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SOLAR DRYER

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1.INTRODUCTION

Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years.

Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting. Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications requiring low to moderate temperature below 80°C, such as crop drying and space heating

Drying is the oldest preservation technique of agricultural products and it is an energy intensive process. High prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources. Drying of agricultural products using renewable energy such as solar energy is environmental friendly and has less environmental impact.

Different types of solar dryers have been designed, developed and tested in the different regions of the tropics and subtropics. The major two categories of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers the airflow is established by buoyancy induced airflow while in forced convection solar dryers the airflow is provided by using fan operated either by electricity/solar module or fossil fuel. Now the solar dryer designed and developed for and used in tropics and subtropics are discussed under two headings.

LITERATURE SURVEY

Crop drying is the most energy consuming process in all processes on the farm. The purpose of drying is to remove moisture from the agricultural produce so that it can be processed safely and stored for increased periods of time. Crops are also dried before storage or, during storage, by forced circulation of air, to prevent spontaneous combustion by inhibiting fermentation. It is estimated that 20% of the world‘s grain production is lost after harvest because of inefficient handling and poor implementation of post-harvest technology, says Hartman‘s (1991). Grains and seeds are normally harvested at a moisture level between 18% and 40% depending on the nature of crop. These must be dried to a level of 7% to 11% depending on application and market need. Once a cereal crop is harvested, it may have to be stored for a period of time before it can be marketed or used as feed. The length of time a cereal can be safely stored will depend on the condition it was harvested and the type of storage facility being utilized. Grains stored at low temperature and moisture contents can be kept in storage for longer period of time before its quality will deteriorate. Some of the cereals which are normally stored include maize, rice, beans.

Solar drying may be classified into direct and indirect solar dryer. In direct solar dryers the air heater contains the grains and solar energy which passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. However, in indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or the roof.

Energy is important for the existence and development of human kind and is a key issue in international politics, the economy, military preparedness, and diplomacy. To reduce the impact of conventional energy sources on the environment, much attention should be paid to the development of new energy and renewable energy resources. Solar energy, which is environment friendly, is renewable and can serve as a sustainable energy source.

Hence, it will certainly become an important part of the future energy structure with the increasingly drying up of the terrestrial fossil fuel. However, the lower energy density and seasonal doing with geographical dependence are the major challenges in identifying suitable applications using solar energy as the heat source. Consequently, exploring high efficiency solar energy concentration technology is necessary and realistic.

Solar energy is free, environmentally clean, and therefore is recognized as one of the most promising alternative energy recourses options. In near future, the large-scale introduction of solar energy systems, directly converting solar radiation into heat, can be looked forward. However, solar energy is intermittent by its nature; there is no sun at night. Its total available value is seasonal and is dependent on the meteorological conditions of the location. Unreliability is the biggest retarding factor for extensive solar energy utilization. Of course, reliability of solar energy can be increased by storing its portion when it is in excess of the load and using the stored energy whenever needed.

Solar drying is a potential decentralized thermal application of solar energy particularly in developing countries. However, so far, there has been very little field penetration of solar drying technology. In the initial phase of dissemination, identification of suitable areas for using solar dryers would be extremely helpful towards their market penetration.

2.2 DRYING OBJECTIVES

The objective of this study is to develop a mixed-mode solar dryer in which the grains are dried simultaneously by both direct radiation through the transparent walls and roof of the cabinet and by the heated air from the solar collector. The problems of low and medium scale processor could be alleviated, if the solar dryer is designed and constructed with the consideration of overcoming the limitations of direct and indirect type of solar dryer. So therefore, this work will be based on the importance of a mixed mode solar dryer which is reliable and economically, design and construct a mixed mode solar dryer using locally available materials and to evaluate the performance of this solar dryer.

2.2 JUSTIFICATION AND OUTCOMES

Food crops are usually for immediate consumption needs, resulting in wastage of food surpluses during the short harvest periods and scarcity during post harvest periods. Drying is one of the methods used to preserve food products for longer periods. It has been established as the most efficient preservation technique for most tropical crops.

