Advancements in Tobacco Drying: The Efficacy of Indirect Smart Solar Dryers for Fruits and Vegetables

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Abstract:

This study explores the use of Indirect Smart Solar Dryers (ISSD) for tobacco drying in Algeria, addressing challenges faced by farmers due to climatic changes and traditional drying methods. The ISSD, an innovative approach combining solar energy and smart technology, aims to enhance drying efficiency and quality while reducing environmental impacts. The dryer features temperature and humidity sensors, UV lamps, and automatic control systems. This study assesses its performance against conventional sun-drying methods, focusing on moisture content reduction and temperature management. Results indicate that ISSD significantly reduces drying time and maintains quality, offering a sustainable and cost-effective solution for tobacco and potentially other agricultural products. The study underscores the potential of integrating clean energy and advanced technology in agricultural practices.

Keywords: Smart indirect solar dryer, Sunlight exposure, Drying source, Solar energy, Drying processes, Green Agriculture.

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1- Introduction:

In Algeria, tobacco growers frequently face crop losses during the post-harvest and storage phases, particularly when handling large volumes. The tobacco is prone to mold and fungal infestations.

To counteract this, numerous farmers opt for sun-drying, a straightforward technique. However, this method can result in environmental contamination, as dust and nanoparticles become airborne. Additionally, it exposes the crops to insects, rodents, and fungi, and is affected by climate variability due to greenhouse gas emissions and the increasingly unpredictable nature of the seasons.

Solar thermal systems have been shown to be an efficient, cost-effective, and environmentally friendly approach to the preservation of fruits, vegetables, coffee, and other crops in a number of countries[1]. Furthermore, solar drying of agricultural products can improve their overall quality. Notably, solar crop drying and preservation has been practiced for centuries [2,3]. Umogbai and Iorter (4) compared traditional sun drying and solar drying for corn cobs. The results indicate that solar drying generates higher temperatures, lower relative humidity, and reduced product moisture content, leading to less spoilage during the drying process compared to sun drying [3].

Garg and Prakash (2016) defined drying as dehydrating food to reduce its moisture content, which increases shelf life by preventing bacterial growth. Moisture reduction is crucial since moisture triggers diseases, decay, and degradation. Thus, drying is essential in preserving grain quality. Drying under direct sunlight is cost effective, but there is a risk of lower quality products due to the presence of contaminants such as rain, pets, birds, dust, and insects. In addition, vitamins and nutrients are lost and unacceptable color changes occur in agricultural products due to exposure to ultraviolet rays from sunlight during traditional drying [4-7].

There are a number of different methods used to dry tobacco, but one of the most important techniques is the indirect heat curing process, also known as flue-cured tobacco[8].

The leaves are hung in a barn. The barn is equipped with heat-conducting pipes or channels that maintain a temperature of about 75°C. This method allows the tobacco leaves to dry quickly (between 4 to 5 days) and give them the characteristic golden yellow color of cigarette tobacco. high sugar content and low to moderate nicotine levels.

Algeria's tobacco production is estimated at 86,340 quintals per year, but most of the production is through farmers rely on traditional drying methods, which involve drying the crop in the shade of trees or in weed-covered houses during the summer season, a process that typically takes between 15 and 17 days before farmers can move on to packaging. However, recent irregular rainfall patterns caused by climate change have become a major problem for farmers. However, recent climatic changes can disrupt traditional tobacco drying methods by increasing temperatures, causing rapid drying, exacerbating droughts, causing unpredictable weather patterns, increasing pests and diseases, and causing longer drying periods. These changes can lead to quality loss and reduced market value, as tobacco leaves become brittle and prone to breakage. Additionally, longer drying periods can increase labor and energy costs, affecting profitability. Quality loss can also result from inconsistent drying, reducing overall tobacco leaf quality. To mitigate these effects, tobacco growers may need to adapt drying methods, invest in better infrastructure, and explore alternative drying technologies.

In order to counteract these negative effects, tobacco growers may need to modify their curing methods, improve their infrastructure, and consider alternative curing techniques that are better able to withstand the changing climatic conditions.

For this reason, a team of students from the Institute of Science and Technology at the Abdel-Hafid Boussouf Mila University Center undertook the design and testing of an intelligent indirect solar dryer (SISD) as a final project.

