularly sunny and has the greatest potential of all of Algeria (Figure I.4).

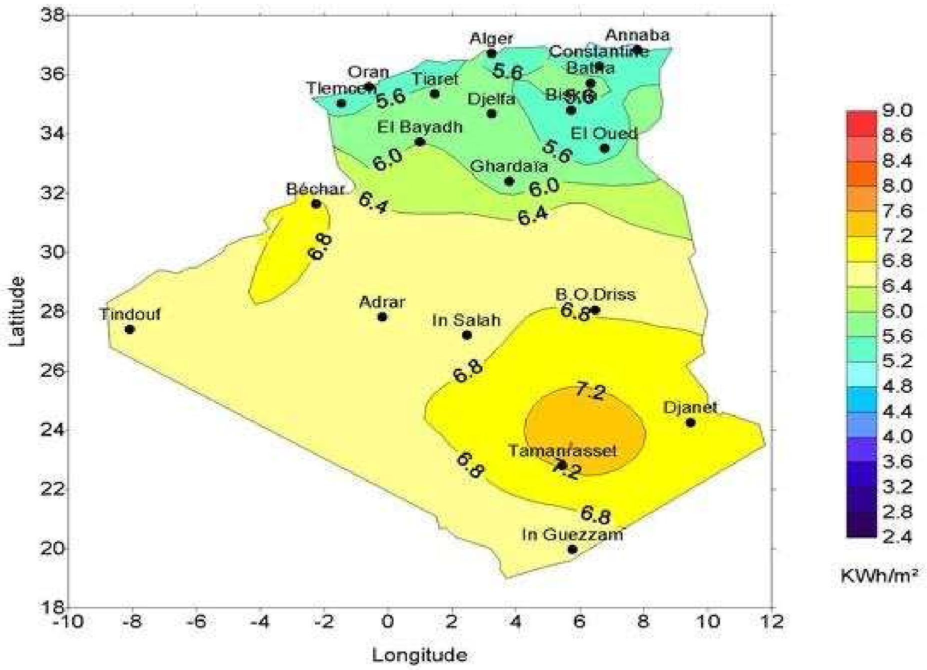


Figure I.4: Annual average of the total solar irradiation received on an inclined plane at the latitude of the place [17]**.**

In Algeria, a network of 78 O.N.M meteorological measuring stations (Appendix D) is scattered across the country (Figure I.5). However, due to the lack of reliability of measuring instruments or the exorbitant cost of such equipment, only 7 weather stations ensure the measurement of the diffuse and global components of the solar energy received on a horizontal plane. Due to the ease of installation, the sunshine duration is controlled using a Heliograph in most situations (O.N.M).

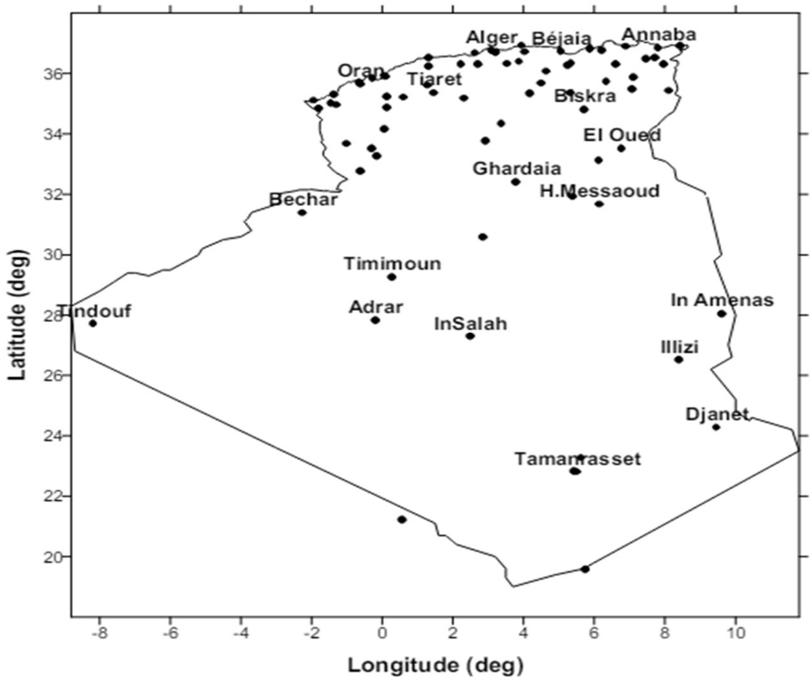


Figure I.5: Territorial distribution of weather stations in Algeria.

I.3.1 Climatic situation

The climate of southern Algeria is characterized by extreme aridity with extremely low humidity. The average annual temperature is about 25°C, with hot summers and cold winters. Extreme temperatures above 50°C.

Rainfall is characterized by its great interannual variability. In the northern Sahara, they are thin while they are diluted. These different climatic characteristics affect Saharan hydrography. Thus, the flow of wadis is temporary. When my valleys do not have a surface flow, they often have an underground flow, which takes a lot of importance given the scarcity of surface water [18].

I.3.2 Meaning of the El-Oued site

El-Oued is a wilaya in the southeast of the country with a total area of 44585 km2.

It has an estimated total population of 990000 at the end of 2013.

Its geographical coordinates are [18]:

Table (I-4): Geographical coordinates

Station	Code A.N.R.H	Altitude (m)	Longitude	Latitude
Guemar	13 04 09	64	06°47'E	33°30'N

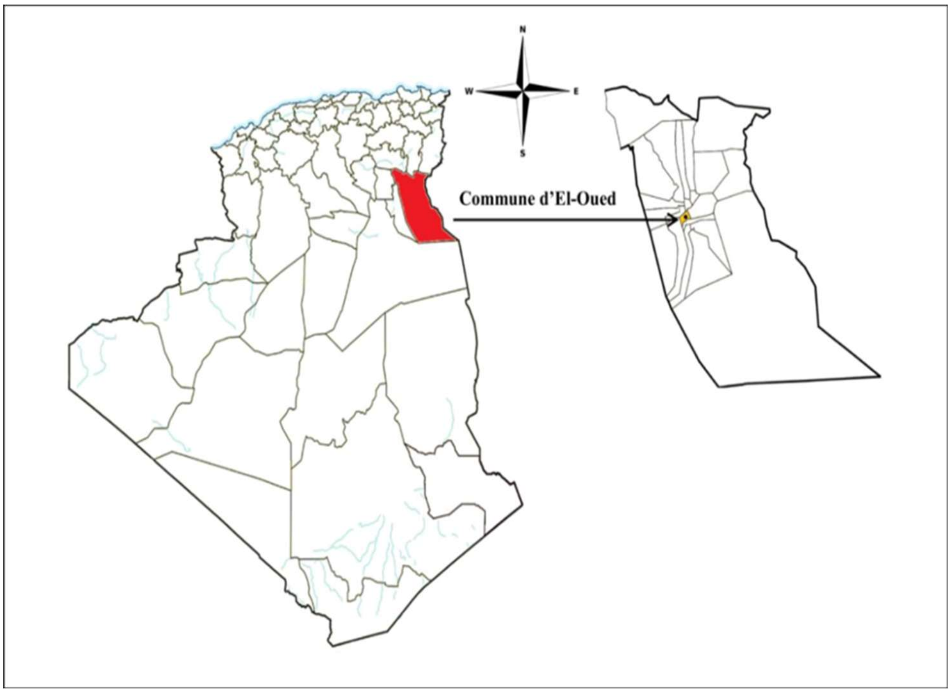


Figure I.6: Superfetation of the El-Oued site.

I.3.2.1 Climate of the El-Oued

The Wilaya of El-Oued has a Saharan climate, with very little rainfall, high temperatures, significant evaporation and a fragile biological life ecosystem.

I.3.2.2 . Temperature of the El-Oued

From 2015 to 2023, the average monthly temperatures for the hottest month (Juli) were 42,2°C. Those for the month are The coldest month (January) has an average temperature of 18,0°C [19].

Table (I-5): Monthly average temperatures (°C) (2015-2023)

Month	Jan	Feb	March	April	May	June	Jul	August	Sep	Oct	Nov	Dec
Tm(°C)	18,0	20,1	23,9	28,5	34,0	39,5	42,2	40,9	36,6	30,3	23,0	19,1

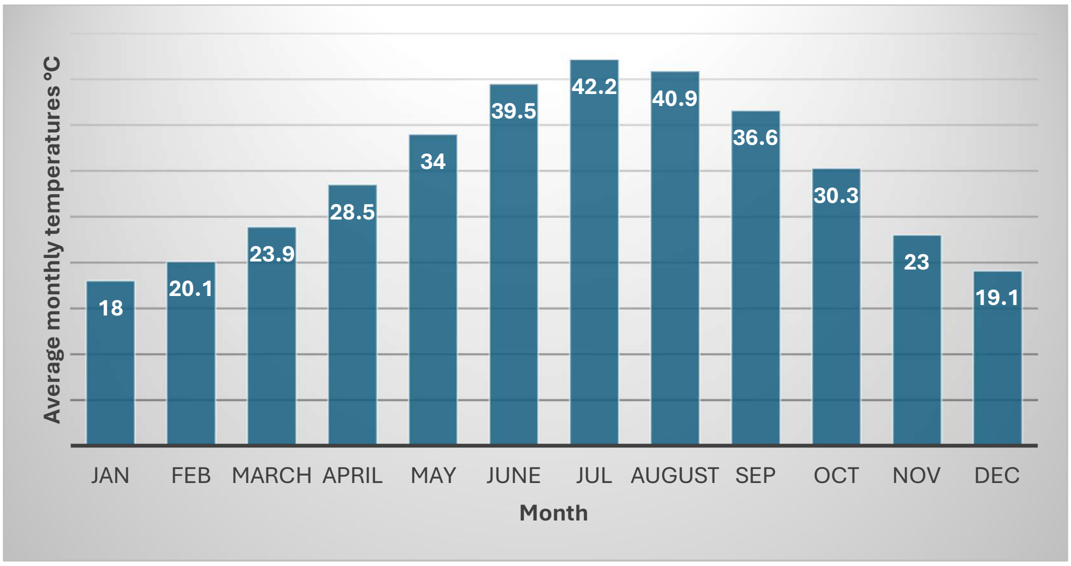


Figure I.7: Average monthly temperatures in the El-Oued region (2015-2023).

I.3.2.3 Rainfall

In El Oued, rainfall totals 85 millimeters per year: they are therefore at the desert level. In the least rainy month (June) they rise to 0 mm, in the wettest month (Sep) they rise to 11.3 mm. Here is the average rainfall [19].