This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74% for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

2.4 PROBLEM CONSTRAINTS

Drying processes play an important role in the preservation of agricultural products. They are defined as a process of moisture removal due to simultaneous heat and mass transfer. The purpose of this project is to present the developments and potentials of solar drying technologies for drying grains, fruits, vegetables, spices, medicinal plants.

The traditional method of drying, known as sun drying, involves simply laying the product in the sun on mats, roofs or drying floors. Major disadvantage of this method is contamination of the products by dust, birds and insects – Some percentage will usually be lost or damaged, it is labour intensive, nutrients loss, such as vitamin A and the method totally depends on good weather conditions.

Because the energy requirements - sun and wind - are readily available in the ambient environment, little capital is required. This type of drying is frequently the only commercially used and viable methods in which to dry agricultural products in developing countries. The safer alternative to open sun drying is solar dryer.

This is a more efficient method of drying that produces better quality products, but it also requires initial investments. If drying conditions such as weather and food supply are good, natural circulation solar energy, solar dryers appear to be increasingly attractive as commercial proposition.

DESIGN AND APPROACH

Solar drying refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material.

3.1 DESIGN APPROACH

3.1.1 DRYING MECHANISM

In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process: the migration of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air

The drying of a product is a complex heat and mass transfer process which depends on external variables such as temperature, humidity and velocity of the air stream and internal variables which depend on parameters like surface characteristics (rough or smooth surface), chemical composition (sugars, starches, etc.), physical structure(porosity, density, etc.), and size and shape of products. The rate of moisture movement from the product inside to the air outside differs from one product to another and depends very much on whether the material is hygroscopic or non-hygroscopic. Non-hygroscopic materials can be dried to zero moisture level while the hygroscopic materials like most of the food products will always have residual moisture content. This moisture, in hygroscopic material, may be bound moisture which remained in the material due to closed capillaries or due to surface forces and unbound moisture which remained in the material due to the surface tension of water as shown in Figure 2.1

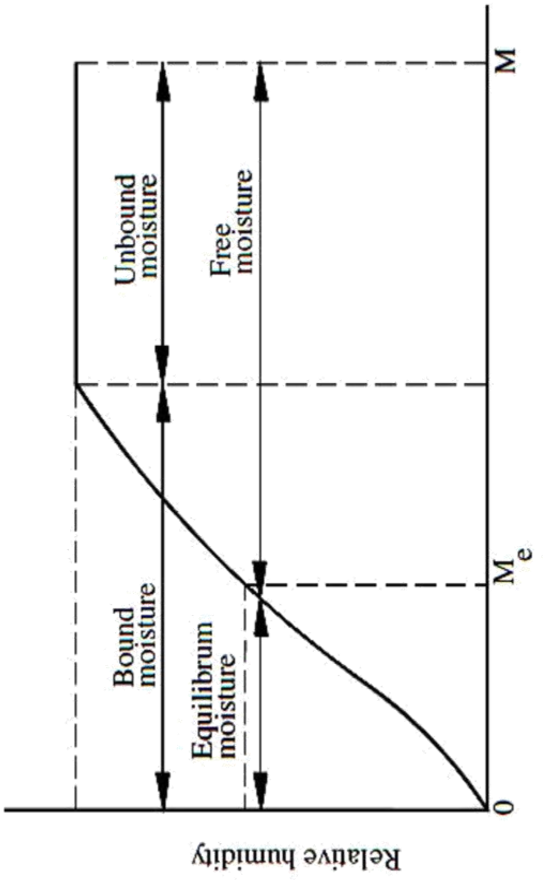

Figure 2.1 Moisture in the drying material.

When the hygroscopic material is exposed to air, it will absorb either moisture or desorbs moisture depending on the relative humidity of the air. The equilibrium moisture content (EMC = Me) will soon reach when the vapour pressure of water in the material becomes equal to the partial pressure of water in the surrounding air. The equilibrium moisture content in drying is therefore important since this is the minimum moisture to which the material can be dried under a given set of drying conditions. A series of drying characteristic curves can be plotted. The best is if the average moisture content M of the material is plotted versus time as shown in Figure 2. 2.

