# Design and Fabrication of Solar Assisted Food Grain Disinfestation System

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**Abstract -** *Food grain disinfestations has an ever growing demand, owing to the damage of food grains that happen during grain handling and storage. In this project, a Solar assisted food grain disinfestations system is proposed, where food grains are dried with a combined effect of direct Solar drying and Hot air drying. This reduces the moisture content of the food grains, to a recommended level for that grain, which aids in storage and preservation of the grains for a longer duration, and avoid spoilage during storage. The system will be designed, developed and fabricated using suitable materials. Food grade materials are to be used where ever necessary. The equipment is expected to dry food grains in a shorter duration, compared to traditional direct solar drying, and also be economical, using very less amount of electricity.*

***Key Words*: Food grain disinfection, disinfestation, Solar drying, Solar energy, Grain moisture Content, Grain handling and storage, Grain spoilage.**

## 1. INTRODUCTION

Issues such as rapid urbanization and environmental pollution, and urbanization are causing agricultural land to reduce day by day. The yield is twice or thrice in a year but the consumption is continuous. Human population is increasing exponentially. Losses are high in food grains due to insects, rodents, moisture etc., during storage. Produce gets spoiled at various stages such as while seeding, growth, harvest, and storage. This has resulted in uneven demand and supply pattern and thus leading to shortage and further adding to high prices of food grains.

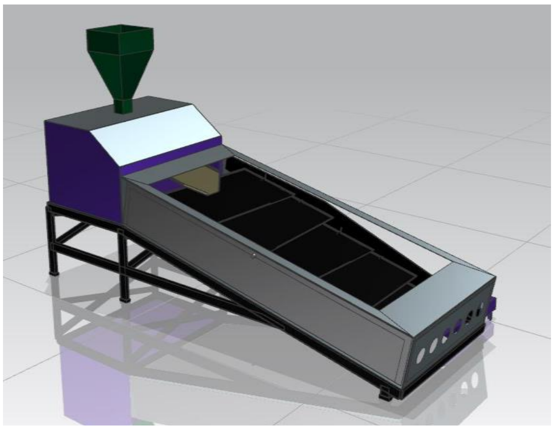

Fig. 1 Solar assisted disinfection equipment 3D CAD Model

It is found that, about 30% of this spoilage occurs during the storage of the produce. An effort will be made in this project by employing an innovative method for the disinfestation of food grains by using Solar Radiation. Solar energy, which is abundant in nature, can be economically employed for the disinfection of the food grains. The main advantage of this system is that the food grains are not treated chemically; they are only exposed to sunlight, which heats up air, heating and disinfecting the grains. Also the technology is energy efficient. This system will help the farmers and agriculturists in preservation of food grains, by disinfesting and drying them by removing moisture content at a low-cost. It can be scaled up to any required level. This will also help food industries to dry the food grains and other food products at a faster rate by adopting this system.

## 2. PROBLEM DEFINITION

Food grain drying for preservation is a well discussed, vast topic. Solar drying, being effective and economical, is of utmost importance. As discussed earlier, about 30% of spoilage of the produce takes place during storage. This is, due to the presence of moisture content. The moisture content may support the growth of bacteria, yeasts and molds (fungi). These kinds of spoilages are of a serious threat in a developing country, like India, where agriculture is considered as a backbone.

There is a gap in demand and supply of the produce. Increasing the produce increases the cost by a large scale. The other way of dealing this imbalance, would be to increase the efficiency of the produce. Spoilage occurs during seeding, growth, harvest, and storage. Storage spoilage takes out a major chunk of the produce. This can be overcome by proper storage methods. Drying of the food grains to reduce the moisture content, is one such methods, wherein, the moisture content can be reduced to such an extent, where the microbial activity is not supported, hence reducing the spoilage during storage.