Table (I-6): Average monthly precipitation (mm) (2015-2023)

Month	Jan	Feb	March	April	May	June	Jul	August	Sep	Oct	Nov	Dec
Pm(mm)	0.4	9.3	5.3	11.2	4.8	0.0	0.2	2.3	11.3	1.8	8.6	2.8

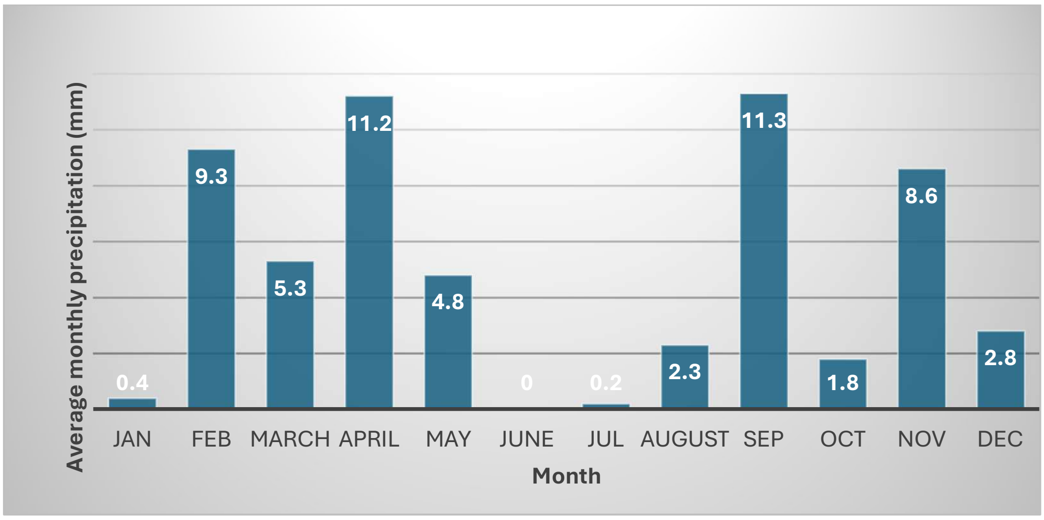


Figure I.8: Average monthly precipitation in the El-Oued region (2015-2023)

I.4 capturing solar energy

I.4.1 Photovoltaic solar energy

This method produces electricity by converting part of the solar radiation using photovoltaic cells.

Photovoltaic cells exploit the photovoltaic effect, consisting of a layer of semiconductor material and a semiconductor junction. Although silicon is the most commonly used material, gallium arsenide offers better performance, but at a higher cost.

There are multiple approaches to capturing some of this solar energy, which involve: Solar thermal energy:

The process of converting solar energy into heat, used in:

- Direct heat applications: solar water heaters, solar heating systems, solar stoves and dryers.
- Indirect applications where heat is used for other purposes: thermodynamic solar power plants, solar refrigeration systems.

I.4.2 Thermodynamic solar energy

This method uses solar thermal energy to produce electricity, similar to the operation of conventional power plants, but using solar thermal installations.

Three main types of plants are used:

- Parabolic cylindrical sensor plants, reaching temperatures between 300 and 350°C.
- Parabolic sensor plants capable of reaching temperatures of 1000°C or higher.
- Tower plants, also reaching temperatures of 1000°C.

I.4.3 Solar thermal energy

The process of converting solar energy into heat, used in:

- Direct heat applications: solar water heaters, solar heating systems, solar stoves and dryers.
- Indirect applications where heat is used for other purposes: thermodynamic solar power plants, solar refrigeration systems.

- Solar drying, the central theme of this paper, is considered the predominant drying technique. Subsequently, it delves into a comprehensive exposition of its details and types.

I.4.4 Solar drying

I.4.4.1 Definition of the Drying Process

By definition, drying is a purification technique aimed at ridding a homogeneous or heterogeneous mixture of a liquid constituent. Drying a product consists in providing the energy necessary for the vaporization of the water of the product (latent heat of vaporization), then to evacuate the vapor formed. The purpose of such an operation is either to restore to a treated substance its initial mechanical or physicochemical qualities, or to facilitate its storage and preservation. There are several drying processes: mechanical processes (press, settling or centrifugation), Physicochemical processes (adsorption, absorption, refrigeration and evaporative drying). The latter consists in transferring the liquid to be eliminated in the gas phase that bathes it. The phase change requires a considerable heat input. It can be direct (heating by exchanger, by joule effect, by infrared radiation or by high frequency currents) or it is the gas phase itself that ensures the necessary heat supply (hot air). Evaporative drying is a very complex process involving a double transfer. The first is a heat transfer to reduce the water content in the product. The second is a mass transfer which involves a displacement of the fluid from the inside of the product to its surface. These two transfers require considerable heat input, hence the value of using a renewable heat source. This is the case of solar dryers.

I.4.4.2 Purpose of Drying

Drying is one of the main ways of preserving perishable food. Indeed, by removing water, the action of microbial germs (yeasts, mold, bacteria) responsible for rot is inhibited. It is also a necessary step in the freezing of some products, because the elimination of water decreases their weight and volume. In short, drying helps to improve the preservation of products, facilitate their transport, reduce the risk of losses of products after harvest and especially expand the marketing of these products by making them available throughout the year.

I.4.4.3 Drying with Solar Energy

The natural drying known and practiced by our ancestors consists in exposing the product to dry directly in the sun, spreading it on the ground on mats or beds. This type of drying, although simple and free, has the disadvantage of requiring long drying times, exposing the product to dust, rain and insects. Hence the deterioration of the quality and risk of rot and mold that can reach up to 50% of the crops.

Until the 20th century, when the concept of water activity (WA) and knowledge of moisture transfer mechanisms in products came into being, scientists were unable to develop the first artificial dryers according to scientific rules.

I.4.4.4 Different Types of Solar Dryers

- Tunnel Dryers:

They are industrial dryers for drying large crops and in the preservation processes of certain foods. They consist of a field of solar collectors and an Aeraulic circuit, all constituting the hot air generator. The product that needs to be dried is placed on trolleys that are attached to rails and constantly move through a tunnel (Figure I.9).

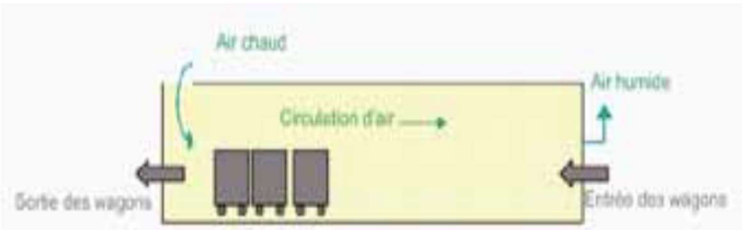


Figure I.9: Tunnel Dryers [20]

- Stock drying equipment:

Also called drying ovens, they are stationary dryers, or the product to be dried is stored on racks or shelves. Stock dryers are available in either direct or indirect forms:

❖ Direct Solar Dryers (Greenhouse Dryers)

In this type of dryer, the insulator (solar collector) and the stock (drying chamber) form a single block. The dryer consists of an insulated box at its base and covered with a glass or clear plastic. The food to be dried receives direct sunlight through the transparent cover (Figure I.10). This type of dryer is suitable for drying fruits and vegetables with a large initial water content and long drying times (Figure I.11).

Figure I.10: Direct Solar Dryers (Greenhouse Dryers). [20]

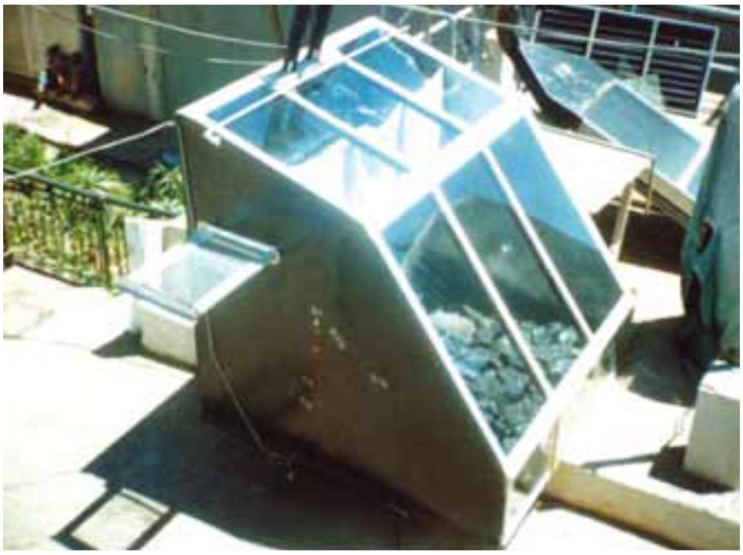


Figure I.11: Greenhouse solar dryer at CDER [21]

❖ Indirect Solar Dryers

They are made up of couple's insulators with a drying chamber. The insulator is used to heat the air and send it into the latter (Figure 4). In natural convection, this is not enough to heat the air to the desired temperature, which explains the addition of a fireplace. The additional energy at the base of the chimney significantly improves the operation of the dryer by increasing the air flow in the mass of the product to be dried.

The indirect solar dryer is categorized into two types:

1) Passive indirect solar dryer
2) Active indirect solar dryer

I.5 Conclusion

In this chapter, we have learned about the drying process and its purpose combined with the needed data for this study, some data about the solar field in Algeria, also we have provided a brief look on the solar drying system types, on the light of this information, we decided that the next chapter will be about indirect solar drying expanding.

Chapter II:

Indirect solar drying systems

II.1 Introduction

This chapter contains an extended information on the indirect solar drying systems such as Drying tent, Box dryer, rocking dryer, Solar Cabinet Dryer, Solar Cabinet Dryer, Active solar dryers with ventilated cabinet, Dryers with auxiliary heating and Greenhouse dryers which is extremely important to this study.

II.2 Indirect solar drying

Indirect solar drying is a fairly new technique, not yet widely standardized or marketed, and includes some thermal energy assembly devices and dryers with special techniques. There are several types of dryer sizes, whose manufacturing technique meets the special drying requirements of food products, many of which still operate on the basis of experience rather than scientific basis.

II.2.1 Passive System

Passive solar dryers are also known as natural circulation systems. Natural convection is another option. It is generally of an appropriate size for use on the farm. Solar energy is the sole source of power for solar dryers that use natural circulation. The air heated by the sun circulates through the product in such systems because of buoyancy forces or wind pressure.

II.2.1.1 Drying tent

Tent dryers, as shown in Figure I.3, are inexpensive and simple to Construct and consist of a frame of wooden poles covered with plastic sheet. Food to be dried is placed on a rack above the ground. However, drying times are not always much lower than when drying in the open air. The main purpose of these dryers is to provide protection from dust, dirt, rain, wind or predators, and they are usually used for fruit, fish, coffee or other products. These dryers can also be disassembled and stored when not in use. The major disadvantage of this type of dryer is that it is easily damaged by High winds.