Another curve can be plotted between drying rate i.e. dM/dt versus time t as shown in Figure 2.3. But more information can be obtained if a curve is plotted between drying rate dM/dt versus moisture content M as shown in Figure 2.4.

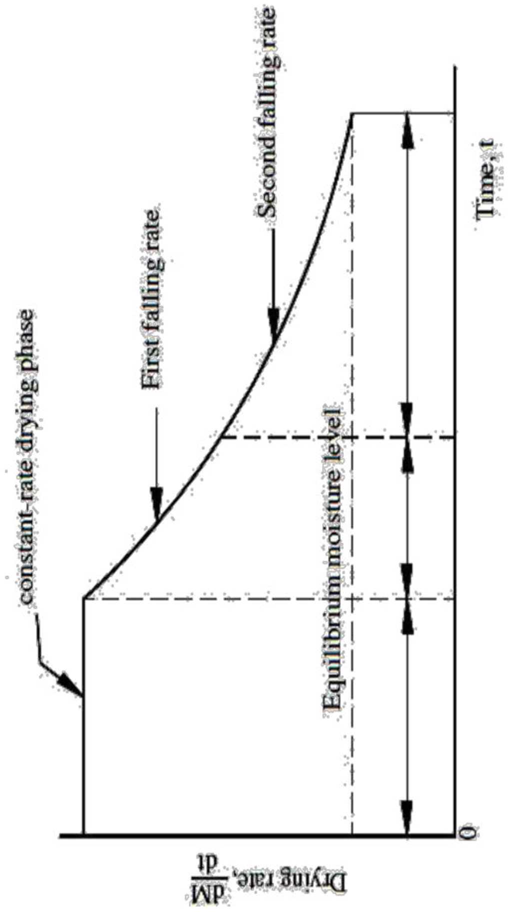

Figure 2.3 Drying rate with time curve

As is seen from Figure 2.4 for both non-hygroscopic and hygroscopic materials, there is a constant drying rate terminating at the critical moisture content followed by falling drying rate. The constant drying rate for both non-hygroscopic and hygroscopic materials is the same while the period of falling rate is little different. For non-hygroscopic materials, in the period of falling rate, the drying rate goes on decreasing till the moisture content become zero. While in the hygroscopic materials, the period of falling rate is similar until the unbound moisture content is completely removed, then the drying rate further decreases and some bound moisture is removed and continues till the vapour pressure of the material becomes equal to the vapour pressure of the drying air. When this equilibrium reaches then the drying rate becomes zero**.**

The period of constant drying for most of the organic materials like fruits, vegetables, timber, etc. is short and it is the falling rate period in which is of more interest and which depends on the rate at which the moisture is removed. In the falling rate regime moisture is migrated by diffusion and in the products with high moisture rate regime moisture is migrated by diffusion and in the products with high moisture As is seen from Figure 2.4 for both non-hygroscopic and hygroscopic materials, there is a constant drying rate terminating at the critical moisture content followed by falling drying rate. The constant drying rate for both non-hygroscopic and hygroscopic materials is the same while the period of falling rate is little different. For non-hygroscopic materials, in the period of falling rate, the drying rate goes on decreasing till the moisture content become zero. While in the hygroscopic materials, the period of falling rate is similar until the unbound moisture content is completely removed, then the drying rate further decreases and some bound moisture is removed and continues till the vapour pressure of the material becomes equal to the vapour pressure of the drying air. When this equilibrium reaches then the drying rate becomes zero.

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3.2 FACTORS ON WHICH THE RATE OF DRYING:

1) Gas Velocity :
When the velocity of gas or air high, the rate of drying will also be high.

2) Humidity Of Gas:
Lesser the relative humidity, the more will be the rate of drying.

3) Area Of Drying Surface:
If the area of the wet surface exposed to the gas or air is more the drying will also be more.

4) Temperature:
If the temperature of the gas is increased its relative humidity decreases. And thus increases a driving force and the rate of drying increases.