Electricity is a luxury to most of the villages. A constant supply of electricity for drying, or refrigeration, is not economical. These issues may be addressed by using the abundantly available solar energy. The Solar energy can be used to directly used for drying grains, indirectly by heating air, which dries the grains, or a mixture of both kinds.

## 3. LITERATURE SURVEY

i. **DESIGN AND FABRICATION OF A SOLAR DRYING SYSTEM FOR FOOD PRESERVATION, MS. VAISHNAVI BHARAT CHOUGULE ET AL, IJRET 11TH AND 12TH MARCH.**

The study reviews construction and fabrication of mixed-mode solar dryer in which the grains are dried simultaneously by indirect radiation through the transparent walls and roof of the cabinet, and the heated air from the solar collector.

ii. **DESIGN AND DEVELOPMENT OF SOLAR SEED DRYER, MANGESH GAVHALE1 ET AL, IJISET VOLUME 2 ISSUES 4, APRIL 2015.**

The study in this paper focuses on the available solar dryer systems and new technologies. And also details of construction and operational principles of the wide variety of practically realized designs of solar-energy drying systems.

iii. **A REVIEW OF SOLAR DRYER TECHNOLOGIES, ASHISH D. CHAUDHARI, INTERNATIONAL JOURNAL OF RESEARCH IN ADVENT TECHNOLOGY, VOLUME 2 FEBRUARY 2014.**

In this paper various types of solar driers like mixed mode, natural circulation, forced circulation, green house type and tunnel type are reviewed with design parameters and performance, along with their advantages and limitations.

iv. **A REVIEW ON SOLAR DRYING OF AGRICULTURAL PRODUCE, ANUPAM TIWARI, JOURNAL OF FOOD**

This Paper reviews basic study of the type of solar dryers and distribution of global radiation, characteristics of solar drying and early work done on the process of solar drying, and also the factors to be considered for the design of solar dryers.

v. **A REVIEW PAPER ON SOLAR DRYER, UMESH TOSHNIWAL AND S.R KARALE, IJERA, VOLUME 3 ISSUE 2 MARCH-APRIL 2013.**

This paper reviews the fact that the solar dryer is more beneficial than the sun drying techniques. , and its efficiency during fair weather they can work too well. The use of solar dryers in the drying of agricultural products can significantly reduce or eliminate product wastage, food poisoning and at the sometime enhance productivity of the farmers towards better revenue derived.

vi. **SOLAR DRYING OF AGRICULTURAL PRODUCTS: A REVIEW, A.A. EL-SEBAII AND S.M. SHALABY, RENEWABLE AND SUSTAINABLE ENERGY REVIEWS 16(2012)37-43.**

This paper detail explains the type of solar dryer's i.e. direct solar dryer, indirect solar dryer and mixed mode solar dryer. It also discusses about the heat storage and air heater.

vii. **DRYING OF CHILLI USING SOLAR CABINET DRYER COUPLED WITH GRAVEL BED HEAT STORAGE SYSTEM A.K. KAMBLE ET AL, JOURNAL OF FOOD RESEARCH AND TECHNOLOGY VOLUME 1 ISSUE 2 OCTOBER- DECEMBER 2013**

This paper studies about the sample specification of the solar cabinet dryer and also it provides the results of the experiment conducted. In this study and experimentation, chilly is used as the testing material and finally it is concluded that the solar cabinet dryer coupled with gravel

viii . **SOLAR DRYING TECHNOLOGIES: A REVIEW, MEGHA S. SONTAKKEI AND PROF. SANJAY P., IRJES VOLUME 4, ISSUE, 4 APRIL 2014**

This paper reviews solar dryer is the best alternative option to avoid disadvantages of conventional drying methods. It is found that time required for drying in mixed mode solar dryer is less than other types of dryers. Forced circulation drying gives better result than natural circulation solar dryer.