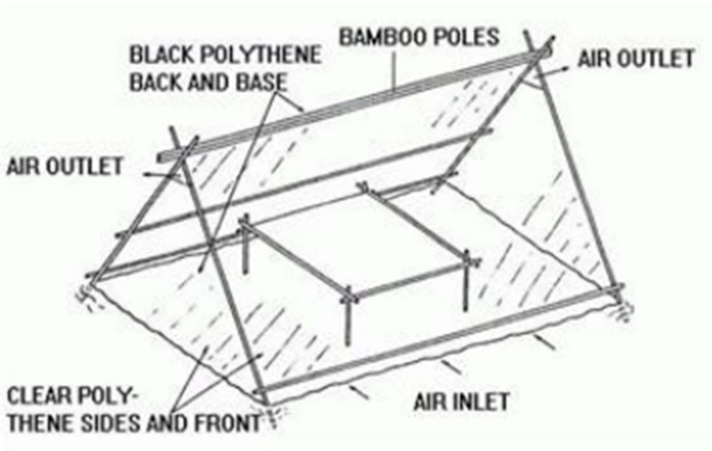


Figure II.1: Tent dryer [22]**.**

II.2.1.2 Box dryer

Box type solar dryer has been widely used for small scale food drying. It consists of a wooden box with a transparent lid. The interior is painted black, and the food is supported on a mesh tray. Air enters the chamber through holes in the front and exits through vents at the top of the rear wall.

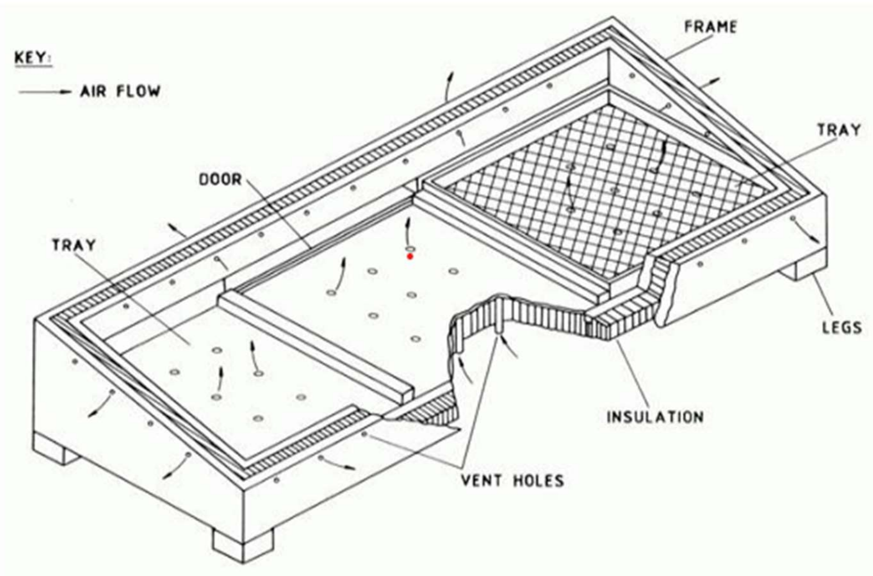


Figure II.2: Box dryer [23]**.**

II.2.1.3 Rocking dryer

The traditional rocking dryer [24] has a rigid rectangular frame whose length is 3 times the width' resting on a support with an axis. This support is oriented north-south and high enough to allow a 30° tilt of the frame eastward in the morning and westward in the afternoon.

The product is placed on a number of trays, which have a wooden frame of 100 x 50 cm and a mesh bottom, which can be made of various materials, such as wire mesh, old fishing nets, bamboo mesh or any other material that will allow vertical air circulation and maximum evaporation.

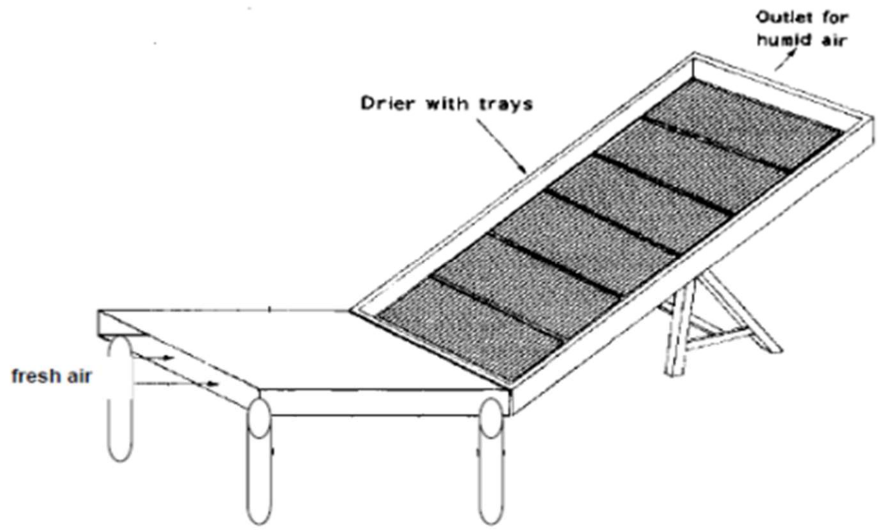


Figure II.3: Rocking dryer [24].

II.2.1.4 Solar Cabinet Dryer

The harvest is located in trays or shelves inside a drying chamber. If the chamber is transparent, the dryer is called integral or direct type solar dryer. If the chamber is opaque, the dryer is called a distributed or indirect type solar dryer. Mixed mode dryers combine the characteristics of the direct and indirect type.

In most cases, the air is heated as it flows through a solar collector and passes through air pipes in the drying chamber and on drying trays containing the crops. The moist air is then evacuated through vents or a chimney at the top of the chamber.

The cabinet is a large wooden or metal box. It must be properly insulated to minimize heat loss and made durable. Construction from water-resistant sheets or coatings is recommended.

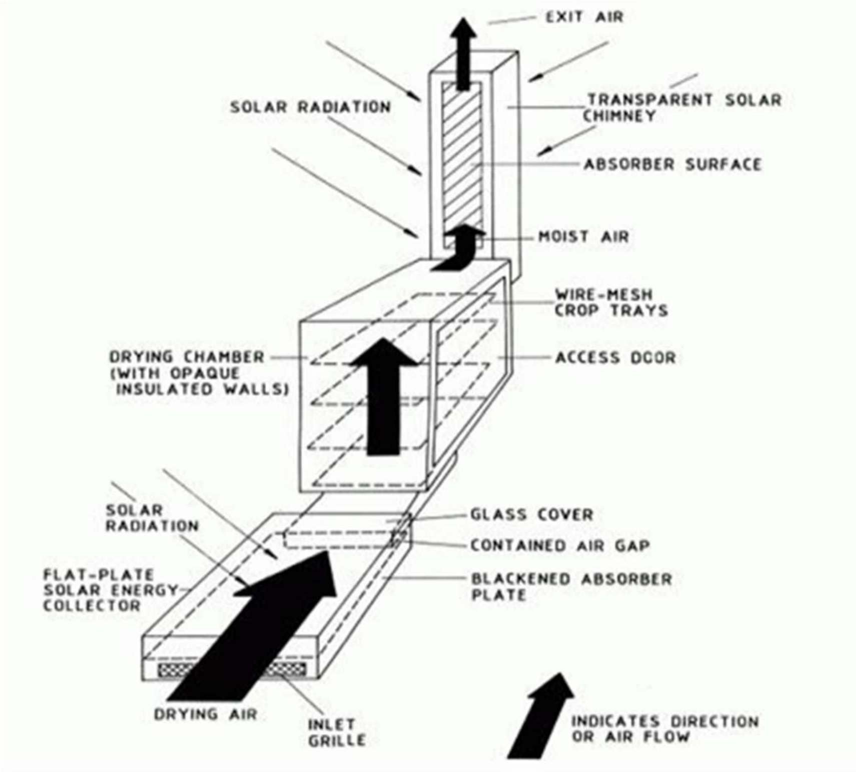


Figure II.4: Cabinet drayer (indirect mode) [23]**.**

II.2.2 Active Solar Dryers

Active solar dryers are also called convection solar dryers forced or hybrid. Optimal air flow can be provided in the dryer throughout the drying process to control temperature and humidity in wide ranges regardless of weather conditions. In addition, the apparent depth is less air flow can be controlled. Thus, the capacity and reliability of the dryers are significantly increased compared to natural convection dryers. It is generally accepted that well-designed forced convection solar dryers are more efficient and controllable than naturally circulating types.

The use of forced convection can reduce the drying time by three times and decrease the required sensor area by 50%. Therefore, a dryer using fans can achieve the same flow rate as a natural convection dryer with a collector six times larger [25].

Fans can be supplied with electricity if available or with a photovoltaic solar panel Almost all types of natural convection dryers can also operate by forced convection.

II.2.2.1 Active solar dryers with ventilated cabinet

If utility electricity is available, it is cheaper to connect the Fans to the grid, compared to a connection to a PV installation. In addition to fans, an electronic controller can also be connected to the network, capable of setting the appropriate temperature according to the variable speed of the fan.

In a system powered by a photovoltaic panel, the fan is directly coupled to the solar module, operating without accumulator or charge controller. The increase in solar radiation increases the power of the module, thus accelerating the fan. This has the advantage of allowing simple temperature control, thus avoiding any additional control device as long as the system is sized appropriately.

Figure II.5: Fan powered by photovoltaic panel.

II.2.2.2 Dryers with auxiliary heating

A significant disadvantage of solar dryers is that they are normally used with no form of auxiliary heating. For commercial producers, this factor limits their ability to process a crop when the weather is bad. This also prolongs the drying time as drying can only occur during the day when solar radiation is sufficient. This not only limits production but can result in a lower quality product. For commercial producers, the ability to reliably process continuously is important to satisfy their markets [26]. So, it is necessary to add a backup system to remedy this problem.

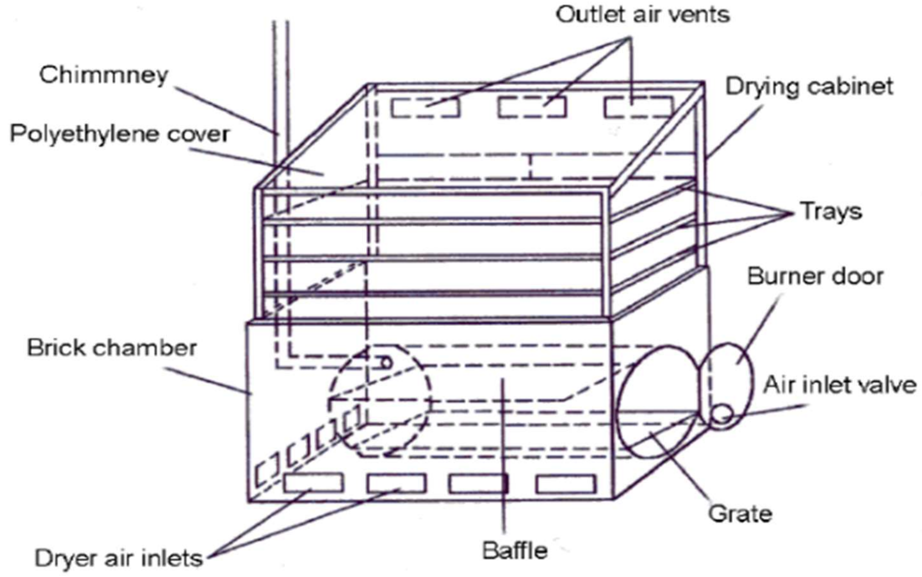


Figure II.6: Natural convection dryer with booster.