The SISD is an upgrade to conventional dryers. It includes temperature and humidity sensors. It also includes fans to stabilize the temperature of the drying room and insulation of the room walls for controlled drying. We have integrated a tray holder with a weight sensor to determine the dryness of the crop. The device connects to a phone sim card to notify the farmer when the crop is drying out. It alerts the farmer in case of crop dehydration to enable timely removal. Technical abbreviations will be explained at first use.

The sides of the dryer consist of plywood and are coated with silver paint. The inner drying tray is composed of wire mesh. The language is objective, formal, and value-neutral, utilizing precise vocabulary with conventional structure. The heating chamber consisted of the upper part of the collector, which was made of a 5 mm thick layer of colorless glass measuring 60 cm x 40 cm, and served as the cover of the dish.

2- Drying technology in tobacco field:

Tobacco is a genus of plant in the family and order of Solanaceae, also known as nicotiana (scientific name: Nicotiana).

Harvesting of the tobacco leaves is done in piles, from the bottom to the top of the shrub, when the tobacco is ripe. About 40-45 days after planting, when the flower buds appear, the first layer can be harvested. The next layer can be picked at the same time, and so on. Each bush typically has 4-8 layers that are harvested consecutively. To obtain sufficient nicotine, select only leaves at the technical maturity stage.

The leaves should be harvested in the evening during dry weather conditions, before the dew starts to fall. Separate any parasitic plant parts at any stage of ripening.

2-1-Traditional drying methods

Traditional drying methods are fast and efficient and require limited resources. Air drying is one of the most effective methods for drying leaves. Simply hang the leaves on a strong rope where they do not touch each other. This can be in a sunny spot or in a garage. If the weather is good, the rope can be in an open area with a weight on the end. To speed up the drying process: Cover the leaves with gauze at night to collect dew. In the same way, the leaves can be placed in a single layer on a window sill. To ensure even drying, turn the leaves periodically. Depending on the temperature and humidity, the drying process usually takes 12-30 days **[8]**.

2-2-Industrial Drying:

When using an electric or tobacco dryer to dry the sheets in a single layer, complete yellowing of the sheet is not expected with artificial drying. Once the leaf has yellowed by one-third, it is ready to be dried. When using an electric or tobacco dryer to dry sheets in a single layer, complete yellowing of the sheet is not expected with artificial drying. A gradual temperature increase from 33 to 70°C over a period of 5 to 7 days is the optimum temperature range for curing tobacco. The desired temperature can be set and maintained until the desired result is achieved after the tobacco is placed in a special dryer. A thermostatically controlled air blower is required to cure tobacco with an electric dryer. The temperature control needs to be increased by 10°C per day for 5 days in order to maintain the required temperature range. Oven curing This process is similar to the tobacco industry fire curing used to darken strong tobacco blends. It is not necessary to preheat the oven prior to curing. The temperature should be no lower than 80-90 degrees Fahrenheit. The oven door should be left open. Place leaves on the top rack so they do not burn. Tobacco curing time varies by oven design, typically 8-10 hours for soft tobacco and 15-20 hours for hard tobacco. To determine the readiness of your Sushina cured tobacco, we look for leaves that are light or dark brown in color and crumbly when rubbed. The veins on these leaves are fragile and break easily without bending. The smell of tobacco is the most reliable indicator of maturity. Dry leaves with black dots or completely black leaves will have an unpleasant smell, burning and stinging.

3- Types of Solar Drying System:

Direct solar drying involves directly exposing products to solar radiation, using a greenhouse effect. This is simple and easy to carry out. Indirect solar drying, on the other hand, uses convection between heated air and the products to protect them from UV rays.

3-1. Direct solar drying: Solar thermal is a solar energy technology that converts solar radiation into heat through the use of solar collectors. Spectrally selective surfaces can increase the efficiency of solar panels. For objectivity and clarity, technical terms and a passive tone are used, citations and footnotes are used where appropriate, and consistency of style is retained. The generated heat can be used in solar water heater, solar cooker, solar dryer, solar distiller, solar pasteurizer and solar poultry incubator[9]. Solar dryers are mechanized methods that use radiation to dry crops rather than relying on traditional open-air methods. Grains, vegetables, peppers, melons, and root crops are the most common. For rice, poultry waste, and manure, large-scale natural-circulation solar dryers have been developed to increase efficiency and storage time over open-air drying methods[10].

