SOLAR DRYER

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ABSTRACT

Different commodities are dried locally using different methods including natural drying in open area, solar drying. Different solar dryer designs can be found in various parts of india and a suitable design can be selected for the prototype depending on the type of drying contents, climatic condition, etc.

Open air drying was reported as most common method of drying agro-commodities. The farmers were not happy with with uncontrolled open air method and desired to design a simple and easy to use low cost dryer suitable for drying any agro commodities in a clear or /rainy day.

The purpose of this project was to study, design, fabricate and test a solar cabinet type of dryer for drying mango. Main emphasis was givenin designing a simple dryer to be made from locally available materials and different products or materials are dried like cereals,legumes, condiments, fruites, vegetables, meat and fish mostly in open air or under shade. A prototype dryer was designed for 1kg of mango slices to be dried by means of direct solar heat in conjunction with an auxiliary heater. Mango pulp is perfectly suited for conversion to juices, nectars, jams, bakery fillings, fruit meals to children, flavours for food industry, to make ice-cream& yog hurt. Processed mangoes enable exporters to serve their market even during off season period for fresh mangoes.

Having gained the confidence on the dryer performance, detailed tests were conducted to study the effects of drying modes. From performance and graphs it is seen that the percentage moisture removal desired at the design stage was achieved.

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1. INTRODUCTION

Drying has been used to preserve food throughout the world since prehistoric times. When people learned that dried foods left out in the sun remain wholesome for long periods. The dried foods industry has greatly expanded after World War II but remained restricted to dried foods, including milk, soup, eggs fruits, yeast some meats and instant coffee etc. several mechanical drying units were built on experimental basis and a few commercial units were in operation primarily for dehydration of fruits, vegetables, and hay and seed corn. Much of the research in agriculture product up to 1955 was concerned mainly with field result. Since 1955 considerable research has dealt with theory and principles of drying in the design of farm level of commercial driers. Drying in one of the oldest user of solar energy. The practice has been cheaply and successfully employed all over the world for thousands of years. The basics philosophy of drying foods is to remove water for prevention of micro organisms to grow and limit food enzymatic activity. It reduces an item to roughly 50% of its original volume and 20% of its original weight through gradual elimination of water. Three basic methods of drying are used today (i) sun drying, a traditional method in which foods dry naturally in the sun, (ii) hot air drying in which foods are exposed to a blast of hot air and (iii) freeze drying in which frozen foods are placed in a vacuum chamber to draw out the water. Removing the water preserves foods because micro organisms need water to grow and food enzymes cannot work without a watery environment.Historical records indicate that solar heat has been widely used to dry cereals, vegetables, fruits, fish, meat and other agro-commodities. Solar radiation is very widely used in developing countries as direct source of energy by which to dry dehydrate food of many kinds in many countries because, drying by use of fossil fuel is uneconomical. Drying of foods is carried out primally to ensure stability of the product quality for a given storage period or to ensure product availability in off-season. In such drying, the product is spread thinly over the ground directly exposed to solar radiation. Solar heat vaporized the water in the product and ambient air with allow relative allow relative humidity carry this moisture to the atmosphere. No doubt, the method is cheap but there are problems associated with sun drying which often result in quality of dried commodities. For example no control over drying process, possible contamination of the product by dirt, dust storms, rains, rodents, animals, infestation by insects and moulds, and possible contamination from environmental pollution. Improvements could possibly be brought about in the traditional sun drying mats and drying trays placed over the ground. The best way to ensure better product quality and chances of probable contamination is to dry the product in chamber type enclosed dryers either directly or indirectly. The enclosed chamber with a transparent cover receives direct solar heat and act as a green house. Thus the heat of the sun remains trapped in the enclose thereby enhancing the temperature of the chamber. As a result drying process quick water evaporation from the product compared to direct sun drying.