II.2.2.3 Greenhouse dryers

The idea of a greenhouse dryer is to replace the function of the solar collector with a greenhouse system. The roof and wall of this solar dryer can be made of transparent materials such as glass, fiberglass or polycarbonate sheets. The transparent materials are fixed on a steel frame support or pillars with bolts and nuts and a rubber gasket to prevent wet air or rainwater from seeping into the chamber other than those introduced through the inlet opening. To improve the absorption of solar radiation, black surfaces must be provided inside the structure. Intake and extraction fans are placed at the right position in the structure to ensure uniform distribution of drying air. Greenhouse dryers allow a greater degree of control over the drying process than cabinet dryers and they are more suitable for large-scale drying [27].

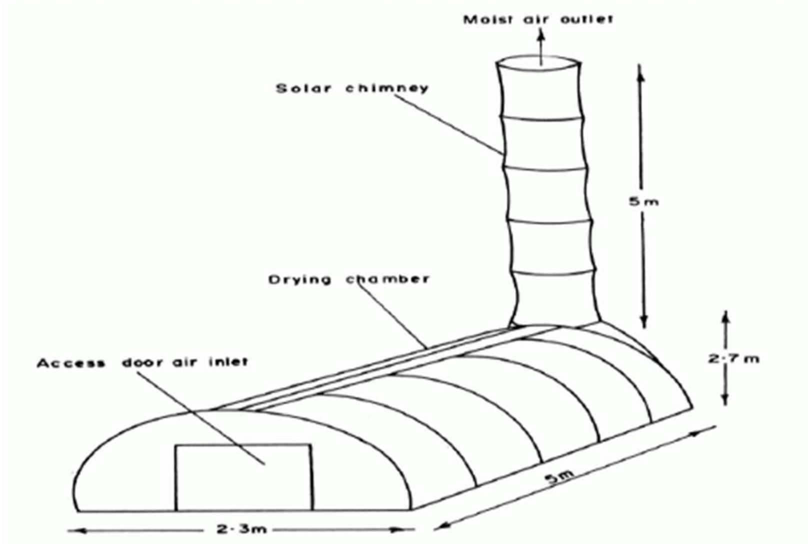


Figure II.7: Greenhouse dryer with chimney [23].

II.3 Bibliographic study

II.3.1 Heat Storage for Drying Systems

Energy storage is necessary for places with high or low radiation density and in cases where harvesting products must be dried in a continuous process, immediately after harvesting. The use of storage devices increases the cost of initial capital plus the cost of operation. To avoid unnecessary expenses, storage of expenses must be applied in the following cases:

- When the solar energy density is high, and the energy must be stored to avoid over-drying the product at higher temperatures.
- When the agricultural product is very sensitive to temperature. By storing excess solar energy, temperature can be easily regulated and controlled.
- When the drying process should continue overnight. This case concerns sensitive products that must be dried immediately after harvest.

The two most common methods of heat storage include:

1. Heat storage by working fluid in the complex.
2. Direct heat storage by irradiation.

In the first case, sensitive heat can be stored in water, if water is used as a collector's work fluid, or when using air, in an inexpensive solid medium, such as gravel, rock, etc [28].

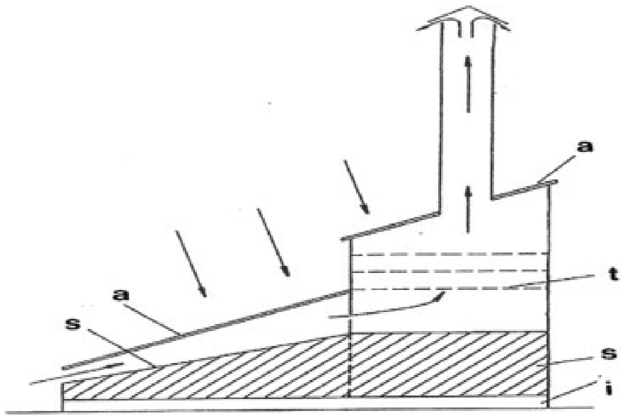


Figure II.8: A typical, mixed-mode, natural circulation solar dryer with integrated heat storage [28]**.**

a: transparent cover.

i: straw insulation.

t: trays with the material.

s: pebble storage space.

When water is used as a means of heat transfer, it is necessary to have an intermediate heat exchanger. In figure 31, a drying system that uses water as a means of heating and storage is displayed. Water is heated inside the complex (c) and is stored by heating dry air in the heat exchanger (h), and is therefore returned either to the storage tank or to the complex, depending on the time of day or the intensity of solar radiation. Hot air flows directly to the dryer (d). Pumps (p) and valves (v) regulate water flow [28].

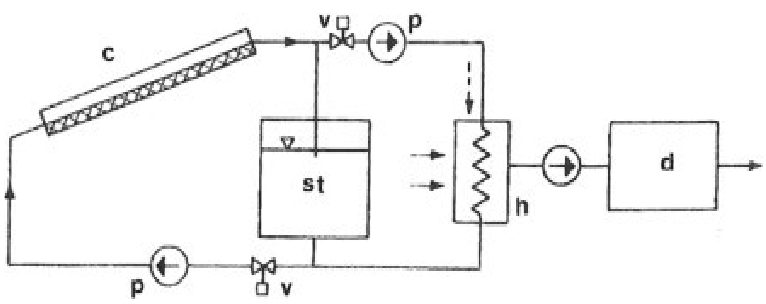


Figure II.9: Drying system with water as working and storage fluid [28]**.**

When air is used as a heat transfer medium, there is no need for a heat swap and hot air from the complex is directed directly to the dryer or through storage, where heat is stored in the rocks, as sensitive heat. Storage by direct thermal irradiation is used either as a variable-phase material or as liquid/air hybrid type complexes. It appears in a cross-section of the two types of direct radiation assembly/storage systems [28].

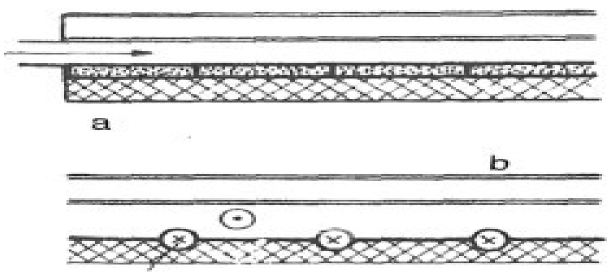


Figure II.10: Integrated direct heat storage by irradiation. a, latent heat [28]**.**

A greenhouse-type solar dryer with pebble accumulators. The north and side walls are brick-built and the south-facing slash wall is covered with ordinary window. A Space (b) contains the thermal complex, a gravel-filled cylindrical tank (AK) and air heater. Both form a "hot box room." A black metal plate (s) is installed in parallel to the transparent cover, forming a "semi" thermal complex that simultaneously protects the material from direct exposure to solar radiation. The top of the drying chamber (d) is connected to the accumulators, by a tube (e), where the warm, humid air releases part of its heat before it is exhausted to the ocean, while the air tube below the chamber is connected to the air heater (e). Can dry 500 to 600 kg of apricots, tomatoes and other fruits and vegetables per drying cycle [28].

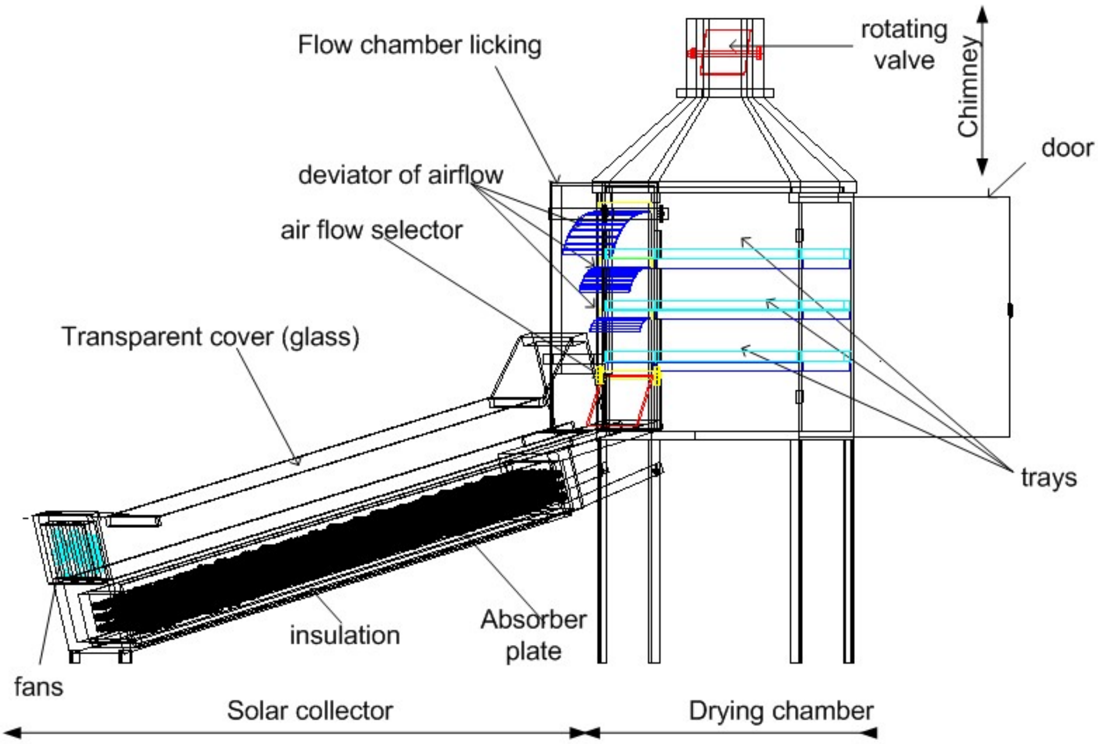


Figure II.11: Indirect solar dryer [28]**.**

II.3.2 Advantages and disadvantages of indirect solar drying

Indirect solar drying technology has only advantages. Its only disadvantage is the high initial capital cost of the dryer, the assembly field and all necessary auxiliary equipment, such as channels, tubes, blowers, control and measurement tools, and fairly skilled personnel to operate the drying process. Advantages are [28]:

1. The drying rate is high. Agricultural products are dried within 15-30 hours instead of a few days for example.
2. The drying process can be controlled scientifically, ensuring the moisture content suitable for the finished product, as per specifications. Thus, the dried product can be stored for a long time.
3. There are no losses whatsoever, as the product is not subject to any natural phenomena.
4. For the same amount of material, they need smaller surface areas due to the placement of trays in piles, one on top of the other, inside the dryers.
5. Increase productivity, as dryers can be loaded back within a few hours.

6. The flexibility of the dryer in accepting similar seasonal crops, thereby expanding the operation of the system almost throughout the year.
7. The rise in initial capital and operating costs partially balances direct sun drying.

