ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1368

Design and Development of Solar Food Dehydrator Made of Recycled Materials

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Abstract:- The project is based on fabricating a Solar Food Dehydrator made of recycled materials. The dehydrator was made using simple techniques and recycled materials such as beverage cans and reclaimed wood. The unit can be reconstructed. The portable dehydrator works on a simple principle. Performance tests revealed that the temperatures inside the dehydrator were much higher than the ambient temperature that aided the dehydration process. The advantage of a solar dehydrator is that it is more hygienic, and avoids contamination by dust, airborne molds, fungi, insects, rodents, or animals. The dried fruits and vegetables are healthier as drying preserves nutrients and enzymes and uses no additives or preservatives. Besides food, the dehydrator may be used to dry other materials. Solar dehydrators have no additional fuel expenses; thus, they support using non-renewable energy sources for drying.

I. INTRODUCTION

There are two sources of energy: renewable and non-renewable energy. Non-renewable resources are fossil fuels and nuclear energy which may not last very long in the future.

Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Solar Energy is the energy emitted by the sun in the form of heat, light, and radiation. Sun drying is the most common method used to preserve agricultural products in many countries of the world (Udomkun et.al,2020). Over the years, a whole culture of pickling has been implanted in the daily life of Mauritians. The art of making pickles, or 'Achard' or 'Zasar' has an ancient history and forms part of one of the oldest methods of preserving food. Traditional recipes have been passed down from generation to generation. Most meals are accompanied by pickles and making of pickles has become an opportunity for many women to supplement their income. With the abundance of tropical fruits and vegetables in Mauritius sellers of dried fruits, herbs, and vegetable pickles are omnipresent in all SME fairs. The typical way of drying fruits, herbs, and vegetables in Mauritius consists of cutting and sun drying by placing them on 'Vacoas leaf' mats until most of their water is evaporated. The dehydration process is long and requires appropriate techniques to avoid wastage besides retaining its original colour and flavour. These are then mixed with authentic spices, marinated, and preserved. This study presents the design, construction, and performance of a homemade solar dehydrator for food preservation.

II. LITERATURE REVIEW

- *Solar Energy*

Solar Energy or Power is the process of turning sun beams into electricity. Sunlight contains Energy. When sunlight hits an object, the energy turns into heat. When sunlight hits certain materials or objects, the energy is transformed into an electrical current. This can be harnessed for power. This can be done by using photovoltaic (PV), or indirectly using concentrated solar power (CSP). PV converts sunlight in an electric flow using photovoltaic effect. CSP systems make use of lenses or mirrors and a tracking system to focus a large area of sunlight into a small beam.

- *Drying of Food*

Mauritius is a tropical island where a variety of fruits, vegetables, and herbs are available. Many of them can be dried and used to make pickles, crystallized fruits, infusions (tisane) among others.

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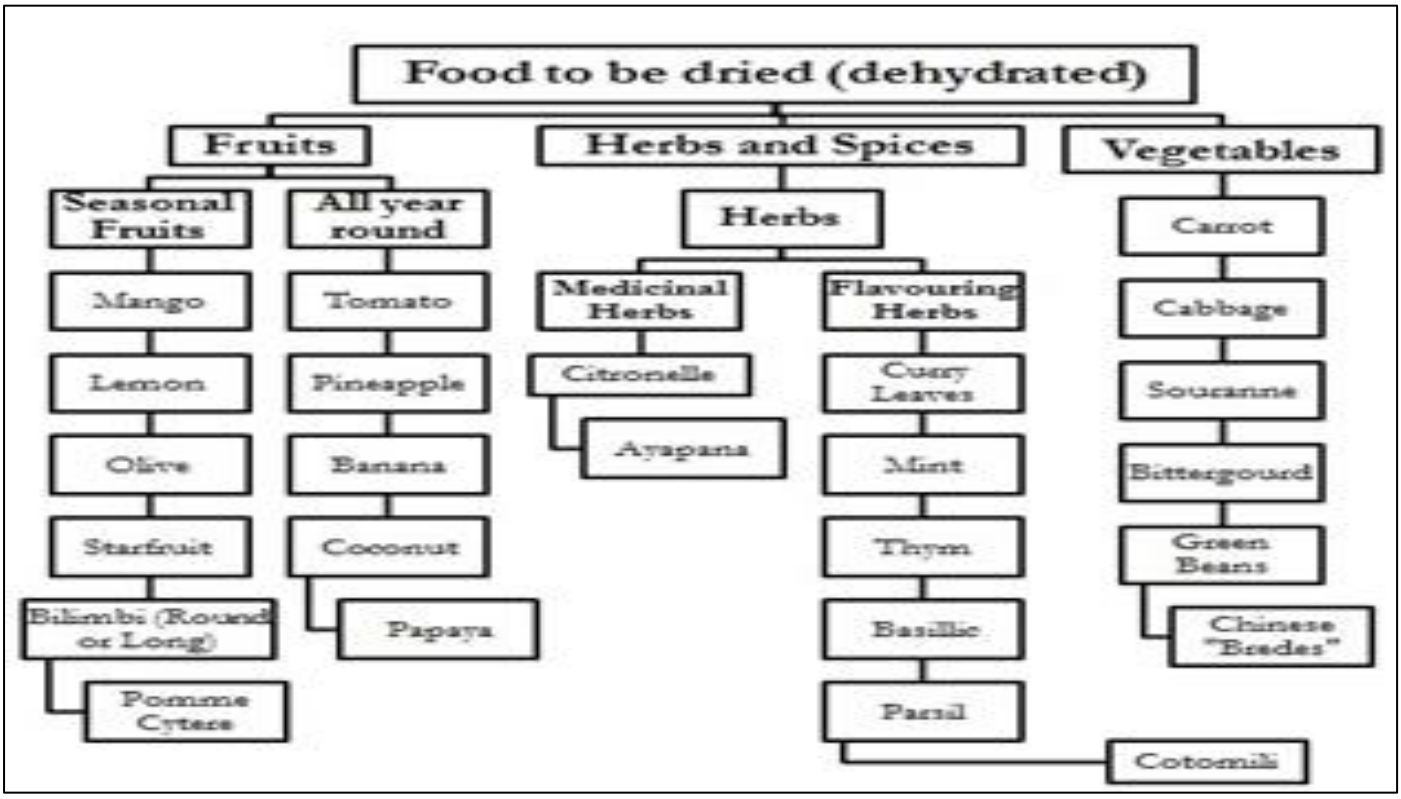