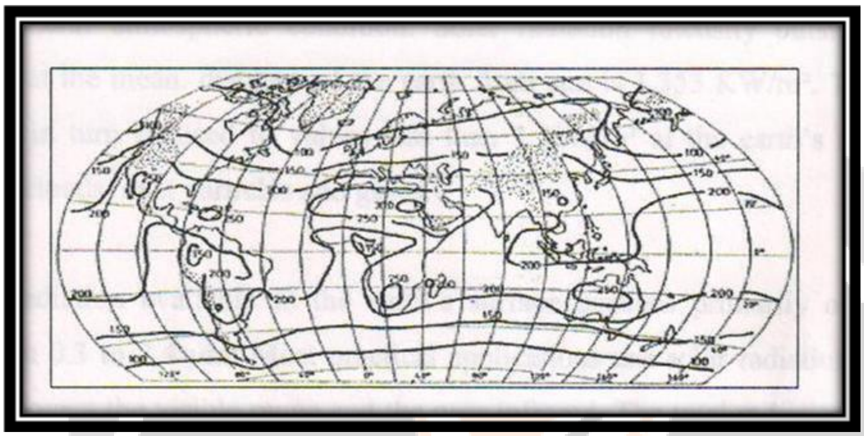

Fig -1: annual mean global irradiance on a horizontal plane at the surfaceof earth W/m averaged over 24 hours

In most of the developing countries and particularly in India the solar energy is abundant , averaging 15-22 Mj/m^2 day , the people and the governments are very much inclined to harness the benefits of rich source of energy gifted by the almighty. Moreover, solar radiation is inexhaustible, non-polluting , and renewable and is economically feasible to be used by the rural masses particularly for drying agro-commodities. Solar radiation is receiving a considerable due to its limitless treasure available year round. Solar energy as collection near the earth's surface is essentially a low temperature heat source. This characteristic may limit its use in high temperature drying but may make it ideally suited for the seasonal and low temperature drying various agricultural commodities.

1.1 1.1 SOLAR ENERGY

Recent work on solar drying has been devoted in two directions. There has been work on direct drying where in the material is exposed to direct solar heat and the product moisture is evaporated to the atmosphere to the other method drying is indirectly accomplished by the use of some type of collector, which furnishes hot air to a separate drying unit . Since solar heat is not a constant source of heat due to weather conditions. Systems that are more effective are possible in some cases if a supplemental oil/gas or electric heater is used when the weather is cloudy. The magnitude of available radiation depends on the location, time of the year, time of the day and general atmospheric condition. Solar radiation intensity outside the earth's atmosphere at the mean. Distance of the earth from sun is 1,353KM/ m2 . This amount of radiation is in turn reduced to values less than 1 KW/m2 at the earth's surface by the presence of clouds, dust particles and gases. The solar radiation available at the earth's surface consists primarily of wavelengths ranging from 0.3 to 2.4um. Most practical applications use solar radiation 0.38 and 2.0 um, which covers the visible range and the near infrared. The total radiation incident on a horizontal surface is called global radiation or insulation. It includes the direct beam radiation, the diffuse radiation and the reflected radiation. The directed radiation is received from the sun in a linear path. The diffuse radiation however is directed from all over the sky. It is the radiation that is scattered by gases, particle etc in the air. The defuse component of radiation may vary from 10% to 100% of the global radiation. The reflected radiation originates from surfaces such as a wall of buildings, the ground and other equipment. The methods of utilizing solar energy for drying to date have largely been based on open air-drying. However to better utilize this abundant source of energy effectively. Systems need to be developed based on specific needs. Crop dryers that can be used active dryers and passive dryers. Active dryers use an external device operated for example a fan to circulate the air, but passive dryers do not. Although a passive system tends to be more realistic for application in developing countries because of the relatively low initial capital and operating costs, it is possible to use active system for relatively large-scale applications. There are various needs in which solar energy can be used for drying.

The open air-drying method use solar insulation, wind velocities, ambient air temperatures and relative humidity of the air to reduce the moisture content of crops. The crop is generally spread on clean ground in a thin layer. The mechanism by which the incident solar radiation. The solar radiation heats the ground and the surrounding air. Heat is transferred to the crop by conduction from the ground, by conduction and convention form the air close to the crop and by radiation from the sun. The moisture at or near the surface of the crop is thus heated And is vaporized, which causes movement of moisture to the surface. The heat transferred to the croup may also be transmitted to the inner core by conduction, which will in turn liberate further vapour. Thus the rate of drying depends upon the available radiation and ground temperature. Because there is little or no vertical circulation of air through the croup, they have to be spread thinly, which required large land area.