II.4 Drying Requirements for Certain Crops

Solar dryers are used to dry many crops and products such as cereals and herbs Vegetables, fruits, dairy, and fish. For each type, the design of the solar dryer must be adapted so that the temperature and airflow are optimal to achieve good drying while maintaining a good quality product. Wet foods like mangoes, pineapples, and tomatoes require two full days of sun drying. Even though food can be. Dried others, like apples, coconuts, potatoes, onions, in one day. As for hardwood products, like herbs take only part of the day. [29]

Table (II-1) contains information on the initial, final and maximum permitted moisture content for drying certain crops [30]

Crop	Initial moiteur content (percent)	Final mouture content (percent)	Maximum heat Allowed for drying (C °)
Raw rice	22-24	11	50
Boiled rice	30-35	13	50
Yellow maize	35	15	60
Wheat	20	16	45
Corn	24	14	50
Rice	24	11	50
Legumes	20-22	9-10	40-60
Oilseeds	20-25	7-9	40-60
Green peas	80	5	65
Cauliflower	80	6	65
Carrots	70	5	75
Green bean	70	5	75
Onions	80	4	55
Garlic	80	4	55

Cabbage	80	4	55
Sweet potato	75	7	75
Potatoes	75	7	75
Spices	80	5	65
Apricot	85	18	65
Apples	80	24	70
Raisins	80	15-20	70
Banana	80	15	70
Guava	80	7	65
Gumbo	80	20	65
Pineapple	80	10	65
Tomatoes	96	10	60
Beetroot	80-90	5	70
Auvergne	95	6	60

II.5 Conclusion

in this chapter, the expanded information about indirect drying systems and structures also the Bibliographic study about the heat storage in mentioned systems, helped the team to build the solar drying system that is going to be shown with details in the next chapter.

Chapter III:

Experimental Study

III.1 Introduction:

We are currently focusing on a project that explores the practical application of using a combination of salt and aluminum for solar energy conversion. Our research involves a comprehensive examination of this innovative technology and its thermal efficiency within the overall drying system. The solar dryer we are developing utilizes a "salt and aluminum filings" material to efficiently absorb and transfer solar heat to the drying chamber, ensuring durable moisture removal. Our objective is to evaluate the thermal efficiency and benefits of the dryer using a mixture of salt and aluminum filings through experimental methods.

III.2 Solar Flat Collector Presentation:

It is a flat air solar collector with simple circulation and well isolated Door-shaped glass (1.75m x 0.75m) which transforms solar radiation and preserves heat. It consists of 4 drawers (0.6m x 0.39m), painted in matt black containing a mixture of salt and aluminum in 2 different ways. The air flows between the window and the absorber. The sensor is tilted 33° angle (latitude of the city of El-Oued) to the horizontal and oriented plane southbound.

III.3 Building the solar dryer

III.3.1 The design and dimensions of the solar dryer.

Based on earlier study, the team chose the design shown in Figure (III.1)

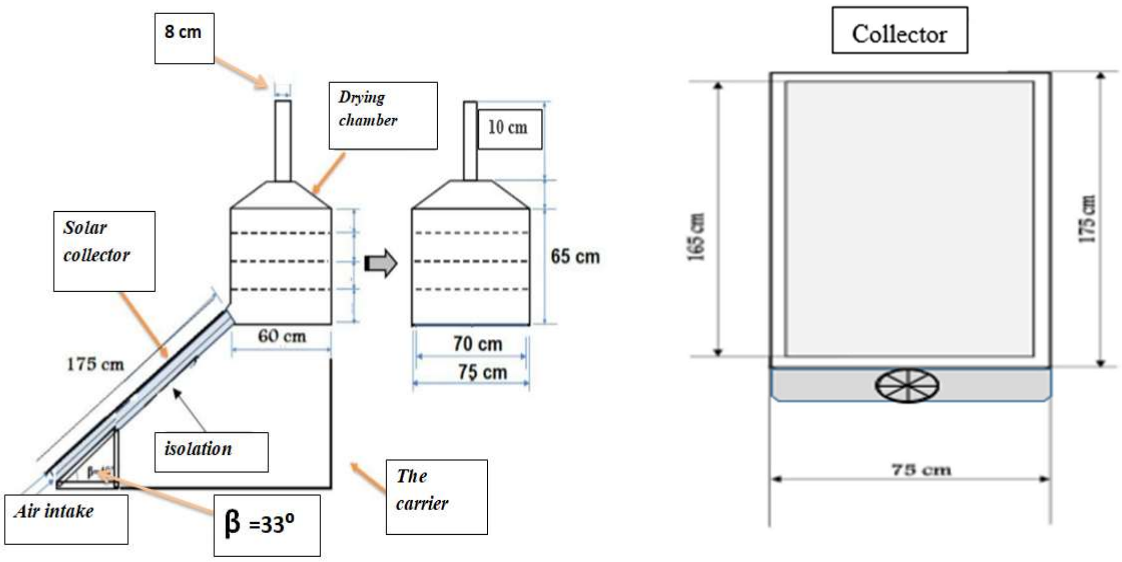


Figure (III.1): The design and dimensions of the dryer.

III.3.2 The equipment used for building the dryer

These components have been specially selected to manufacture our sensor.

These components are summarized in the table (III.1)

Table (III.1): the used equipment for the Experiment

Materials	Dimensions	Amont	Photo
L-Shape iron cane	**6m**	**3**	
Iron cane in the shape of a square	**6m**	**3**	
Steel gratte hinge	**-------**	**4**	
Wading Rod	**---------**	**45**	
Silicone	**-------**	**1**	
fan	**(0.12m*0.12m)**	**2**	
Black Paint (black mat)	**--------**	**11**	

Black Paint		**1**	

III.3.3 Design and Implementation of Solar Collector

III.3.3.1 The carrier

As shown in Photo (III.1), We built a carrier with suitable dimensions. The carrier was made from an L-shaped iron cane, length 2 m, width 1.20 m, height 50 cm tilt angle is 33°

Photo (III.1): The carrier design

III.3.3.2 Drying chamber

As shown in Photo (III.2) We crafted the part using the same type of wood, following the initial measurements, and properly installed the insulators to enhance the drying efficiency.

Photo (III.2): Drying chamber

III.3.3.3 Solar collector

We made sure to install our collector properly by applying its measures to our dryer. Additionally, we added insulation to enhance its effectiveness against global warming and to minimize the impact of external factors.

Our collection consists of the following

- Chest (Exterior Cover)
- Transparent cover
- Insulating
- The trunk or frame
- Absorber

a) Chest

A Melamine wood chest of dimensions (1.75 m, 0.75 m 0.2 m) and 0.02 thick is used, for this purpose:

Photo (III.3): Chest (Exterior cover)

b) Glass roof (glass)

For its simplicity and low cost, ordinary glass was used. Because this type flat air solar collector does not require advanced techniques.

The glass dimensions are:

• Length: 1.65m

• Width: 65 cm.

• Thickness: 0.5 cm.

Ordinary glass was chosen for its good thermal conductivity Photo (III.4), good transmission of visible radiation and wettability. To ensure a good level.

Photo (III.4): Glass cover

c) Thermal insulation

To insulate the collector, polystyrene must be used as insulation Photo (III.5):, to withstand operating temperatures. Polystyrene was used with 4 cm thickness at the back and 4 cm side sides.

Photo (III.5): Thermal insulation

d) Drawers

The collector's drawers Photo (III.6), are designed for easy experimentation, allowing for quick changes to the absorbing material for studies.

Photo (III.6): The collector's drawers

e) Absorber

Use Us in Salt Photo (III.7) Experience Absorber with Aluminum filling Photo (III.8)

- Salt thickness: 3 mm
- Aluminum filling thickness: 3mm

Photo (III.7): salt

Photo (III.8): Aluminium filling

III.3.4 The final shape of the solar collector

After the steps we get the following structure:

Photo (III.9): the utilized solar dryer

III.4 Used measuring devices

III.4.1 Temperature Sensors

This device is designed to measure the temperature of the dryer at various points during operation. Sensors are distributed throughout the dryer, and Photo (III.10) displays the sensors used.

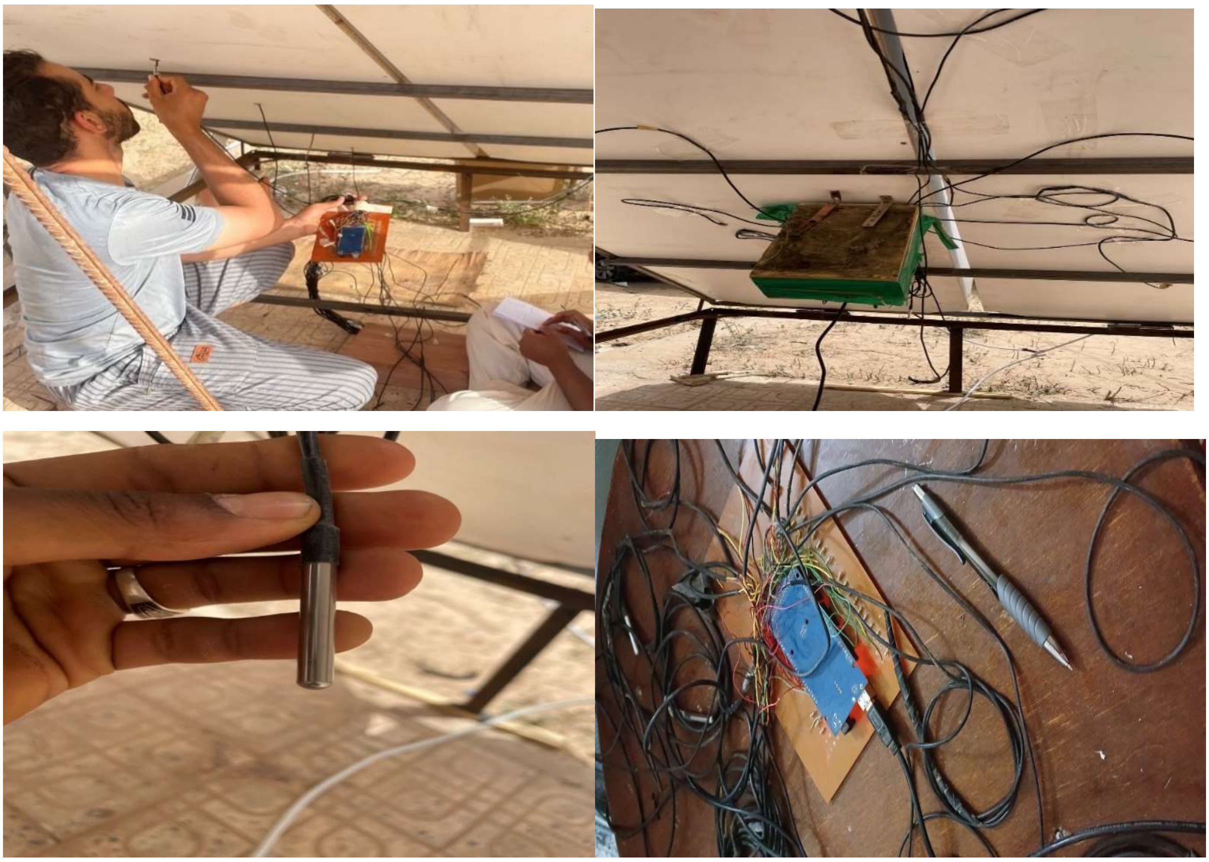


Photo (III.10): the board of the sensors.