Fig 1 Categories of Fruits Herbs Spices Vegetables Dried in Mauritius

Figure 1 shows various categories of fruits herbs spices vegetables dried in Mauritius. Solar dehydration of vegetables and fruits reduces waste and the costs of final products (Fernandes et.al.,2022).

➢ *Advantages of Dehydrating Food in the Sun*

The dehydration of foods leads to less wastage as fruits and vegetables can then be bought in bulk and preserved over a longer period. Drying food does not alter their taste and the flavour is retained. The process of drying foods is much easier and more sustainable than canning or freezing as it involves only washing, slicing, or grating and then drying the food. The drying duration is rather fast in most cases. Dried foods occupy less space thus it saves space. The drying of food preserves its nutrients and enzymes and contains no additives or preservatives. Due to the dehydration of foods, products can now be available all year round. Fruits and vegetables in season can be dried for later use. Figure 2 shows the drying details of various foods. It presents an easy way to preserve or store foods for a long period. New meals or recipes can be derived from dried foods. It represents great snacks.

Foods	Process	Drying Time	Uses
Olives	sliced	5-6 hours	pickles
Starfruit	sliced	6 hours	pickles
Mango	sliced	1 day	pickles
Pommecythere (fruit citere)	sliced / removed seeds	3 hours	pickles
Souranne	sliced	3 hours	pickles
Coconut	grated	3-4 hours	cakes
Bilimbi(round / long)	sliced / salted	6 hours	pickles
Carrots, cabbages and green beans	sliced/ salted	3 hours	vegetables pickles
Herbs	**Process**	**Drying Time**	**Uses**
Curry leaves Persil Mint Thyme Basillic	washed	3 hours	add flavor to food
Citronelle (lemon grass) Bettel leaves Ayapana	washed	3 hours	Infusion (tisane)

Fig 2 Food and Drying Details

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➢ *Types of Drying Methods*

Traditional Sun Drying involves placing food on racks in direct sun exposure. In oven Drying, food is dried in a ventilated oven at about 60 degrees for about 24 hours. In Air Drying, food is dried in the open air. During Solar-drying the food absorbs heat energy from the sun and is dried by evaporation. In Vine Drying foods are displayed on the vine till it dries. Spray Drying is drying rapidly with hot gas to produce a dry powder from a liquid or slurry. Drum Drying involves drying at relatively low temperatures over rotating, high-capacity drums that produce sheets of drum-dried product. During pasteurization, the dried fruits are sealed in plastic bags and frozen. Heat can be transmitted from a higher temperature to a lower temperature.