3.3Air Properties

The properties of the air flowing around the product are major factors in determining the rate of removal of moisture. The capacity of air to remove moisture is principally dependent upon its initial temperature and humidity; the greater the temperature and lower the humidity the greater the moisture removal capacity of the air. The relationship between temperature, humidity and other thermodynamic properties is represented by the psychometric chart. It is important to appreciate the difference between the absolute humidity and relative humidity of air. The absolute humidity is the moisture content of the air (mass of water per unit mass of air) whereas the relative humidity is the ratio, expressed as a percentage, of the moisture content of the air at a specified temperature to the moisture content of air if it were saturated at that temperature.

3.3 Classifications of Solar Drying System

All drying systems can be classified primarily according to their operating temperature ranges into two main groups of high temperature dryers and low temperature dryers. However; dryers are more commonly classified broadly according to their heating sources into fossil fuel dryers (more commonly known as conventional dryers) and solar-energy dryers. Strictly, all practically-realized designs of high temperature dryers are fossil fuel powered, while the low temperature dryers are either fossil fuel or solar-energy based systems.

1. High temperature dryers

High temperature dryers are necessary when very fast drying is desired. They are usually employed when the products require a short exposure to the drying air. Their operating temperatures are such that, if the drying air remains in contact with the product until equilibrium moisture content is reached, serious over drying will occur. Thus, the products are only dried to the required moisture contents and later cooled. High temperature dryers are usually classified into batch dryers and continuous-flow dryers. In batch dryers, the products are dried in a bin and subsequently moved to storage. Thus, they are usually known as batch-in-bin dryers. Continuous-flow dryers are heated columns through which the product flows under gravity and is exposed to heated air while descending. Because of the temperature ranges prevalent in high temperature dryers, most known designs are electricity or fossil-fuel powered. Only a very few practically-realized designs of high temperature drying systems are solar-energy heated.

2. Low temperature dryers

In low temperature drying systems, the moisture content of the product is usually brought in equilibrium with the drying air by constant ventilation. Thus, they do tolerate intermittent or variable heat input. Low temperature drying enables products to be dried in bulk and is most suited also for long term storage systems. Thus, they are usually known as bulk or storage dryers. Their ability to accommodate intermittent heat input makes low temperature drying most appropriate for solar-energy applications. Thus, some conventional dryers and most practically-realized designs of solar-energy dryers are of the low temperature type.

3.4 Design and Approach

3.4.1 Types of solar dryer

Solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. In broad terms; they can be classified into two major groups, namely.

- Active solar-energy drying systems (most types of which are often termed hybrid solar dryers)
- Passive solar-energy drying systems (conventionally termed natural-circulation solar drying systems).

Three distinct sub-classes of either the active or passive solar drying systems can be identified which vary mainly in the design arrangement of system components and the mode of utilization of the solar heat, namely

- Direct (integral) type solar dryers;
- Indirect (distributed) type solar dryers.

Direct solar dryers have the material to be dried placed in an enclosure, with a transparent cover on it. Heat is generated by absorption of solar radiation on the product itself as well as on the internal surfaces of the drying chamber. In indirect solar dryers, solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then ducted to the drying chamber to dry the product. Specialized dryers are normally designed with a specific product in mind and may include hybrid systems where other forms of energy are also used. Although indirect dryers are less compact when compared to direct solar dryers, they are generally more efficient. Hybrid solar systems allow for faster rate of drying by using other sources of heat energy to supplement solar heat. The three modes of drying are: (i) open sun, (ii) direct and (iii) indirect in the presence of solar energy. The working principle of these modes mainly depends upon the method of solar-energy collection and its conversion to useful thermal energy.

3.4.2 Applications of solar driers

1. The Drying Cabinet:

The drying cabinet together with the structural frame of the dryer was built from well-seasoned woods which could withstand termite and atmospheric attacks. An outlet vent was provided towards the upper end at the back of the cabinet to facilitate and control the convection flow of air through the dryer. Access door to the drying chamber was also provided at the back of the cabinet. The size of the cabinet is (190mmx210mmx210mm). The black color is sprays all side of cabinet to maintain maximum heat within the cabinet of the solar dryer, and also single tray is provided to mount the aluminum sheet.

1. Design and construction of solar dryer

2. Side view of Solar dryer

DESIGN PROCEDURE

4.1 Design Procedure

In many parts of the world there is a growing awareness that renewable energy have an important role to play in extending technology to the farmer in developing countries to increase their productivity. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting.