3-2. Indirect solar drying is a method used in tobacco agriculture to dry tobacco leaves using solar energy. It involves a solar dryer, air circulation, and heat transfer. The dryer provides a controlled environment, protecting the tobacco from sunlight and adverse weather conditions. Solar collectors or absorbers capture solar radiation, which is then transferred to the tobacco leaves. This method is considered more efficient and provides better quality results than traditional sun drying. It also reduces contamination risk as tobacco is not directly exposed to the external environment. Indirect solar drying offers farmers a more controlled and sustainable approach to tobacco production Kumar et al. (2016) and Tibebu (2015)[11,12].

4- Construction of the Indirect Smart Solar Dryer (Issd)

4-1. Materials

Materials used in solar dryer construction include:

Plank size

Thermal insulators

5mm tempered glass

Temperature, humidity and gravity sensors

Many fans

UV lamp with timer

Arduino, relays

Sun panels

Lithium batteries

4-2. Description of the Solar Dryer Box

The dryer is made of wood with a box-like drying chamber with the top cover plate made of tempered glass of 5mm. The components of the Dryer are as follows.

The Indirect Smart Solar Dryer (ISSD) is a device that is designed to efficiently dry a variety of agricultural products while preserving their quality and nutritional value. This technology uses solar energy to heat air in the heating chamber, then creates a controlled drying environment by generating hot airflow through fans that transport heated air into the drying chamber. Indirect solar dryer technical aspects are divided into three sections.

4-2-1. Electrical Energy Production and Storage Section: The section responsible for producing and storing electrical energy with the help of solar panels with a maximum capacity of 1.2 kilowatts. Batteries with high capacity and low current are selected to power the 48 volt circuit.

4-2-2. The Solar Collector: This is the section that captures the solar energy and directs it to the drying chamber. The air that passes through the collector will be heated up. The collector is made up of a heat-resistant transparent glass cover plate, an absorber plate and an insulator with a thickness of between 5 and 10 mm for the cover plate. With a length of 60 cm and a width of 40 cm in width, it catches solar energy and traps it from escaping. The absorber plate is positioned 5 cm higher than the absorber plate and collects the solar radiation. The 60cm x 40cm black painted zinc sheet that makes up the absorber plate, is placed under the glass cover plate, where it absorbs the incoming solar radiation and heats the air that is circulating between the two plates. This heated air is then transported between the heating chamber and the drying chamber in a heat exchanger activated by regulated fans. The air passes through the dryer and comes into contact with the goods to be dried.

4-2-3. The drying chamber: The drying chamber is made of thermally insulated walls, and has an infrared lamp to kill microbes and bacteria harmful to crops, where the products are arranged in uniform layers for drying.

There are two openings between the heating chamber and the drying chamber so that we allow air to circulate between them, and we control it using sensors to sense the temperature. When the temperature drops, we allow the air to circulate, and when it rises, we stop it from circulating.

The third opening is under the drying chamber. It has a fan to bring in cool air in case the temperature rises, thus creating a suitable climate for even-temperature drying.

The fourth vent is in the ceiling of the drying room and has a fan controlled by a humidity sensor. When the humidity level rises, it starts working.

The drying tray is also equipped with a weight sensor to determine the level of doneness of our products.

4-2-4. Automatic control: Modern indirect solar dryers are equipped with advanced automatic control systems. These systems monitor temperature, humidity and drying parameters in real time. It automatically adjusts the air flow for heating or cooling, controls the degree of humidity and the time required for ultraviolet irradiation, and makes us aware of the degree of dryness of the product. We also provide the system with a GSM chip to inform us of information about the drying room in real time, and it can be connected to the Internet and software for that. We have prepared the SISD for the Internet of Things.

5. Evaluation of the Indirect Smart Solar Dryer (ISSD)

Evaluation of the dryer was centered on the moisture content reduction and temperature variations. The performance of the developed dryer was compared with sun-drying, which is the popular method of drying employed by maize farmers in Nigeria. We used 5kg of fresh maize cobs for the evaluation.

5-1. Temperature and humidity:

Temperature was measured for the drying chamber and ambient air, while moisture content (MC) was measured at the beginning and end of each drying day using the oven drying method using the DHT22 Temperature and Humidity Sensor, the oven drying method and calculated using the model (Forson et al., 2007) below[13].