III. EXISTING FOOD DEHYDRATOR

➢ *Excalibur ED-39000 Nine Tray Food Dehydrator*

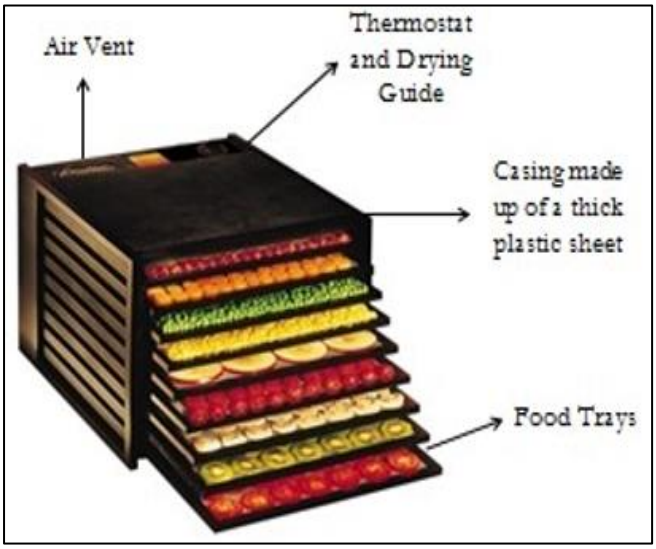

Fig 3 Excalibur ED-39000 Nine Tray Food Dehydrator

Figure 3 shows Excalibur ED-39000 Nine Tray Food Dehydrator. It has a large capacity; up to 9 trays, suitable to dry large amounts of fruits. The cost is about $220 (US); MUR 6700. It can be used to dry both fruits and vegetables. The model incorporates heavy-duty components and is very durable with a warranty of up to 10 years. It consists of a heating unit and a fan. It makes use of electrical energy to provide the heat energy required to dehydrate the food. It has an output power of 600w to provide the heat energy. The heat energy is provided by the heating element found at the back of the dehydrator. It includes a fan that helps the heat to circulate uniformly through the trays and the food. The fan establishes the horizontal drying system in the food dehydrators. The user must adjust the thermostat to the required temperature. The products are dehydrated through hot air and after a few hours, they are ready to be used as dehydrated food.

- Disadvantages: Expensive; Energy is lost if a small amount of fruits is being dehydrated; Large pieces of fruits cannot be dehydrated, only small flat pieces can; Quite bulky and need to be stored in a dry place.

➢ *FD-1010 Gardenmaster Pro Dehydrator of Nesco Brand*

Fig 4 FD-1010 Gardenmaster Pro Dehydrator of Nesco Brand

Figure 4 shows FD-1010 Gardenmaster Pro Dehydrator of Nesco brand. It can dehydrate large quantities of food in a row as it can be expanded to 12 trays. It includes an opaque exterior surface that prevents harmful light from entering and helps to retain natural nutrients and vitamins during the drying process. It can be used to dehydrate fruits, and vegetables and make other types of food like jerky. It has a fast powerful fan that works at 2400- RPM motor (40Hz). This provides a faster and more nutritious drying. The fan helps to force the heated air up the exterior pressurised chamber allowing fast and even drying.

- Disadvantages: Expensive; A lot of energy is lost while dehydrating; Cannot dehydrate large pieces of food – the food has to always be cut or sliced before drying; Should be placed on a table, no stand-alone platform; Dried only in a horizontal drying system.

➢ *The L'EquipTM Model 528 Dehydrator*

Figure 5 shows The L'EquipTM Model 528 Dehydrator. It has been designed to dehydrate freshly picked fruits and vegetables. It captures the in-season flavours and nutrients of almost any food for out-of-season eating enjoyment. This L'Equip dehydrator is more practical, economical, and easy to use. The heating element can produce an output power of 550W. This power is sufficient to provide the heat energy required to remove moisture and water from the food to be dehydrated.

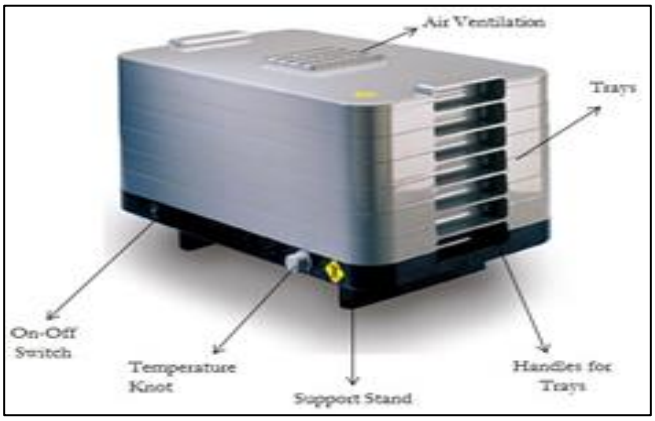

Fig 5 The L'EquipTM Model 528 Dehydrator

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- Disadvantages: The vertical drying method is not as efficient as the horizontal drying system; The trays need to be constantly washed after each use as some fruits might stay stuck to them; A fragile appliance, made up of plastic only and it will be constantly exposed to high temperature.

➢ *Homemade Dehydrator*

The solar food dehydrator as seen in Figure 6 is used by Mrs. Brigette, a Mauritian inhabitant residing at Curepipe. Its original purpose was to be a display cabinet in a cake shop and now reused as a solar food dehydrator. Mrs Brigitte finds an alternative way of using her old cabinet. She found it suitable for displaying her dried fruits and vegetables and also preserving them further by keeping them in the sun. With the help of the upcycled dehydrator, she has the opportunity to further her business in pickle making. The fruits and vegetables are cut into pieces and placed on a tray. A net fabric is placed over the tray. The tray is then placed in the dehydrator. The fruits and vegetables are left to dry in the sun for an adequate duration. They are removed to be finally used or served.