III.4.2 Anemometer device

The Anemometer is a device that measures wind speed and direction. It is a common instrument used in weather stations.

Photo III (11): anemometer device

III.5 The process of the experiment

III.5.1 Preparing the materials for the Soler collector drawers

- Prepare equal amounts of coarse salt and aluminum filing for the experience

- Dividing the materials into two equal parts and mixing half of each to be placed in the first collector as a solar heat-converting material, as shown in Photo III (12).

Photo III (12): a mixture of Salt and Aluminum filing

after placing the mixture in the draws, it is painted matt black for good solar radiation absorption the process is demonstrated in Photo III (13)

Photo III (13): salt and Aluminum filing mixture before and after painting

III.5.2 Preparing the second collector

In the mentioned drawings, the team prepared 0.08m x 0.6m lanes side by side of aluminum filings and salt in each drawing, as shown in Photo III (14).

Afterward, it is painted matte black to effectively absorb solar radiation, as shown in Photo III (15).

Photo III (14): preparing the side-by-side lanes for the second collector.

Photo III (15): painting the side by side before and after painting.

III.6 Testing and observation

During the experiment, the team used an anemometer device to test the airflow inlet and outlet of the solar dryer. A tube was also utilized for more precise measurements on the intake side Photo III (16) .

Photo III (16): inlet airflow measurement

Photo III (17): outlet airflow measurements

III.7Conclusion

In this chapter, we explained how we built and installed the solar dryer. We also studied the thermal efficiency for two cases: the mixer case and the side-by-side case. In the next chapter, we will review and analyze the data from the experiment.

Chapter IV:

Results and Interpretations

IV.1 Introduction

In this chapter, we will discuss the experimental results of our work conducted on May 21st and 22nd, 2024, using the designed dryer. These results primarily focus on the variation of outlet temperatures, the maximum temperature for the used collectors, the airflow at the inlet and outlet over time, and the thermal storage capacity for the two collectors in the climatic conditions of the El Oued area, The results are displayed in graphical form, showing the measured quantities.

IV.2 Study of the thermal behavior of the simple indirect solar dryer

IV.2.1 Climatic conditions

IV.2.1.1 Variation of environmental air temperatures and solar radiations

Figures (IV-1) and (IV-2) depict the daily changes in solar radiation and environmental air temperature over time. Solar radiation and air temperature exhibit similar patterns because higher solar radiation levels correspond to higher air temperatures. The solar radiation reaches its peak value of 1534 W/m2 at noon (14:00). On the first day, solar radiation fluctuates between 128 and 1534 W/m2, while on the second day, it ranges from 117 to 951 W/m2. The maximum environmental air temperature recorded is 39°C at 15:30 on the first day and 38°C on the second day, with a general range of 28.2°C to 39°C.

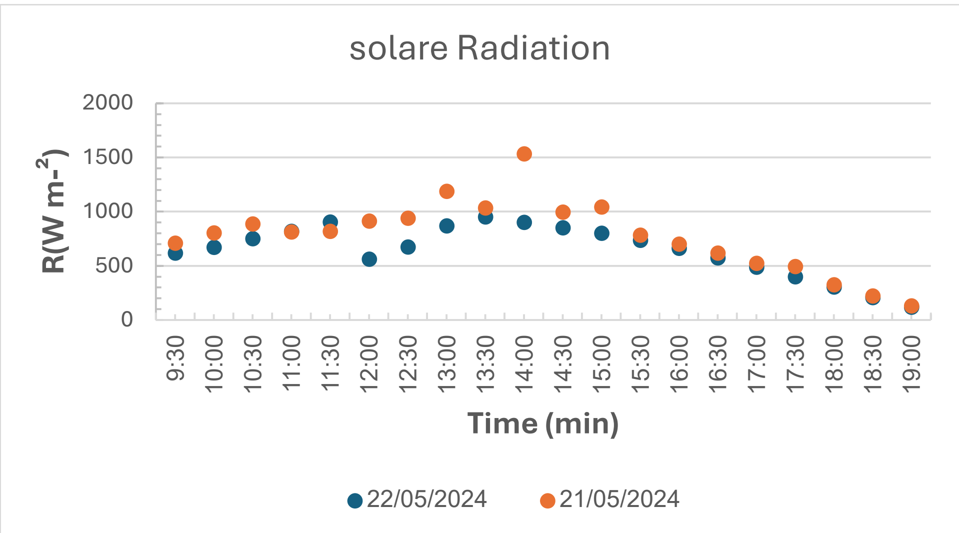


Figure (IV- 1): solar radiations

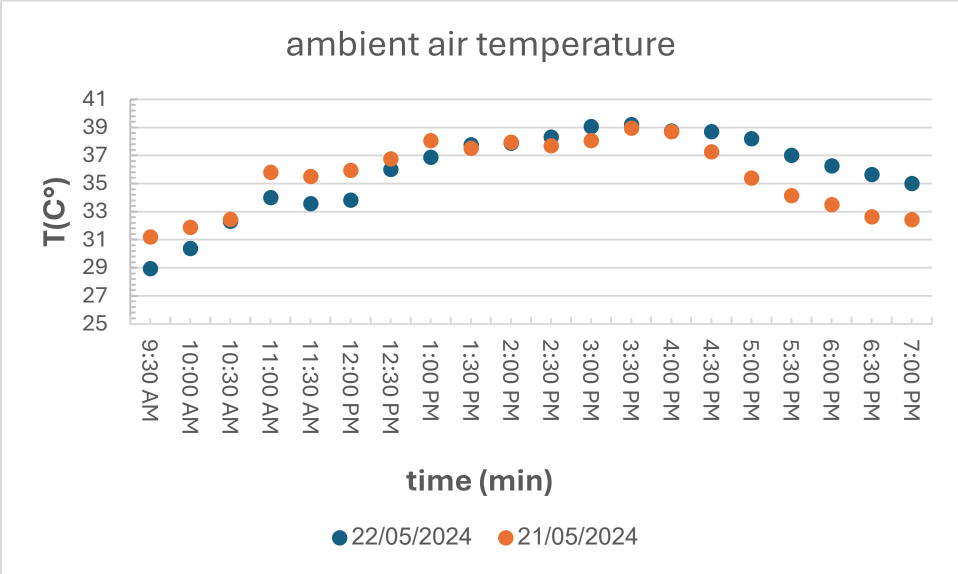


Figure (IV -2): environmental air temperature.

IV.2.1.2 variation of the ambient air

In Figure (IV-3), the graph illustrates how the ambient air evolved over the course of the experiment. It is interesting to note that the speed of the ambient air influences the entry of the dryer, thereby regulating the heat exchange between the solar collector and the air. On the first day, the wind speed was lower compared to the subsequent day. The maximum wind speed recorded on the first day was 3.18 m/s, while the minimum was 1.84 m/s. On the second day, the maximum wind speed reached 4.13 m/s, and the minimum was 2.33 m/s.

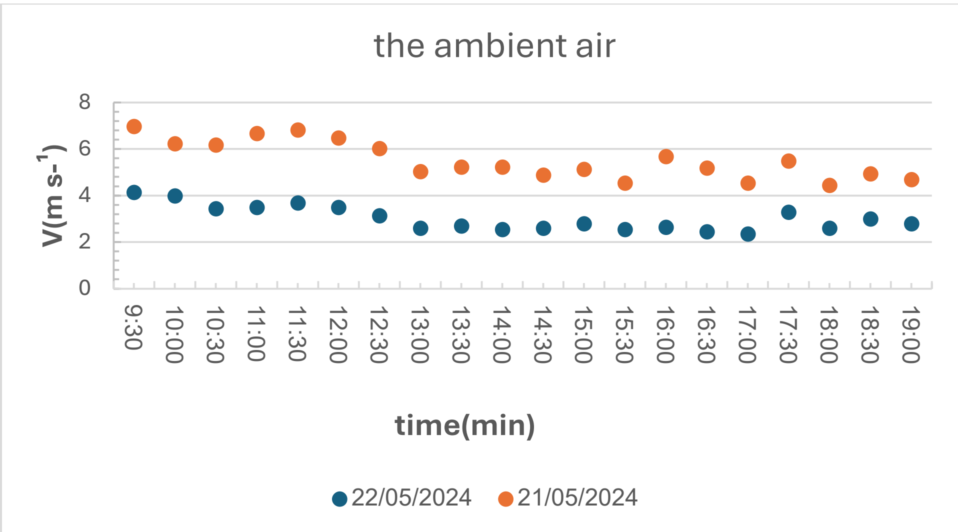


Figure (IV- 3): variation of the ambient air for the experiment days.

IV.2.2Variation in solar collector outlet temperature:

We observed that the maximum temperature at the sensor input was 38.19°C for both sensors. In Figure (IV-4), the graph illustrates the variation in air temperatures at the output of both solar collectors. It is evident that the output temperatures of the mixed collector generally have higher values than the side-by-side collector. Between 09:30 and 14:00,

the output temperature increases in both collectors with the increase of solar radiation. The temperature of the outputs reaches maximum values and then begins to decrease around 16:00.

- On the first day

the maximum air temperature at the sensor outlet for the mixed collector was 52.38°C at 14:00.

For the side-by-side collector, the air temperature at the outlet sensor reached a maximum of 48.69°C at 13:30.

- On the second day

the maximum air temperature at the outlet sensor for the mixed collector was 51.06°C at 14:00.

For the side-by-side collector, the air temperature at the sensor outlet reached a maximum of 49.69°C at 13:30.

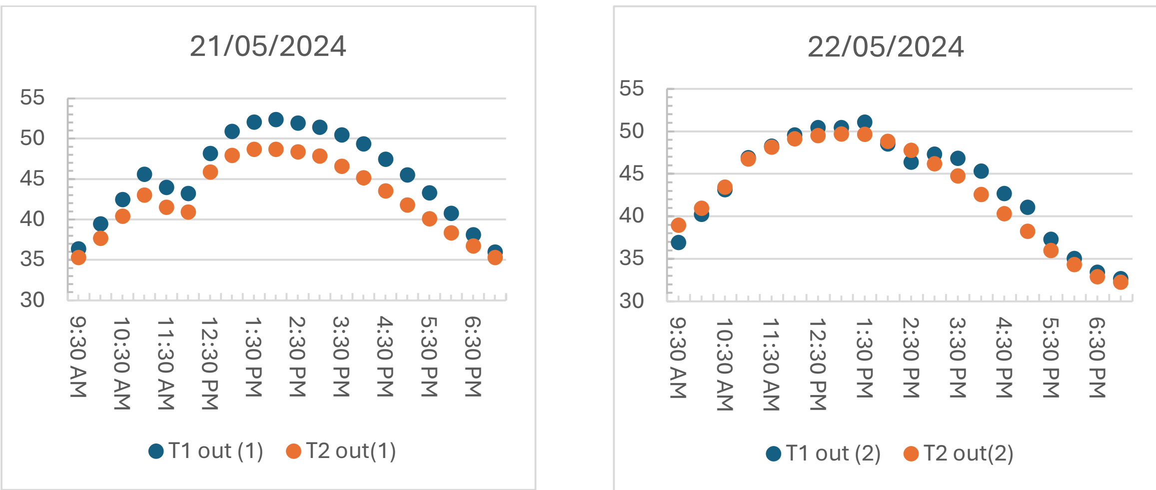


Figure (IV- 4): variation of the output temperature of the two collectors.