Solar air heaters are simple devices to heat air by utilizing solar energy and employed in many applications requiring low to moderate temperature below 80oC, such as crop drying and space heating. Drying processes play an important role in the preservation of agricultural products.

They are defined as a process of moisture removal due to simultaneous heat and mass transfer. According to two types of water are present in food items; the chemically bound water and the physically held water. In drying, it is only the physically held water that is removed. The most important reasons for the popularity of dried products are longer shelf-life, product diversity as well as substantial volume reduction. This could be expanded further with improvements in product quality and process applications.

The application of dryers in developing countries can reduce post harvest losses and significantly contribute to the availability of food in these countries. Estimations of these losses are generally cited to be of the order of 40% but they can, under very adverse conditions, be nearly as high as 80%.

APPLICATIONS

Agriculture Products

The solar dryer can be used for agricultural crop drying. Solar dryer can dry value added products for amla, Banana, Potato.

Textile Industries

Our solar dryer is also used in textile industries for fabric drying purpose, to increase quality of fabrics.

Easy operating procedure

One can operate the solar dryer only after getting the knowledge of basic things to be followed while using the dryer. The process is completely an easy one.

Chemical industries

In the chemical industries all the semisolids products and slurry are converted into the powder form.

Pharmaceutical industries

Trey dryer is well suited for small scale products and drying valuable material like dyes and pharmaceuticals it is especially useful for drying wt. lumpy solids and filter cakes which must be spread the over the trays.

And all the other industries such as food industries dairy industries detergent industries dyes industries.

Eco-friendly process

Our solar dryer process is completed in the most hygienic and eco-friendly way. Solar drying machine can use as mostly in food processing industries. Our genuineness ensure complete safety regarding our solar dryer your products will retain in the natural quality and hygiene even after through our solar dryer the major section of the food processing industries deals with drying.

COST ANALYSIS

Sr. no.	Material Required	Quality	Amount (Rs)
1	Wooden Plywood	1 Sheet	1760
2	Glass Sheet	1 Sheet (4mm)	150
3	Fevicol	1Kg	190
4	Oil Paint	250gm	100
5	Black Aluminum	1 Sheet(210x190)mm	150
6	Steel Tray	1 Tray(210x190)mm	500
7	Support Scale	2 Scale (20 feet)	200

8	Screw	250 gm	30
9	Labor Remuneration	1 Person	700
10	Sheet	1Sheet	110
TOTAL			3890/-

RESULT AND ANALYSIS

4.1 RESULT AND DISCUSSION

This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74% for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

4.2 APPENDIX

Table no1: Experiment is performed from 11.00am to 04.00pm in summer season.
Drying of Amla using solar dryer

Time (min)	**Cabinet Sample Reading**	**% moisture removal**	**Atmospheric Sample Reading**	**% moisture removal**
01.10pm	143.71	--	143.71	--
01.10-01.30	123.58	21.05	130.20	17.48
01.35-01.55	103.52	20.98	114.83	19.89
02.00-02.20	90.00	14.14	102.81	15.55
02.25-02.45	77.55	13.82	91.76	14.30
02.48-03.08	68.00	09.99	83.34	10.89
03.11-03.31	60.90	07.42	76.30	09.11
03.34-03.54	55.76	05.37	71.32	06.44
03.58-04.18	51.22	04.74	68.55	03.58
04.22-04.42	48.12	03.24	66.45	02.71
4.45-5.15	48.12	03.24	66.45	02.71

The drying curve for Amla in solar dryer

Fig. 5.2 shows the diurnal variation of the moisture loss % of the ambient air and drying chamber. The drying processes were enhanced by the heated air at very low humidity.