Fig 6 Homemade Solar Dehydrator

- Disadvantages: As the back of the dehydrator is left open, the user has to cover each tray she placed inside to prevent insects from contaminating the foods; It is a risk for the user, as there are no rubber pieces to cover the edge of the glass tray at the edge; Difficult to displace trays: has to stoop to move them; It seems to be bulky and difficult to transport; Birds and other animals can easily get in contact with the trays and foods. It is a direct sun-exposed dehydrating method.

➢ *Traditional ways of drying foods in Mauritius*

Fruits and vegetables are preserved and made available during off-season periods. The fruits and vegetables are cut into pieces and placed on a tray. A net fabric is placed over the tray. The tray is placed in the dehydrator. The food is left to dry in the sun for an adequate duration. After some long hours, the food can be removed and used or served. Traditional ways of drying foods in Mauritius - Trays are made of Vacoas leaves with a net used to dry the fruits and vegetables. It allows the food to be placed safely in the tray. A stainless steel plate is used as a tray to dehydrate the foods allowing faster drying by attracting more heat energy. The trays are uncovered and insects can get in contact with the foods, thus contaminating them. As the trays are placed on a small stool, other bigger animals such as cats, dogs, or birds can affect the food. This system is not hygienic as the foods are exposed to dust and harmful particles. Exposing food to direct sunlight may lead to a decrease in their nutritious values. Strong winds can blow the tray off the stool leading to the loss of all the foods. Supervising is required. The tray with the stool has to be displaced several times during the day as the sun changes position.

IV. DESIGN AND DEVELOPMENT

Solar dryers are usually categorized according to their, air movement, heat transfer, and type of drying chamber. Six design proposal ideas were sketched and analysed for product development. Based on the specifications and characteristics of each a final design was selected for prototyping.

➢ *Design Idea 1*

The idea consists of two boxes. One to be used as a solar panel and a second where the fruit trays will be kept for drying. The food dehydrator will use a hot air system to dehydrate the food. Materials used included Aluminium Frame; Metal Grids; Joints; Pop Rivets; Hinges

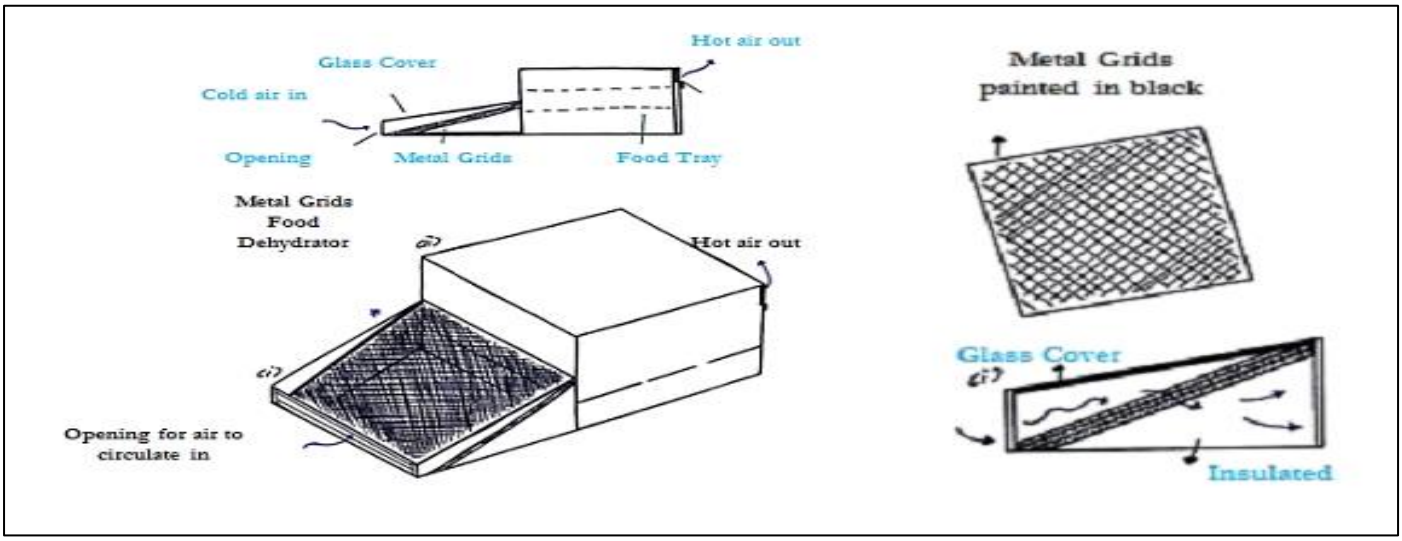

Fig 7 Design Idea 1

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Figure 7 shows design idea 1 for a homemade solar cooker with panels. Metal Grids may be used to make the solar panel. Three to four layers are to be placed in a 30-degree angle position which will allow the air coming in the box to heat up by passing through the hot metal grids. As hot air rises, the air will then flow to the box containing the fruits and veggies. The solar dehydrator is made of aluminium sheet thus this may increase the cost of the final product. The metal grids might not attract enough sunlight to dry the food which leads to a longer time process. The dehydrator needs to be positioned facing in the direction of the sun.