Another method is to use trays slacked one above the other with their base of wire mesh. This process increases the drying rate and reduces the space needed for the crop spreading. Direct drying use dryers that consist of an enclosure with a transparent cover. The crops are placed on trays in the enclosure and elevated temperatures cause evaporation of water from crops. The moist laden air through dryer. The design of direct dryers is such that the croup is directly beneath the transparent top cover that is sloped at the appropriate angle to collect maximum solar radiation. The recommended value of this angle is α = latitude + 15˚ . indirect dryers however , use heated air in a solar air collector to dry out commodities without direct contact of solar energy with commodities. The heated air could be circulated using a fan or just natural convection.

1.2 OBJECTIVES

1. to design and fabricate a suitable prototype for drying common agro-commodities usually dried traditionally in open air

2. to evaluate the performance of the prototype using some common agro-commodities with different loads and drying modes.

Following are the some of the selected research studies mainly on vegetable and fruits drying where the post harvest losses are almost half of the total production which otherwise could be minimized if appropriate drying process were applied to preserve the commodities for off season use, and also to fetch good return for the farmers

1.3 MATERIAL THICKNESS & DRYING

It designed three type of dryers. Direct absorption solar dryer with reflector and combined mode solar dryers models. The second group of dryers had a collector attached to the main drying units. The experimental solar drying of taro roots in slice and shredded forms indicated that the direct absorption dryer with plastic mirrors as reflectors and two mixed mode solar dryers were reasonably efficient in drying taro into stable forms of storage. With taro slices at loading density at 7.3 Kg/m^3 , the direct dryer with reflector was very efficient , the mixed mode dryer and the direct cage dryer were equally efficient, but slightly less than the direct dryer with reflectors, the indirect mode of solar drying was least efficient. While preparing the taro roots into shredded from resulted in larger surface-to-volume ratio and could be useful for making flour after the shred were nit necessarily effective for solar drying because the pieces tended to clump together thereby impending air passage through the shreds. The quality of dried product was found was found acceptable to consumers and nutritionally satisfactory. The storage of dried product for 32 weeks at room temperature showed no adverse effect on quality or change in chemical composition. The dried product had a moisture content of 10-13% Drying experiments over two years showed that if the drying rate due to high air velocity, was too great the product tended to dry mainly from the surface layers and after being removed from the dryer, the surface become monist again. Be at conducted experiments on drying of onions in an indirect solar dryer using forced convection. Properties tested include taste colour and general appearance of the dried onions. The maximum drying temperature was 50 to 55˚C. final moisture content of the product was about 5%.

The collector and drying chamber were made of A-5 aluminum. The collecting surface was 2.32 x 1m with a cover glass thickness of 3 mm and insulation (6 cm of glass wool) on the sides and bottom of the collector. The drying chamber of three trays 15 cm apart each. The trays were made from 1 x 1 cm wire mesh to allow easy flow of air. Measurement were taken every six minutes on temperature of air entering and leaving the collector. The glass plates the collector plate and the air entering and drying chamber and the global radiation with the use of a Hewlett data acquisition system. The results obtained from the limited number of tests were found encouraging.

.2. DESIGN & CONSTRUCTION OF SOLAR DRYER FOR MANGO SLICE-

We have taken help of the design prepared and use in Sudan by admin omda, Mohamed okay, Mohamed ayosub Ismail. The geographical and climatic condition of India and Sudan are almost same, hence the assumption made were taken up into the calculation. Sudan and India are both situated at 20 ° latitude (center) and both are typical countries. The average ambient condition are 30 ° C air temperature 25 % R,H. in month of April with daily global solar radiation incident on horizontal surface of about 20 MJ/m2 per day.