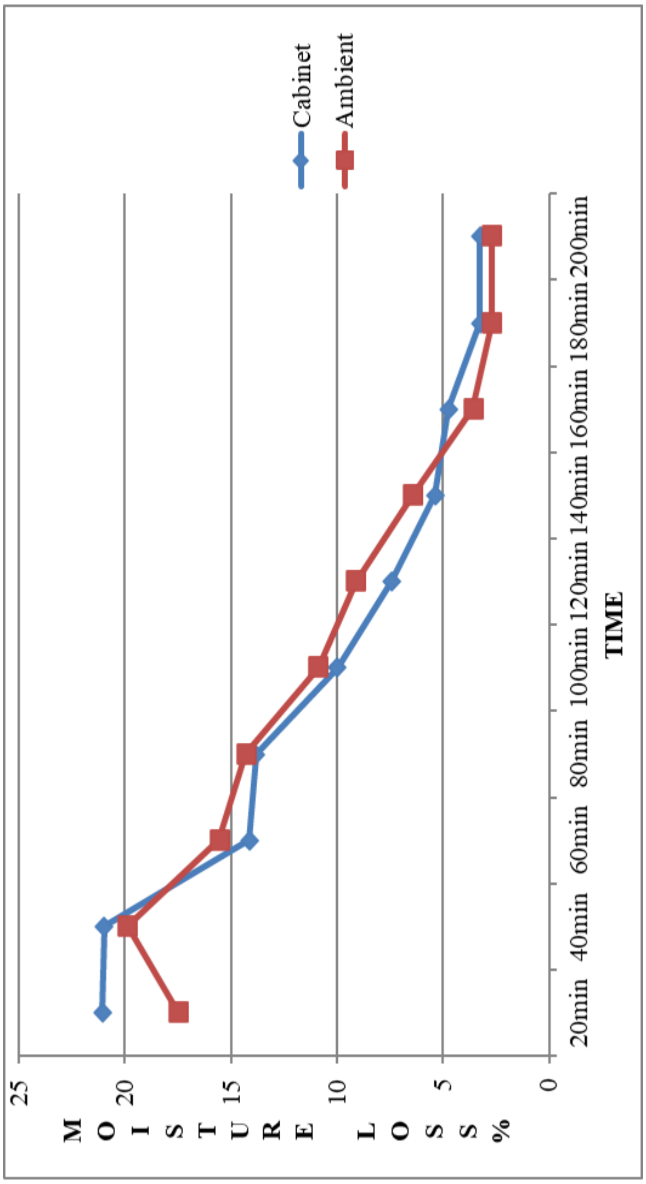


Fig 4.1. moisture loss v/s time (min) curve.

4.3.2 Before drying

4.4 After Drying

Banana sample before drying

Banana sample after drying

Table 2: A typical day results of large pieces of banana in solar dryer.

S.R	TIME	WT.OF SAMPLE IN CABINET	% MOISTURE REMOVEL	WT.OF SAMPLE IN AMBIENT	% MOISTURE REMOVEL
1	2.01PM	185.44	--	185.40	--
2	2.01PM-2.21PM	177.30	16.29	180.12	12.36
3	2.25PM-2.45PM	167.72	19.17	170.25	17.42
4	2.48PM-3.08PM	158.60	18.25	160.08	20.54
5	3.11PM-3.31PM	147.20	22.81	148.75	24.55
6	3.42PM-4.02PM	142.19	10.02	143.52	11.16
7	4.06PM-4.26PM	138.22	07.94	140.92	05.55
8	4.31PM-4.51PM	135.48	05.48	138.56	05.03
9	4.55PM-5.15PM	135.48	05.48	138.56	05.03