- *Design Idea 2*

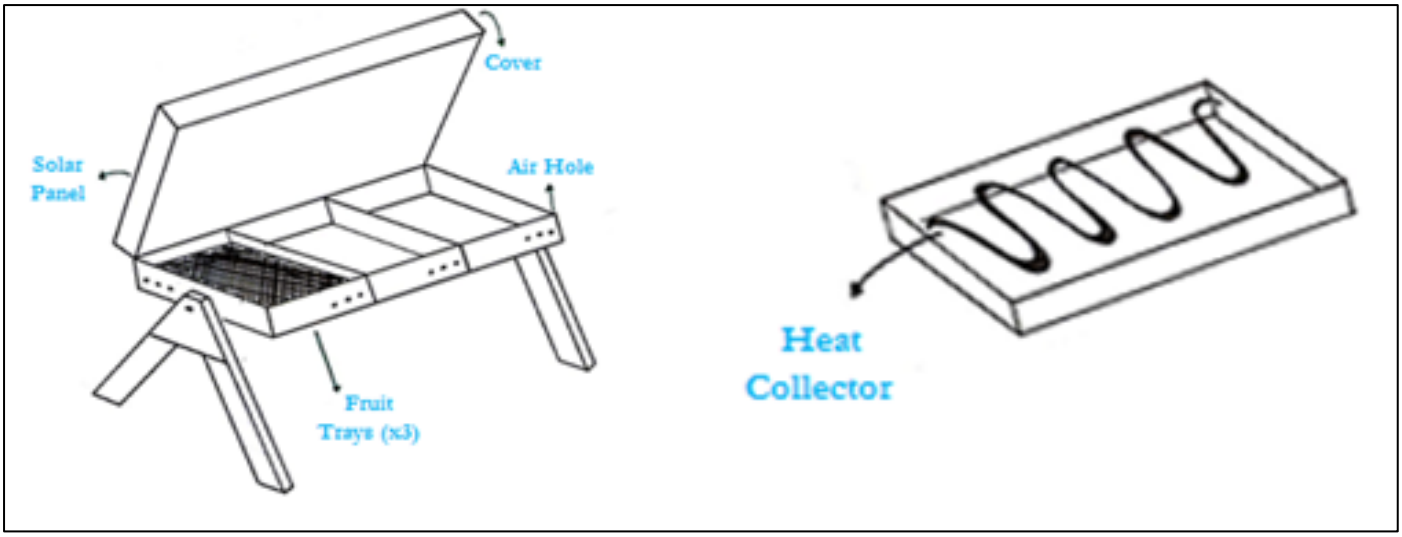

Fig 8 Design Idea 2

The solar food dehydrator as seen in Figure 8 is made of wood and a glass topping. The concept is that the cover retains the heat in the box which accelerates the drying of the fruits. The dehydrator consists mainly of wood except for the glass cover. A metal coil is used as a heat collector to provide sufficient heat energy collected from the sun's rays. This will be used to heat the dehydrator thus allowing the drying process to take place,

The holes for ventilation might become a drawback for the dehydrator. As it will be placed outside insects might get inside the box through them. Also, it cannot accommodate a large quantity of drying food. The sunlight will fall directly on the DIY solar panel, leading to an increase in temperature inside the dehydrator; this will favour a homogeneous drying process.

- *Design Idea 3*

The dehydrator consists of two parts as seen in Figure 9. The hanging drying unit and heating element. It is rectangular and will allow efficient drying on all four sides. The dehydrator is exposed to the sun for drying and also has a supplement heating element. The heating Element will be powered by a battery connected to a solar panel. It will act as a backup heating system in the dehydrator and will ensure homogeneous drying.