IV.2.3 Variation in solar collector maximum temperature

In Figure (IV-5), the graph illustrates the variation in maximum temperature of solar collectors. The mixed collector typically reaches higher temperatures compared to the other collector. However, the side-by-side collector has been shown to achieve higher temperatures in cases of low solar radiation.

- First day:

- For the mixed collector, the maximum temperature was 67.44°C at 13:30.

- For the side-by-side collector, the maximum temperature was 60.63°C at 14:00.

Second day:

- For the mixed collector, the maximum temperature was 67.12°C at 13:30.

- For the side-by-side collector, the maximum temperature was 63.13°C at 14:00

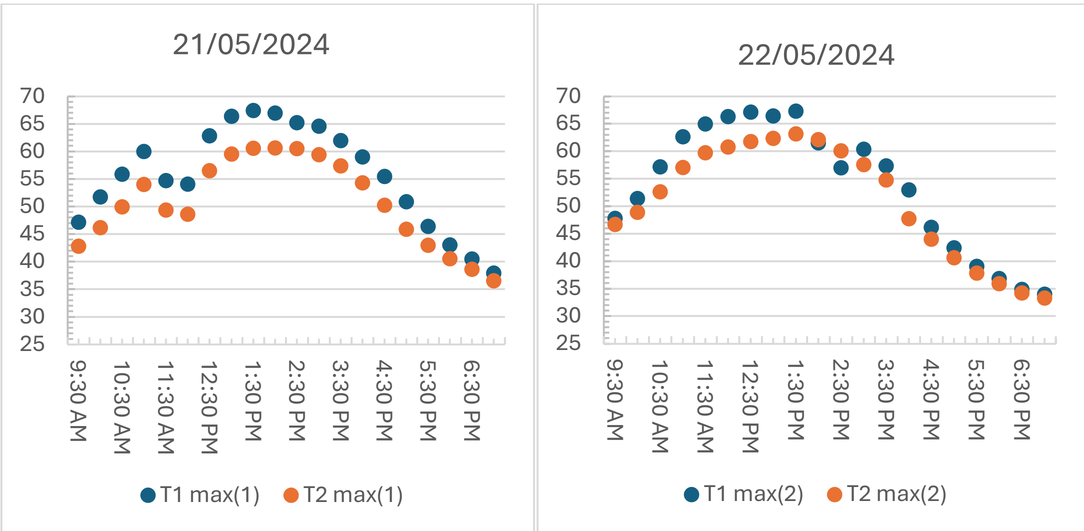


Figure (IV- 5): variation of the maximum temperature of the solar collectors.

IV.2.4 Variation of airflow between the inlet and the outlet of the drying system

Figure (IV-6) illustrates the airspeed variation at the outlet of two collectors. In this study, we tested the airspeed variation at the outlet of both collectors while keeping the inlets fixed, in order to analyze the relationship between temperature and airspeed variation. Consistently throughout the day, both collectors demonstrated similar patterns, with closely aligned values.

This suggests a strong relationship between temperature variation and airspeed variation.

- On the first day

the maximum airspeed at the outlet of the first collector was 17 m/s at 11:00, while for the side-by-side collector, the maximum airspeed was 16 m/s.

- On the second day

the maximum airspeed at the outlet of the first collector was again 17 m/s at 11:00, and for the side-by-side collector, it was 16 m/s. The airspeed at the mixed collector output is often higher than the two individual outputs. This phenomenon occurs as a result of air particles expanding when they absorb energy.

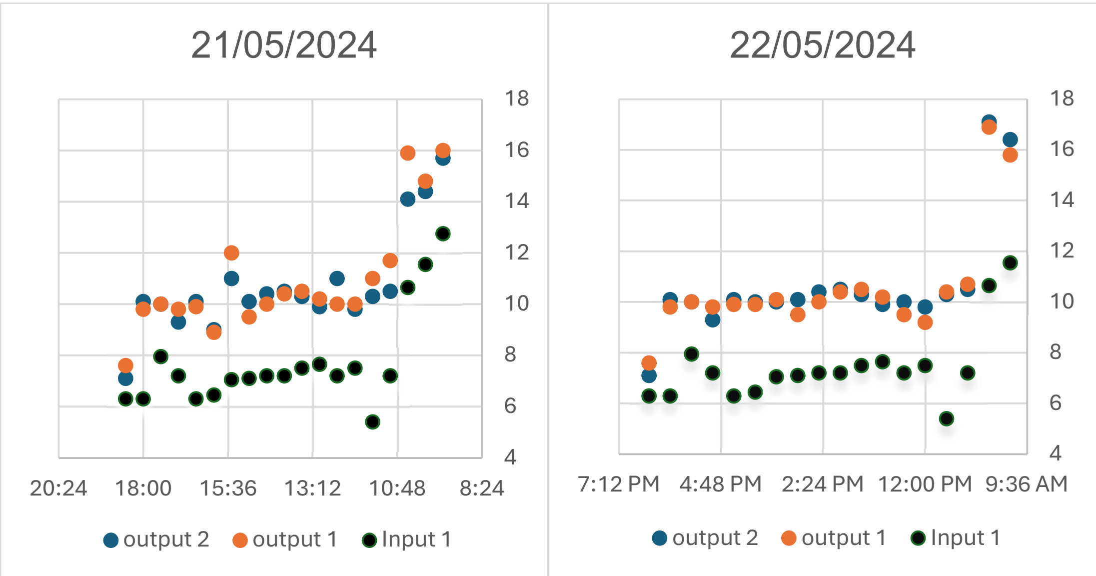


Figure (IV-6): the airspeed variation at the outlet of two collectors.

IV.3 The thermal storage capacity

Throughout the experiment days, the solar collector was exposed to solar radiation from 9:30 to 17:40. After that, we measured the air temperatures at various points within the drying system to study the thermal storage capacity of the two collectors.

IV.3.1 The variation of the outlet temperatures

The variation of the outlet temperatures for the two collectors after the absence of the solar radiation is demonstrated in Figure (IV-7)

- On the first day

for the mixed collector air temperature at the sensor outlet started 41.25 C° at 17:40 and decreased swiftly to 32.6 C° at 19:25 Which is the ambient air temperature.

for the side-by-side collector air temperature at the sensor outlet started 38.44 C° at 17:40 and decreased Slowly to 32.6 C° at 19:25 Which is the ambient air temperature.

- On the second day

for the mixed collector air temperature at the sensor outlet started 42.56 C° at 17:40 and decreased swiftly to 36 C° at 19:06 Which is the ambient air temperature.

for the side-by-side collector air temperature at the sensor outlet started 39.5 C° at 17:40 and decreased Slowly to 36 C° at 19:06 Which is the ambient air temperature.

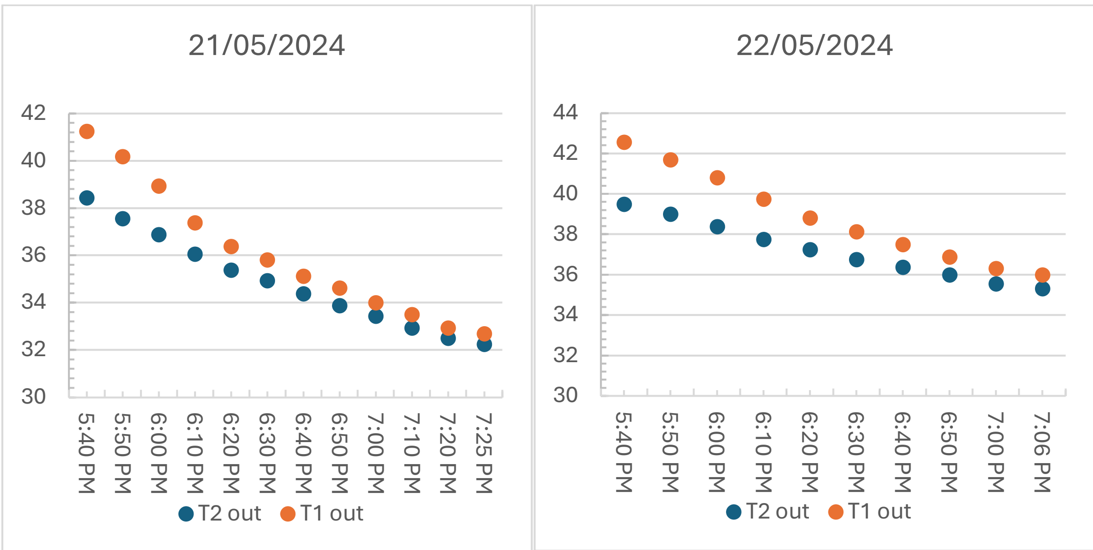


Figure (IV-7): The variation in the outlet temperatures.

IV.3.2 The variation of the temperatures for the first point of the collectors

The variation of the air temperatures for the first point of the two collectors after the absence of solar radiation is demonstrated in Figure (IV8)

- On the first day

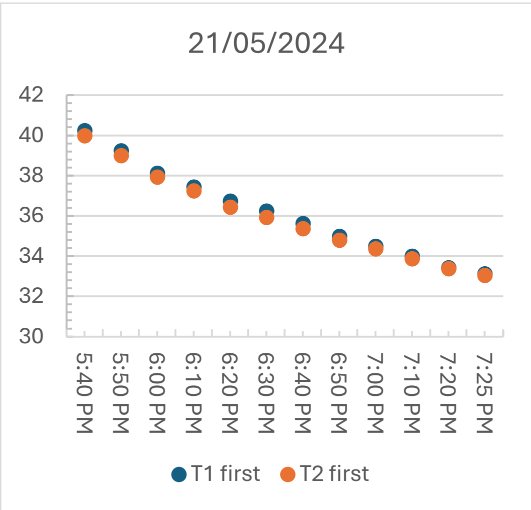
for the mixed collector air temperature for the first point started at 41 C° at 17:40 and decreased swiftly to 33.06 C° at 19:25 Which is the ambient air temperature.

for the side-by-side collector air temperature for the first point started at 40 C° at 17:40 and decreased Slowly to 33.06 C° at 19:25 Which is the ambient air temperature.