OBJECTIVE:

To designed a natural convection solar dryer to dry mango slices. Solar dryer to be constructed to dry 1 kg of mango slice. Initial moisture content of mangoes is 85% & final moisture content desired is 6%.

2.1 DESIGN FEATURES OF THE DRYER

The solar dryers has the shape of a home cabinet with tilted transparent top. The angle of the slope of the dryer cover is 37 ° for the latitude location it provided with air inlet and outlet holes at the front and back respectively. The outlet vent is higher level. The vents have sliding covers which control air and outflow.

The movement of air through the vents, when the dryer is placed in the path of air flow , brings about a thermo siphon effect which creates an updraft of solar heated air laden with moisture out of the drying chamber.

2.2 SOLAR DRYER DESIGN CONSIDERATIONS:

A solar dryer was design based on the procedure described by amprature (1998) for drying dates (a cabinet type) and procedure described by Bosnia Abe (2001) for drying rough rice (natural convection a mixed-mode type)

The size of the dryer was determined based on preliminary investigation which was found to be 2.6 kg / m ¬¬¬¬2 (try loading). The sample thickness is 3 mm as recommended by Bret et al. (1996) for solar drying of mango slices.

The following points were considered in the design of the natural convection solar dryer system:

a. The amount of moisture to be removed from a given quality of wet mango /orange
b. Harvesting period during which the drying is needed.
c. The daily sunshine hours for the selection of the total drying time.
d. The quality of air needed for drying.
e. Daily solar radiation to determine energy received by the dryer per day.
f. Wind speed for the calculation of air vent dimensions.

2.3 DESIGN PROCEDURE:

The size of the dryer was determined as a function of the drying area needed per kilogram of pulp of fruits. The drying temperature was established as a function of the maximum limit of temperature the fruits might support. From the climatic data the mean average day temperature in April is 30 ° C and RH is 25% . from the psychometric chart the humidity ratio is 0.0018kg H2O/kg dry air. From the result of preliminary experiments on the croup, the optimal drying temperature was 74 ° C and final moisture content of the mango for storage is 6% w.b.

Table -1: DESIGN CONDITION & ASSUMPTION

Item	Condition or assumption
Location	Jaipur (latitude 22° N)
Crop	Mango
Variedty	Totapuri
Drying period	April june

Drying per betch(2days/batch)	1 kg of mango
Initial moisture content (moisture content at harvest), Mi	85 % w.b
Final moisture content (moisture content for storage) , Mf	0.6 % w.b
Ambient air temperature, Tam	30 °C (Average for April)
Ambient relative humidity, Rham	25 % (average for April)
Maximum allowable temperature, Tmax	74 °C
Drying time(sunshine hours) td	10 hours (average for april)
Incident solar radiation, I	20 MJ/m^{2-}/day (average for past 30 years)
Collector efficiency, ή	35% (Ampratwum, 1998).
Wind speed	1.5 m/s
Thickness of sliced mango	3 mm

2.4 construction of prototype dryer

a natural convection solar dryer of a box – type (cabinet was designed and constructed. The constructed dryer (cabinet –type) consisted of drying chamber and solar collector combined in one unit.