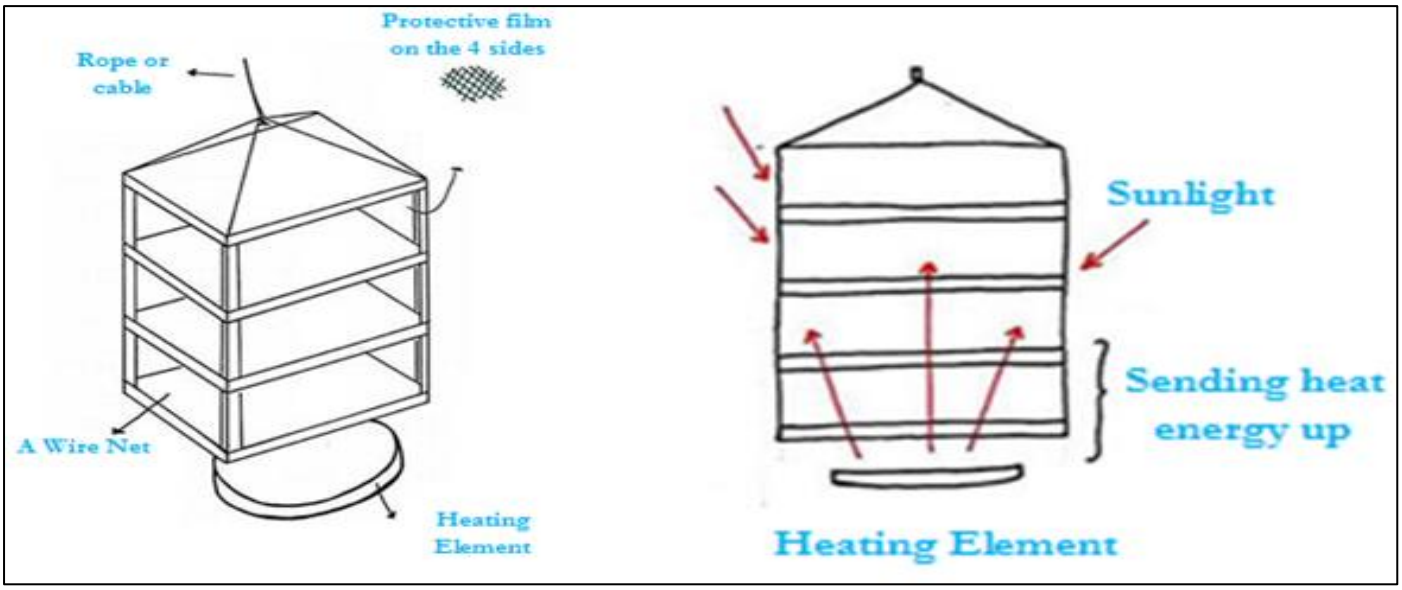

Fig 9 Design Idea 3

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Wood will be used to make the main structure of the dehydrator; a plastic-like net is used as the base for each tray. A cable or rope will be used to hang the unit. The heating element is made of metal and an electronic system. As this dehydrator is supposed to be hung outside, the wind may avoid homogenous drying, and change the direction of the hot air.

➢ *Design Idea 4*

A food dehydrator in the form of a pyramid. It uses direct sunlight to dry the food.

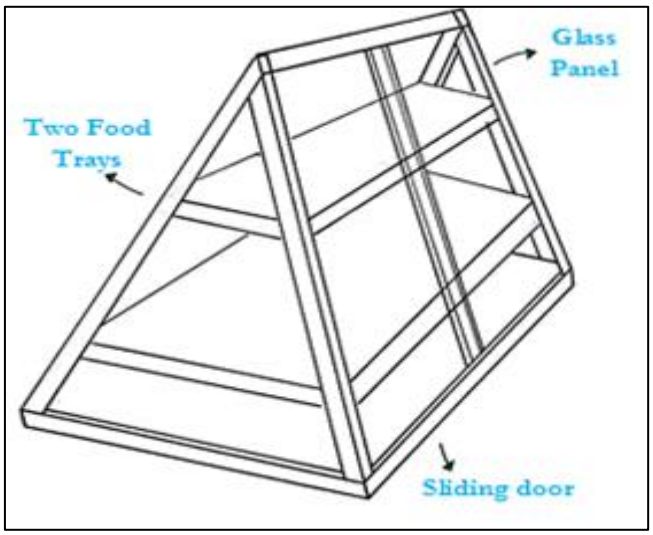

Fig 10 Design Idea 4

The dehydrator as seen in Figure 10 is made of glass panels. They are joined together with aluminium elbows. It is a good conductor of heat and will optimize the drying process. Direct sunrays hit all four sides of the dehydrators and contribute to the drying process.

Direct drying may lead to a decrease in nutrients found in the fruits. The glass panels are expensive. The dehydrator is difficult to transport due to the lack of wheels. There is no adequate air ventilation system inside the dehydrator.

➢ *Design Idea 5*

This dehydrator as seen in Figure 11 uses direct sun rays to dry the fruits. It consists of a black box structure that attracts sun rays and leads to the dehydration of the foods inside it.