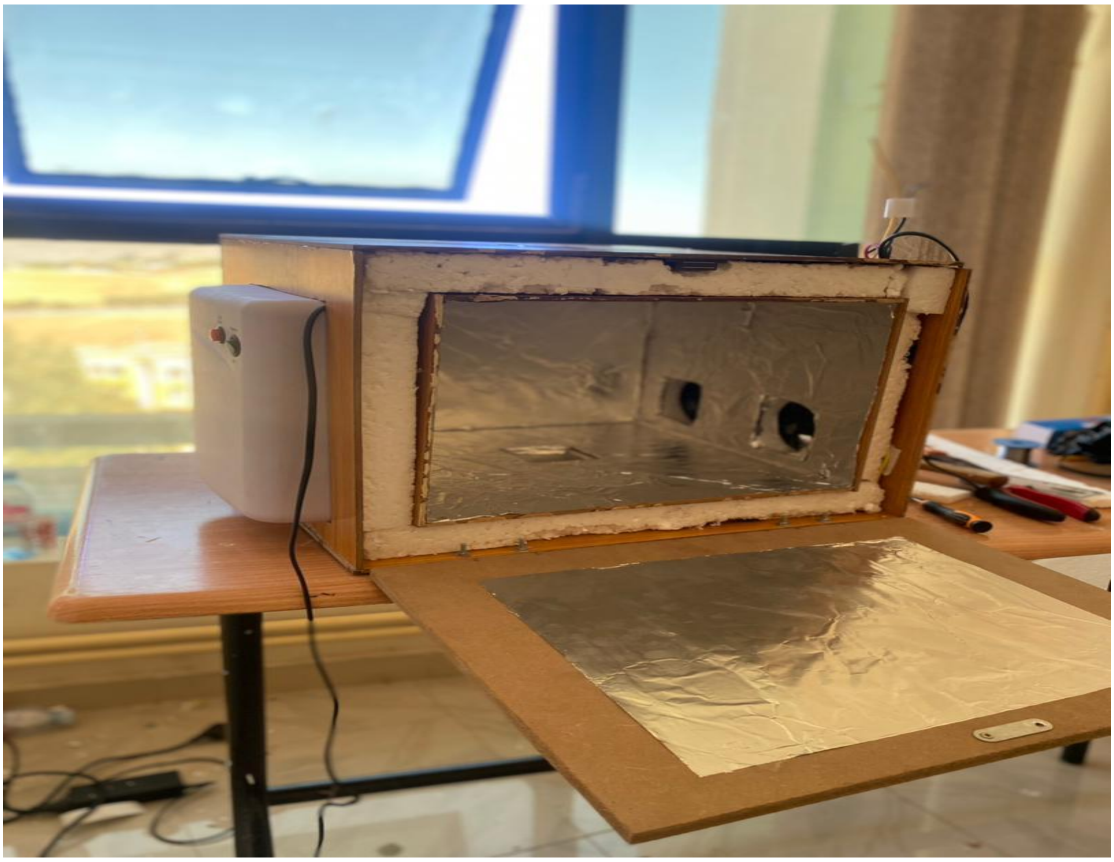

Fig 1: The drying chamber of Indirect Smart Solar Dryer (ISSD) in the laboratory

5-2. Operational evaluation of the dryer (SISD)

The temperature of the solar collector, the drying chamber, and the outdoor environment were measured using a DHT22 sensor. The DHT22 is a device that measures temperature and humidity with a refresh rate of 0.5-2 seconds, an accuracy of ±0.5°C and ±2.5%, and a temperature range of -40°C to 80°C. Abbreviations of technical terms will be explained at first use. This digital thermal sensor, with an accuracy of ±0.5°C and ±2.5%, provides continuous temperature updates to the ECU.

6-Discussions of results

In order to evaluate the performance of the solar dryer, freshly harvested tobacco leaves with a moisture content of 145 grams were used. The results show that it took 5 days to dry variegated tobacco leaves down to a moisture content of 55.7 g, while it took 8 days to dry variegated tobacco leaves down to a moisture content of 25 g. The temperature changes over time from the solar collector to the drying chamber are shown in the table below. The temperature variation from the solar collector to the drying room is shown in the following table. The study recorded the time from 7:00 a.m. to 6:00 p.m., during the period after sunrise and before sunset, with the ambient temperature measured in degrees. The results are shown in Table 2.