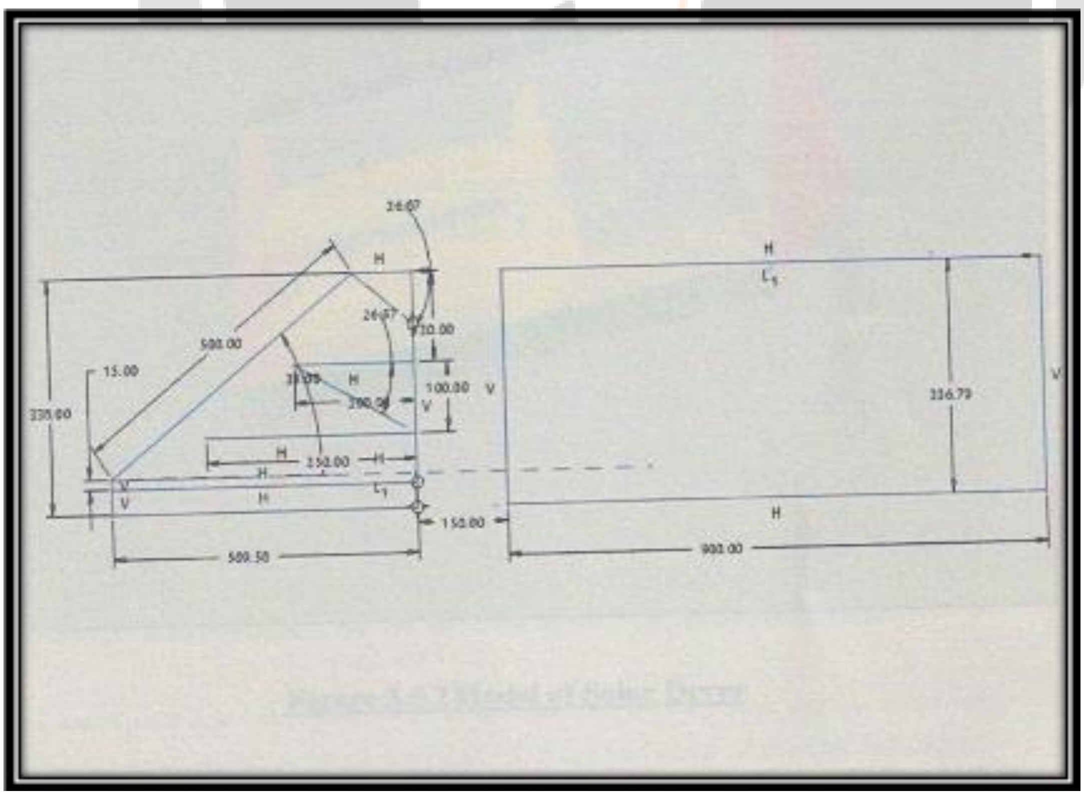

Fig -2: 2D layout of solar dryer

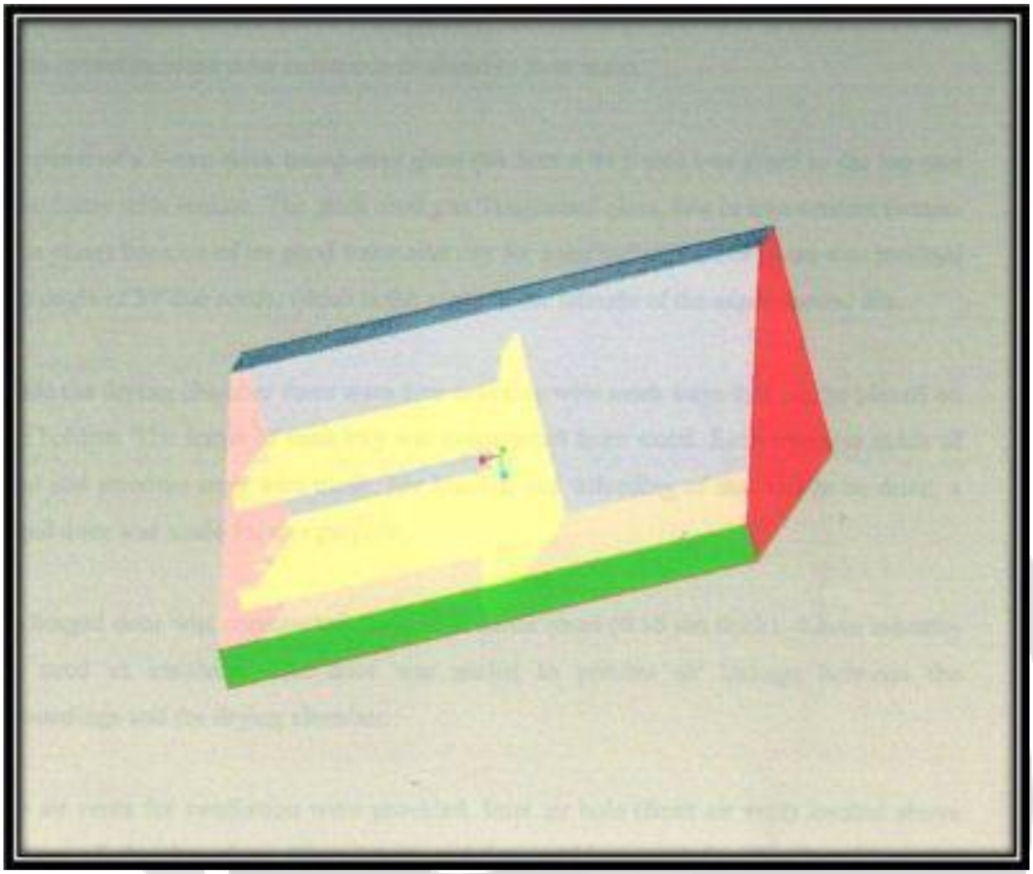

Fig -2: model of solar dryer

A simple box frame 90cm long, 51 cm wide and 34cm hight at the back and 10 cm high in front made of mild steel plates (16 guages) 1.6mm was fabricated. Sheets of mild metal sheet 0.16cm thick were welded onto three sides and bottom of the fabricated frame. Glass wood was used as insulator with a thickness of 1 cm and placed the bottom mild metal sheet.Try holders made of angle iron were welded in such away to hold try inside drying chamber. The lower holder was 15cm above the absorber glass wool and the upper was 15. Asbestos sheet of 0.3 cm thick were used as insulator and fitted to the three inner sides of the frame. Aluminum foil sheets were glued to asbestos sheet and used as moisture barrier and to reflect incident solar radiation to absorber from sides.One panel of a 5-mm thick transparent glass (84.5 cm x 44.5 cm) was glued to the top part of the frame with sealant. The glass used was toughened glass, low in iron content (water white glass) because of its good transmissivity for solar radiation. The glass was inclined at an angle of 37° due south, which is the angle of the experimental site.In side the drying chamber there were four movable wire mesh trays that can be placed on their hiders. The frame of each try was constructed from wood. Each tray was made of wood and stainless steel wire mesh. For loading and unloading of material to be dried, a hinged door was made for this purpose.The hinged door was constructed from M.S. metal sheet (0.16 cm thick) , 0.3 cm asbestos was use as insulator. The door was sealed to prevent air leakage between the