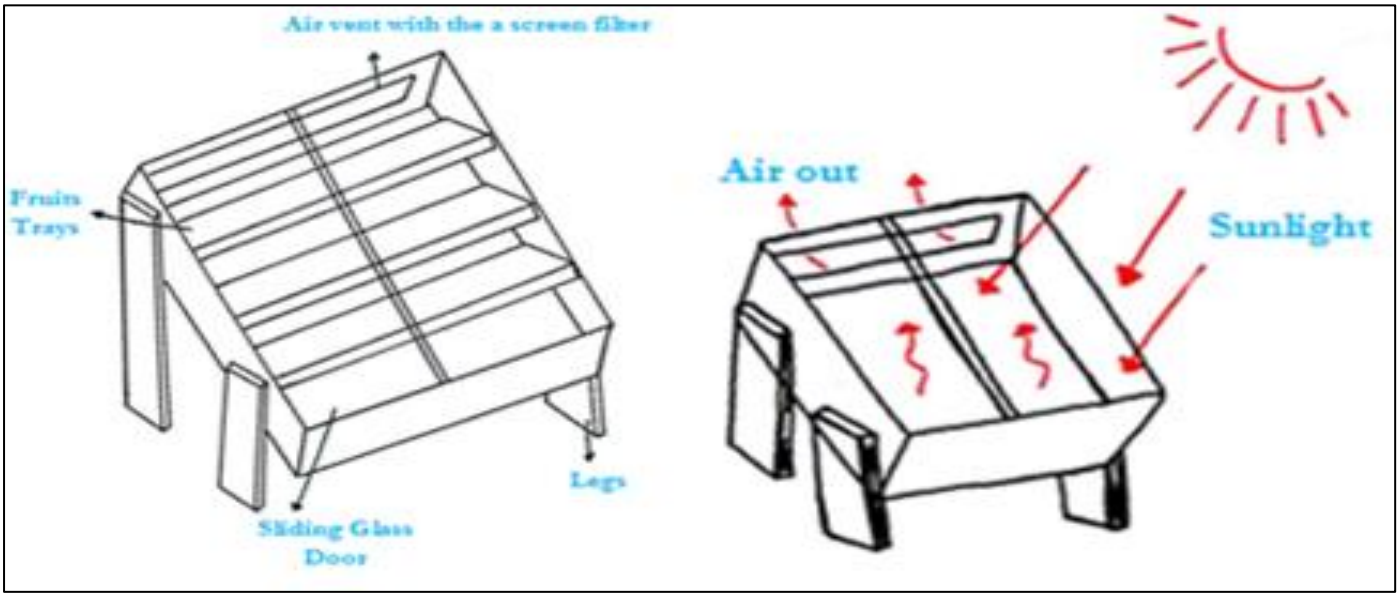

Fig 11 Design Idea 5

An air vent is made at the top of the dehydrator to allow a homogenous drying. The air vents are covered with a thin wire net (screen). The product is made of wood and glass used for making the sliding doors. It may be difficult to transport the dehydrator. It may be inconvenient to open and remove the long fruit trays.

➢ *Design Idea 6*

The design idea 6 of the dehydrator as seen in Figure 12, consists of a solar panel made of black beverage cans and a box for drying. It uses the concept of a hot air system to dry the food.

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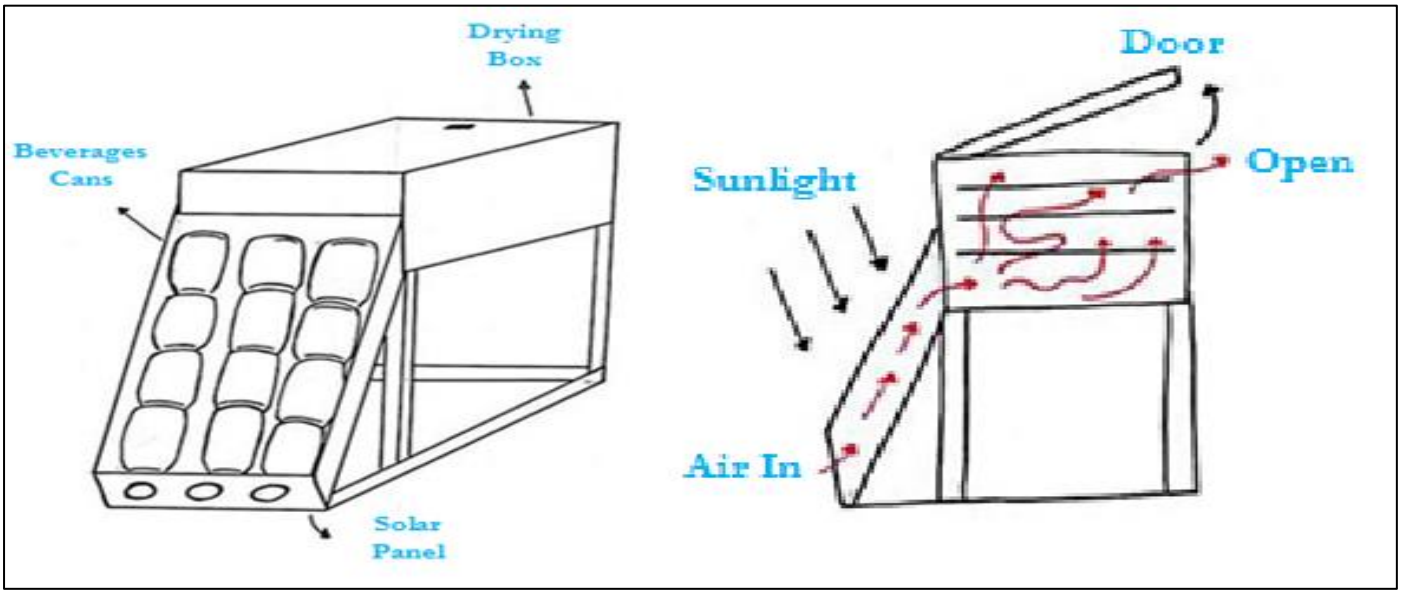

Fig 12 Design Idea 6

Air enters the cans (painted black) from the lower open end. While passing through the dark-coloured cans, the air heats up. As hot air rises and flows into the drying box it contributes to the dehydration of the food. The tray is made of a metal frame and a metal grid.