- On the second day

for the mixed collector air temperature for the first point started at 43.36 C° at 17:40 and decreased swiftly to 36 C° at 19:06 Which is the ambient air temperature.

for the side-by-side collector air temperature for the first point started at 41.85 C° at 17:40 and decreased Slowly to 36 C° at 19:06 Which is the ambient air temperature.



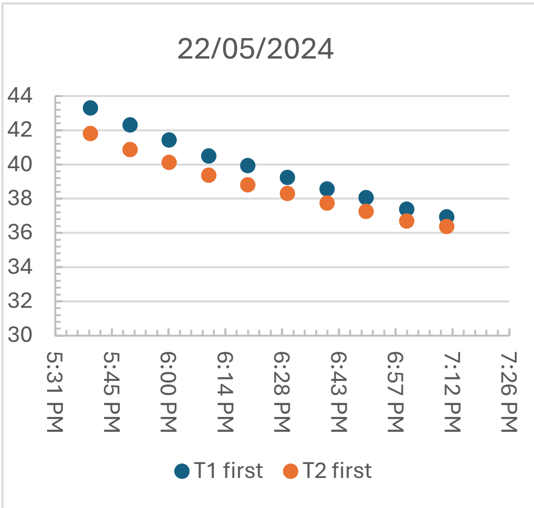


Figure (IV-8): The variation of the temperatures for the first point of the collectors.

IV.3.3 The variation of the air temperatures for the second point of the collectors

The variation of the air temperatures for the first point of the two collectors after the absence of solar radiation is demonstrated in Figure (IV9)

- On the first day

for the mixed collector air temperature for the second point started at 40.69 C° at 17:40 and decreased swiftly to 33.06 C° at 19:25 Which is the ambient air temperature.

for the side-by-side collector air temperature for the second point started at 42.5 C° at 17:40 and decreased Slowly to 33.06 C° at 19:25 Which is the ambient air temperature.

- On the second day

for the mixed collector air temperature for the second point started at 45 C° at 17:40 and decreased swiftly to 36 C° at 19:06 Which is the ambient air temperature.

for the side-by-side collector air temperature for the second point started at 42.13 C° at 17:40 and decreased Slowly to 36 C° at 19:06 Which is the ambient air temperature.

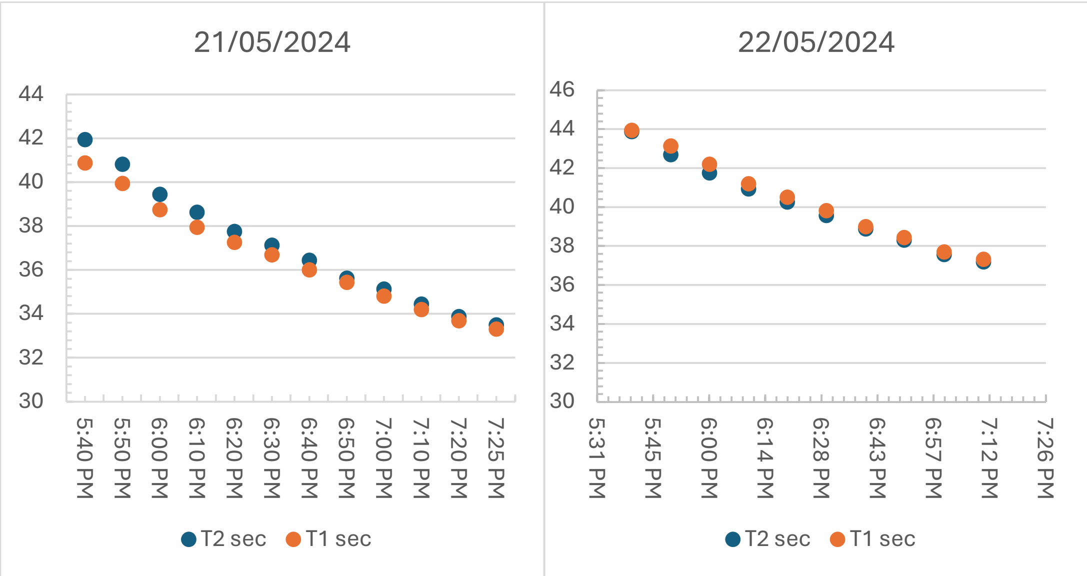


Figure (IV-9): The air temperatures for the second point of the collectors.

IV.3.4 The variation of the maximum air temperatures for the of the collectors

The variation of the maximum air temperature for the two collectors after the absence of solar radiation is demonstrated in Figure (IV10)

- On the first day

for the mixed collector, the maximum air temperature started at 40.88 C° at 17:40 and decreased swiftly to 33.06 C° at 19:25 Which is the ambient air temperature.

for the side-by-side collector, the maximum air temperature started at 40 C° at 17:40 and decreased Slowly to 33.06 C° at 19:25 Which is the ambient air temperature.

- On the second day

for the mixed collector maximum air temperature started at 43.94 C° at 17:40 and decreased swiftly to 36 C° at 19:06 Which is the ambient air temperature.

for the side-by-side collector air the maximum temperature started at 43.94 C° at 17:40 and decreased Slowly to 36 C° at 19:06 Which is the ambient air temperature.

Based on our analysis of the results, we have concluded that the first collector (mixture) has a higher heat exchange capacity. On the other hand, the second collector has proven to be more effective in low solar radiation cases. Additionally, it is more capable of thermal energy storage.

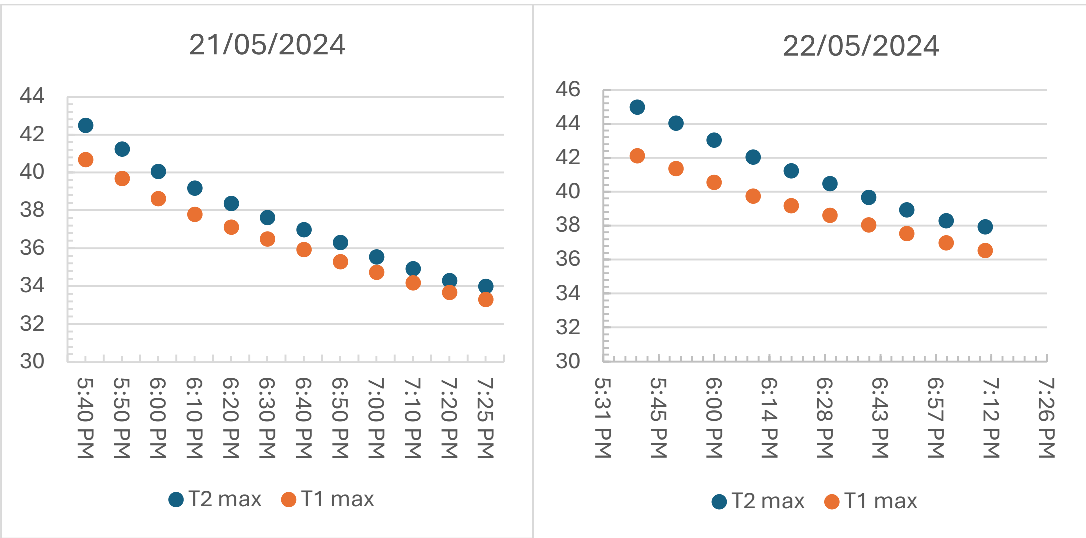


Figure (IV-10): The variation of the maximum air temperatures for the of the collectors.

IV.4 Conclusion

In this chapter, we presented and analyzed the experimental results obtained from testing our designed solar dryer on May 21st and 22nd, 2024. The focus was on examining the thermal performance of two types of solar collectors—the mixture collector and the side-by-side collector—under the climatic conditions of the El Oued area.

Our findings indicate that both collectors have distinct advantages depending on the specific drying requirements. The mixture collector, characterized by its homogeneous combination of salt and aluminum filings, demonstrated higher temperatures during periods of intense solar radiation. This makes it particularly effective for short-time drying of crops like legumes that benefit from rapid, high-temperature exposure.

Conversely, the side-by-side collector, with its alternating lanes of salt and aluminum filings, showed superior performance in terms of thermal storage capacity and efficiency during periods of lower solar radiation. This makes it more suitable for drying crops that require longer exposure to heat at relatively lower temperatures, such as oilseeds. Its effectiveness in low solar radiation conditions also suggests it could be advantageous during winter months.

Overall, these results highlight the versatility of the solar dryer design, which can be adapted to optimize drying efficiency for different crop types and environmental conditions. Future work should focus on validating these findings across a wider range of conditions and exploring potential improvements in the design and materials used to further enhance the performance of solar drying systems.

By understanding the specific strengths of each collector design, we can better tailor solar drying systems to meet diverse agricultural needs, thereby enhancing the sustainability and efficiency of crop drying processes.

This conclusion synthesizes the key findings and implications of Chapter IV, providing a clear summary and direction for future research and application.

GENERAL CONCLUSION

GENERAL CONCLUSION

This study conducted a detailed comparative analysis of two solar collectors to evaluate their efficiency in solar drying applications. Both collectors were constructed using identical materials salt and aluminum filings—but differed in their configurations. The first collector featured a homogeneous mixture of these materials, while the second employed a side-by-side arrangement with 8 cm lanes.

Key findings from the study, supported by precise measurements, indicate the following:

1. Homogeneous Mixture Collector:

-Temperature Performance: This collector exhibited higher temperatures during periods of intense solar radiation. For instance, on the second day, the maximum temperature reached 45°C at 17:40, decreasing swiftly to 36°C by 19:06.

- Suitability: It is suitable for short-term drying processes, particularly effective for crops like legumes that require quick drying due to its ability to achieve high temperatures rapidly.

- Thermal Storage: This collector has limited thermal storage capacity, making it less effective during periods of low solar radiation.

2. Side-by-Side Collector:

- Temperature Performance: Although this collector showed lower temperatures overall, it maintained higher temperatures during low solar radiation periods. On the second day, its temperature started at 42.13°C at 17:40 and decreased slowly to 36°C by 19:06.

- Suitability: This configuration is better suited for longer drying times and for use during winter or periods of low solar radiation. It is particularly effective for crops like oilseeds that require consistent, lower-temperature drying over extended periods.

- Thermal Storage: Its higher thermal storage capacity enhances its effectiveness in maintaining higher temperatures when solar radiation is low.

Environmental Conditions and Variations

The study also monitored climatic conditions, noting that solar radiation reached a peak value of 1534 W/m² at noon, and the maximum environmental air temperature recorded was 39°C at 15:30 on the first day. These conditions significantly influenced the performance of both collectors.

Conclusion

The results underscore the importance of considering specific environmental conditions and drying requirements when selecting a solar drying system. The homogeneous mixture collector is ideal for short-term drying during high solar radiation periods, while the side-by-side collector is more effective for longer drying periods and during low solar radiation.

These conclusions are based on the experimental setup, including sensor orientations, tilt angles, and local environmental factors, which may affect the results under different conditions. Further research is recommended to validate these findings across diverse contexts and optimize solar drying systems for various agricultural applications.

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