surrounding and drying chamber.Two air vents for ventialation were provided. Intel air hole (front air vent) located above the base of absorber plate; 60cm legth and 6 cm width, provided with adjustable cover that was tow level of operating; full and half opening for dryer temperature control.The outlet vent (rear air vent); 60 cm x 6 cm was locked top edge and provided with adjustable cover for dryer temperature control. It has two levels of opening; full and half opening.

3.TYPES OF SOLAR DRYER-

BASIC TYPE & THEIR APPLICATIONS

In choosing a certain type of dryer account must be takken of the following six criteria:

• The use of locally avalible construction materials and skills.
• The investment of the purchase price and maintance costs.
• Drying capacity, holding capacity.
• Adaptability to different products.
• Drying times
• (fall in) quality of the end product

solar dryers can be constured out of ordinary, locally avlible materials, making them well suited for domestic manufacture.

Solar driers can be divided into two categories:

- Dryers in which the sunlight is directly emoloyed; warth absortion occurs here primarily by the product itself. These are further divisible three sorts:
    a. Traditional drying racks in the open air
    b. Covered racks (prodecting agaist dust and insect)
    c. Drying boxes provided with insulation and absorptive material.
- Dryers in which the sunlight is employed indirectly, in this method , the drying air is warmed in a space other than that where the product is stacked. The products then are not exposed to direct sunlight. Various sorts of construction are possible ; this design can also be provide with powered fans in order to optimise the air circulation.