## 4. OBJECTIVES

The main objectives of the project are as follows:

- To attain disinfection through reducing moisture, and hence the pathogens, that would thrive.
- To reduce the equipment cost, and make it affordable to the farmer.
- To remove requisite amount of moisture from the food grains, aiding in its preservation, and obtain optimum results.
- To reduce the time required for disinfecting the grains, and also make the equipment user friendly.

## 5. DESIGN OF SOLAR DISINFECTION SYSTEM

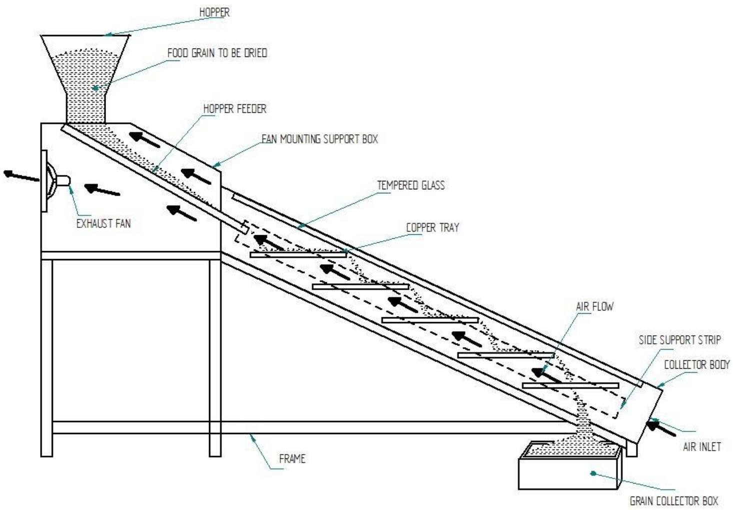


Fig. 2 Solar assisted disinfection equipment Schematic showing various parts

### *A. Collector Body*

The main body of the solar collector is similar to that of a flat plate solar water heater collector, but comprises of copper plates, in place of copper tubes, as in a water heater collector. It is a hollow rectangular box, with doors at both sides, to access the copper trays. The doors are well sealed to avoid air leakage. The bottom end has a plate with holes punched, which allows the air to flow in. The plate is removable, to allow experimentation with different shaped inlets. The other end connects to the box, which has exhaust fans fitted. The top is cut out, and is covered by tempered glass, allowing the solar radiation to be incident on the copper trays. The body is made out of Mild steel, and is not a load bearing component.

### *B. Exhaust fans*

Exhaust fans provide necessary suction in the equipment. It is mounted in a hollow box, much like the water tank in a solar water heater. The fans are two in number. The end opposite to the fans has a cut, which aligns with the cut in the collector body, allowing air to be sucked in, flowing on the copper plates. Hopper and hopper feeder tray are also fitted onto this box.

### *C. Exhaust fans*

Exhaust fans provide necessary suction in the equipment. It is mounted in a hollow box, much like the water tank in a solar water heater. The fans are two in number. The end opposite to the fans has a cut, which aligns with the cut in the collector body, allowing air to be sucked in, flowing on the copper plates. Hopper and hopper feeder tray are also fitted onto this box.

### *D. Hopper assembly*

The hopper assembly comprises of a Hopper, slider for flow adjustment, and a feeder tray. The grains are fed in the hopper. The slider allows the hopper to unload in a controlled fashion, onto the feeder tray. The feeder tray allows the grains to flow naturally from the hopper to the copper trays. The components are made of Galvanized Iron (GI), as it is safely usable in food processing.

### *E. Copper trays*

The copper trays, absorb the heat of the solar radiation, and get heated up. This heats up the food grains flowing over them. They are arranged in a zigzag fashion, with openings at alternate ends, to facilitate the grains to flow over them naturally, by gravity. It is supported by two flat strips, directly attached to the frame, with elongated holes for adjustment of inclination. For grains, which do not flow naturally, vibrations may be applied on the trays, for the purpose.

### *F. Grain collector*

Grains, after drying, are collected here. The grains can be emptied periodically. It is placed below a cut in the collector body. It is made out of Galvanized Iron (GI).