➢ *Prototype and Testing*

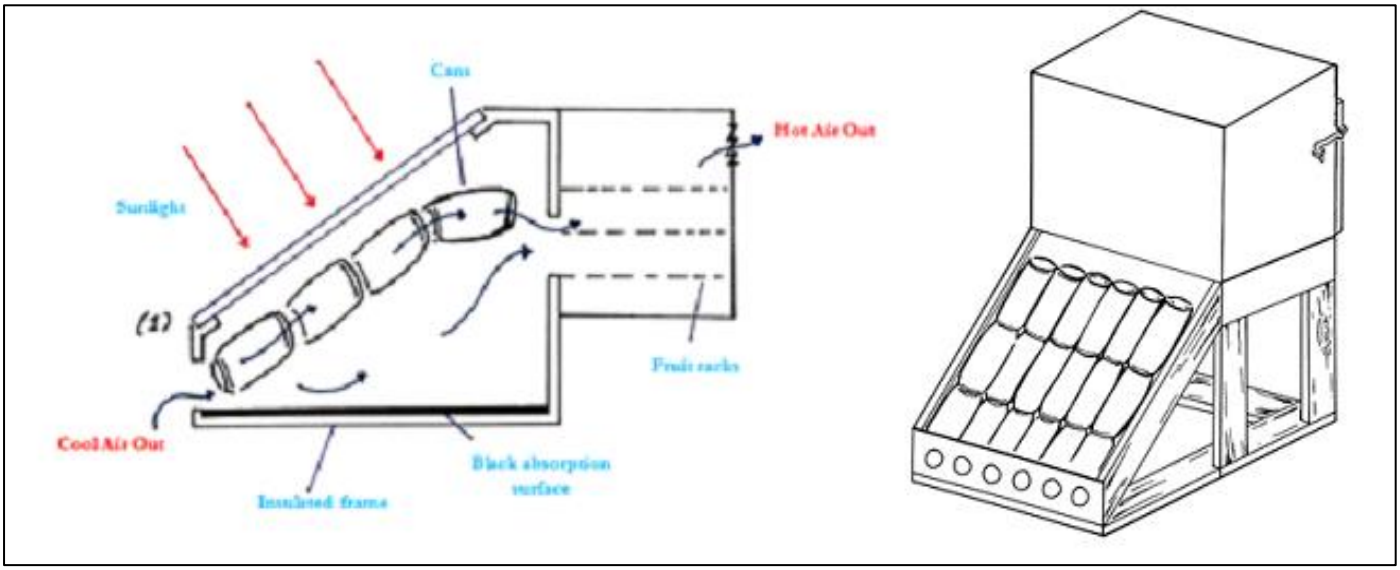

Fig 13 Final Design Idea

The final idea 6 was derived using concepts from ideas 1 and 5. The homemade solar dryer was made with black-painted beverage cans which replace solar panels. They contribute to an efficient heating system. It allows a homogenous drying process. The black cans absorb heat. The materials used for making the solar dehydrator include reclaimed wooden pallets, a glass panel, black paint, a holder, empty beverage cans, screws, nails, and dowels. The concept involves cool air entering through part (1) as seen in Figure 13. The black paint cans absorb the energy of sunlight and heat the air inside the cans. As hot air rises, the air is transported into the drying box leading to the dehydration of the food on the trays placed inside the box. The dehydrator has the advantage of fruits not being directly exposed to sunlight thus, preserving their nutritional value. Reclaimed materials are used. It has an efficient and quick-drying method. A large quantity of drying can be done. It is a hygienic drying technique as bugs cannot get in contact with the foods. Figure 14 shows the final prototype and drying of apples.

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Fig 13 Final Prototype and Drying of Apples

The prototype was tested to demonstrate the proper functioning of all its components. The dehydrator was tested using fruits such as apples. bananas, pineapples, and figs. Herbs such as parsley, thyme, and coriander were also experimented. It took about 5 to 6 hours for crisp drying.

V. CONCLUSION

The paper reviews and reports an overview of solar dryers applied to the processing of food. It showcases different solar dryers that are available for users. The explored aspects range from the technical description of solar dryers. It highlights some strong points and issues posed. Various designs are introduced for making homemade solar dryers with low-cost or readily available materials. An efficient and economical solar dryer for drying vegetables and fruits was designed and developed. Using low-cost and reused materials it is possible to design and construct an effective solar dryer prototype. Tasty and healthy foods can be made with solar drying while addressing environmental sustainability.

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