3.1 ADVANTAGES & DISADVANTAGES OF VARIOUS DESIGNS

DIRECT DRYING

Tradition open-rack drying enjoys four considerable advantages.
• It demands a minimum of financial investment
• Low running costs
• It is not dependent on fuel
• For certain products the dryingtime is very short

On the order hand the product are exposed to unexpected rain, strong winds and the dust the carry, larves, insects and infection by, amongst others, redents Moreover, certain sessitive products can become overheated and evantually charred. Dried fruits so spoiled necessary loses its sale value. Commercially available drivers often appear to be economically unfeasible. Specifically, not enough product can be dried fast enogh to recop the outlay. Larger (combined) installation are more cost-effective but call for sophisticated management if the input and output of product is to be held at a controlled, and high, level. They are also fitted with articial heating (fires) and fans.

. INDIRECT DRYING

The advantages in the indirect system are that:
• The product is exposed to less high temperatures, whereby the risk of charring is reduced
• The product is not exposed to ultraviolet radiation, which would otherwise reduced the chlorophyll and whiten the vegetables.

However, its use demands some care. Faulty stacking of the product to be dried can lead to condensation; rising hot air in the lowest layers becomes saturated, but cool so quickly as it rises that the water condense out again in the upper layers.

This problem can be overcome by:

A dryer which operate optimally is usually the result of a number of adjustment whose value is established by trial and error and simple drying tests. It is therefore important that if a solar dryer is bought or made, these adjustments can be made.

A summary of this adjustment is given below.

• With regard to temperature regulation:

a. The available sunlight is dependent on the season and the location and limited to 4-7 kW. Hr/day/m. the absorbent area can be effectively by directing extra sunlight onto it with reflector. The angle of the absorber is also specified by the latitude. Take care that the collector is facing the sun and that it is out of shadow as far as possible.

b. It is simple matter to insulate the drier better and thereby raise the degree of heat absorption (and air warmth uptake). The wall of a covered dried - which the sun cannot pass through – is better replaced by insulating material which lines the box and painted black.

•The heat collector of an indirect dryer can be improved by:

a. Enlarging the absorptive capacity

b. Reducing heat loss, by means of insulation and keeping hot air-glass contact to minimum.

In the absence of forced ventilation, the chimney-effect is crucial. The difference in height between the air intake and outlet largely determines the draught and therefore the 'natural' ventilation.

• A chimney will help provided that :

a. It is enough; if it is too small it will obstruct the draught.

b. It is warm enough.

The air must not cool – this causes a reverse airflow, a wooden chimney is suitable. A chimney less than 40 cm height will in this case suffice.

Despite the many experiment carried out in almost every tropical area, it still appears to be impossible to design the 'ideal' solar drier. Depending on the building materials used, the product that need drying, and the season in which the drying must take place, the 'ideal ' dryer take many forms.

4.DIFFERENT TYPE OF AVALIBLE DRYER

4.2_MULTI RACK SOLAR DRYER:

PAULUDHIANA

Function : Natural convection type device used to dry product like fruits, vegetables, spice etc. for domestic use under hygienic conditions.

Design Features: high Efficiency, uniform drying of product, option to dry products in shade, suitability for rural/remote places, drying temperature in desirable range, light weight and essay to move.

Important specifications: Aperture area – 0.36 sq m, external dimension – 620x620x350 mm, ;oaring per batch -1-3 kg (depending on product), drying time per batch -2-3 days (depending product), inclination of the dryer – variable – fixed $30^o 45^o$ for north & 30^o for south

Performance :- the maximum stagnation temperature achieve in the dryer in winter months in northern India was 100^o c for solar insulation of 750 W/m^2 and ambient temperature of 30^0c. Solar dried chilies cost 15 % lower than the cost of the unbranded product and 57% lower than the branded product available in local market. Payback period worked out to be 84 days.

Present status: commercially available at a cost of round Rs.1600/- (us $ 35) from M/s vishwa karma solar energy corporation (regd.) , pillars -144410 (Punjab) India.

4.2. FORCED CIRCULATION SALAR DRYER:

FUNCTION:- used to achieved faster drying of high value products at industrial /commercial scale.

Salient feature: consist of solar air heaters, electrical blower, connecting ducts, drying chamber and control system for air temperature and flow rate. Equipped with high efficiently packed bed type and low cost unglazed type solar air heaters and electrical/biomass based heater provided bed type as thermal back up to supplemented heat requirement for operation during cloudy weather and night hours. The system can be designed for drying most of the agro-products.