Table 3: A typical day results of small piece of banana in the solar dryer

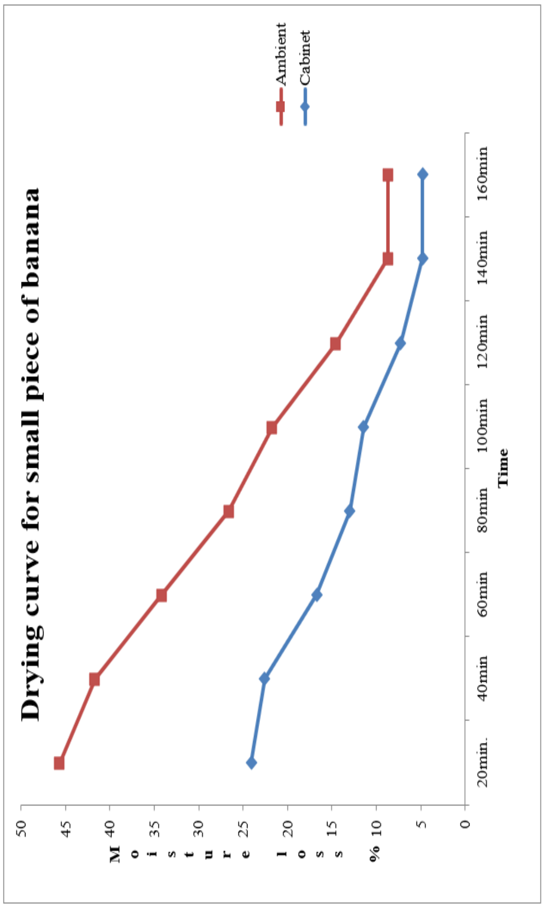
S.R	TIME	WT.OF SAMPLE IN CABINET	% MOISTURE REMOVAL	WT.OF SAMPLE IN AMBIENT	% MOISTURE REMOVAL
1	02.05PM	186.00	--	186.00	--
2	02.05-02.25PM	166.29	24.09	170.13	21.53
3	02.33-02.53PM	147.80	22.60	150.91	19.07
4	02.59-03.19PM	134.10	16.74	138.07	17.41
5	03.25-03.45PM	123.47	12.99	128.04	13.60
6	03.49-04.09PM	114.09	11.46	120.49	10.24
7	04.12-04.32PM	108.12	07.29	115.16	07.23
8	04.35-04.55PM	104.19	04.80	112.29	03.89
9	05.00-5.20PM	104.19	04.80	112.29	03.89

Ambient Temperature

Fig. 4.1 shows a typical day results of the hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rise inside drying cabinet was up to 24oC (74%) for about three hours immediately after 12.00h (noon). This indicates prospect for better performance than open-air sun drying.

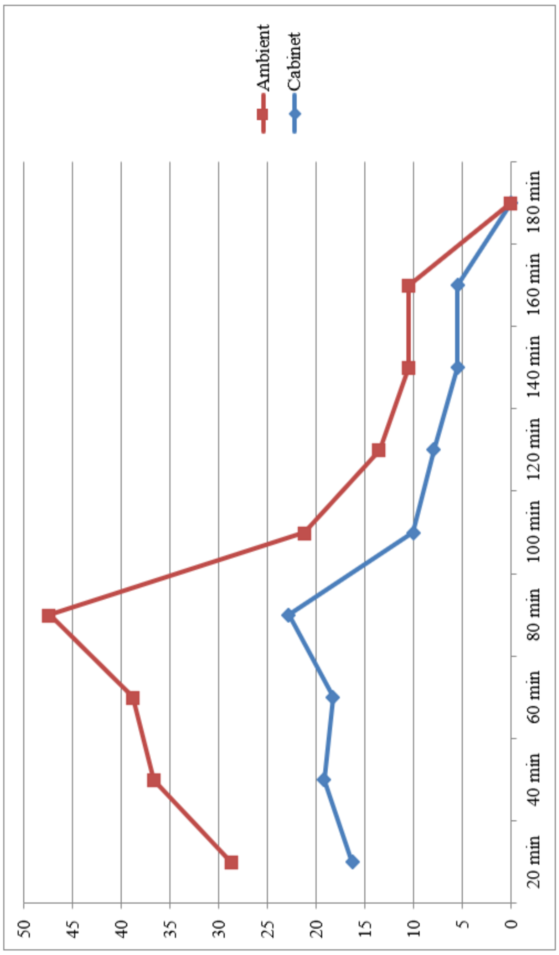
2. A typical day result of small piece of Banana in solar dryer

Fig. 4.2 shows the diurnal variation of the moisture loss % of the ambient air and drying chamber. The drying processes were enhanced by the heated air at very low humidity.



4.4 The drying curve for large piece of banana in solar dryer

Fig. 4.3 shows the diurnal variation of the moisture loss % of the ambient air and drying chamber. The drying processes were enhanced by the heated air at very low humidity



CONCLUSION

From the test carried out, the following conclusions are made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, like attack of the product by rain or pest (both human