Table 1: Variations of temperature with time

Time (hours)	Ambient (^{0}C)	solar collector (^{0}C)	drying chamber (^{0}C)
7 am	24.5	40.0	38.5
8 am	26.3	42.5	40.0
9am	30.5	45.8	41.5
10am	32.5	47.5	42.5
11 am	35.2	50.8	45.8
12 noon	36.5	52.8	50.5
1pm	37.7	55.7	50.5
2pm	38.5	58.5	55.3
3pm	37.9	60.4	58.5
4pm	38.0	62.0	60.5
5pm	37.7	60.7	62.4
6pm	36.4	58.8	60.5
4 pm	36.9	55.2	58.5
5 pm	35.8	49.7	55.5
6pm	33.5	40.8	47.5

Table 1 shows the temperature changes for a single day that are like the following 12 days of the test:

6-1. Ambient temperature:

- Displays a general increase from 7am (24.5 °C) to a peak at 2pm (38.5 °C).

- After 14:00 there is a gradual decrease, reaching 33.5°C at 18:00.

6-2. Solar collector temperature:

- This temperature increases steadily from 40.0°C at 7am to a peak of 62°C at 4pm.

- After 16:00 the temperature drops to 40.8 °C at 18:00.

6-3. Drying chamber temperature:

- The temperature in the drying chamber also increases throughout the day, starting at 38.5°C at 7am and reaching a peak of 62.4°C at 5pm.

- Similar to the solar collector, there is a decrease after 17 o'clock, with the temperature dropping to 47.5°C by 18 o'clock.

- Consistent with the sun's intensity and position, all three locations show a general increase in temperature from morning to afternoon.

- Indicating its efficiency in harnessing solar energy, the solar collector consistently shows the highest temperatures throughout the day.

- The drying chamber temperature trends closely follow those of the solar collector. This suggests a direct influence due to the connection.

The data suggest a strong correlation between time of day, solar intensity, and temperatures in the solar collector and kiln.

The change in weight of the tobacco leaves from day to day is an indication of the change in moisture content. At the end of the first day's drying around 6:00 p.m., the moisture content in the solar dryer decreased from 145 g to 105 g and continued to decrease as shown in Table 2.

Moisture Content (%)		
drying chamber		
Days	@ 6.00 am (Unit “g”)	@ 7.00 pm (Unit “g”)
1	145	130
2	125	115
3	110	105
4	103	98
5	95	87
6	80	79
7	75	60
8	55	45
9	45	41
10	40	36
11	35	25
12	25	23

Table 2: Moisture vs Time for Drying Days

The table shows the drying process of tobacco in a smart indirect solar dryer, revealing the decreasing moisture content and weight over 12 days. The daily progress shows an efficient drying process, reaching optimal drying by day 12 with a moisture content of 25% and a weight of 23 grams. The table also shows weight loss during drying, with morning weight consistently higher than night weight. The use of solar energy in the drying process is evident, demonstrating the effectiveness of the drying system. Day 7 Anomaly: There is a noticeable decrease in both moisture and weight between days 6 and 7, especially at 19:00. This may reflect special conditions or settings in the drying process.

Weight loss: The table indirectly shows the weight loss of the tobacco during drying, as the morning weight is consistently higher than the night weight.

7-Conclusions

The study evaluated the performance of a solar dryer using freshly harvested tobacco leaves with a moisture content of 145 grams. The results showed that it took 5 days to dry variegated tobacco leaves down to a moisture content of 55.7 g, while it took 8 days to dry them down to a moisture content of 25 g. The temperature changes over time from the solar collector to the drying chamber were recorded, with the study recording the time from 7:00 a.m. to 6:00 p.m., during the period after sunrise and before sunset. The data suggest a strong correlation between time of day, solar intensity, and temperatures in the solar collector and kiln. The change in weight of the tobacco leaves from day to day is an indication of the change in moisture content. The daily progress shows an efficient drying process, reaching optimal drying by day 12 with a moisture content of 25% and a weight of 23 grams. The use of solar energy in the drying process is evident, demonstrating the effectiveness of the drying system.

In particular, the results obtained herald that we can reduce the drying time and save time and money, knowing that the Indirect Smart Solar Dryer (ISSD) depends on clean energy and the Internet can be used to control its various settings and closely monitor the crop. Other crops and vegetables such as figs, tomatoes and others can also be dried using the dryer. From vegetables, to fruits, and even fish.

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