Performance: efficiency of the packed bed type solar air heater was found around 40% more than commercial heater, very good quality finished product and agro-product retain their colour and flavor to a large extent.

Approximate cost:- packed bed type and unglazed type flute plate solar air heaters cost RS. 3,500(US $ 77) & Rs.2000/- (US $ 44) per square meter area, respectively. A 200 kg/d capacity solar of the onion flakes cost two that of the electric fired dryers. However, cost of the drying per kg product of the solar dryer is less than half that of the electrical dryer. Present status: A few installations are under operation for drying onion flakes, tomatoes mushroom etc. the design, installation and commixing and commission of the oral dryer system can be taken up on consultancy basis.

4.3 solar tunnel dryer for agro industrial application:-

Function: Natural walk –in type dryer useful for bulk drying of agriculture & industrial products at moderate air temperature.

Design feature: consists of a hemi-cylindrical metallic frame (3.5m x 21.0m) covered with UV stabilized transparent polythene sheet of 200 micron thickness, two chimney on the top and an exhaust fan on one side, product spread on trays put on trolleys moved inside dryer.

Performance: the average temperature inside the tunnel found 15 – 18 ^{0} higher than the ambient temperature. The moisture content of 1.5 ton basic calcium phosphate is reduced to around 15 % from an initial value of 35-40% in 2-3 solar days depending upon the solar insulation.

Approximate cost : Approximately cost of material and labor around RS 50,000 (US $ 1099) and payback period is around 80-100 working days. Costs of drying is reduced by around Rs 800 (US $ 17.6) per ton in solar tunnel dryer compared to the diesel fired mechanical dryer

4.4 STEP TYPE SOLAR COCOON STIFLER:

<u>Function:-</u> A multi-rack natural convection solaqqr dryer has been modified for cocoon stifling (killing papa inside the cocoon).

Design features:- batch type stiffer, portable, eases loading & unloading of cocoons, glass wool insulation, double glass glazing back-up of 2 kW rating with thermostat, collector are of $2m^2$ and loading capacity of 10 kg cocoons per batch.

<u>Performance:-</u> the peak stagnation temperature was found to be around 95^0C in winter and 125^0C in summer in central India. Average capacity in a silk reeling center was found to be 20-60 kg / day depending upon season. The remittal of solar stifled and electric oven stifled cocoons was almost same.

<u>Cost</u>: the stiffer costs around Rs. 15,000/-(US $ 330). Solar stifling of cocoons costs around 35% lower than stifling by electric c oven method.

4.5 APPLICATION OF SOLAR DRYER & DRYED MANGOES

the mango (mangifera indicia)is a tropical fruit, original from the south of asia, and ot is avlible worlwide today. The calture of mango, although still concentrated asia, was become enlarged for some countries, in all the continets, being important in africa and americas and with lesser presence in the Europ, where it is caltivated in small scale in spain. From the annual world production of 18 milion tones, asia accounts for 75% , americas 14%, africa 10% and 1 % remain in other areas, as austalia and europe. The mango is distinguished as fruits with high commercial value in many regions of the world, mainly the tropical regions. Universally, beyond its exellent qualities of flavour and aroma, they have its recognized alimentary value, for being vitamin A and C source. The food dehydration is one of the common used food conservation processes for increase of shelf life, reduation of costs of packing, transport and storage and modification of sensorial attributes (Queiroz,2003).

4.6 DRYING OF FRUITS & VEGETABLES

Drying of agriculture product is the oldest and widely used preservation method . it involves reduction as much water as possible from fooods to arrest enzyme and microbial activities hence stoping deteriation. Moisture left in the dried foods varies between 2-30% depending on the type of food. In tropical countries, solar dryer can be used to dry fresh produce when avarage relative is below 50% during drying period. Drying lowers weight and volume of the product hence lower costs in trasportation and storage. However, drying allows some lowering in natrition value of the product e.g. loss of vitamin C, and changes of colour and appearance that might not be desirable.

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