### *G. Frame and side supports*

The frame is made of MS rectangular tubes, and takes the load of the whole equipment. It also supports, two side supporting strips, which has elongated holes milled, for the trays to be bolted on. The holes also allow a change in tray inclination, as needed by the grains. These supports, bear the loads of the copper trays, and are made of MS sheet metal.

### *H. Insulation and paint*

Rock wool is used as the insulation, and is placed below the copper trays. The sides are covered with reflective aluminum foil, for maximum absorption of solar energy. The insides of the equipment and the copper trays are painted black, for maximum absorption of solar energy.

### *I. Fasteners*

For the copper trays, since inclination is made adjustable, bolts with wing nuts are used. Wherever the fasteners come into contact with the food grains, Stainless Steel fasteners are used, and MS fasteners are used at other places.

## 6 . DESIGN CONSIDERATIONS

1. Temperature – The maximum temperature estimated was 72.27°C, attainable in approximately, 75.28 minutes. The air inlet temperature or the ambient temperature Ta = 30°C (Room temperature).
2. Dryer trays – copper is used, to allow maximum absorption of incident solar energy, to dry the grains. The angle of inclination is to be made adjustable in two axes.
3. Efficiency – It is defined as the ratio of the useful output of a device to the input of the device.
4. Glass and flat plate collector – In this work, 4mm thick transparent glass is used. The metal sheet thickness should be of 0.8 – 1.0 mm; mild steel of 1.0mm thickness is used, since it can be machined without warping. The glass used as cover for the collector was 1m X 2m.
5. Flow of food grains through the equipment – It takes place either naturally by gravity, or is induced by vibration, depending on the grains ability to flow. The trays are arranged in a zigzag fashion, with cuts on the alternate sides, for the same purpose.
6. Exhaust fans – They are used to create the flow of air opposite to the flow of grains, thus using the counter flow principle for maximum rate of heat transfer.
7. Tilt angle of collector – based on the latitude of Bangalore, where it will be tested, and the fixed tilt angle was approximated as 0.87 times the latitude of Bangalore (12.97°), which is approximately 11.3 degrees.
8. Dimension – It is recommended that a constant exchange of air and a roomy drying chamber should be attained in solar food dryer design, thus the design of the collector and the hollow box housing the fans, was made as spacious as possible.

## 7. MATERIALS USED

The following materials were used for the construction of the domestic passive solar dryer:

- MS sheet metal – Used for the collector body. It was selected being relatively cheaper than other metals, and ease of machine ability with good strength.
- Tempered Glass – Used as the solar collector cover. It permits the solar radiation into the system, but resists the flow of heat energy out of the systems.

- Copper of 24-grade (0.6 mm) - Used for constructing the trays, on which grains flow.
- Galvanized Iron (GI) – Used for the parts that comes into contact with food grains. The parts include the hopper, hopper feeder tray and the grain collector.
- Fasteners of MS and SS, welding and adhesives.
- Rock wool for insulation, sides covered with Aluminum foil.
- Paint – Black for copper trays and inner parts of collector. Paint on exteriors of MS parts for aesthetics and avoiding rusting of metal.

## 8. FACTORS AFFECTING DRYING

- Size and shape
- Initial moisture content
- Final moisture content
- Type of product
- Bulk density

## 9. DESIGN CALCULATIONS

### A. APPROXIMATION OF COLLECTOR PLATE TEMPERATURE

G x αsun = αcopper . σ ( Tcopper$^4$ – Tsurrounding$^4$ ) --(1)

Total Incident Radiation = G x Apperture area

= 100 x (2120 x 1040) x 10-6

Qincident = 2204.8 W/m2 ---------------- (2)

Qtransmitted = τglass x Qincident

= 0.726 x 2204.8

Qtransmitted = 1600.6048 W/m2 ------------(3)

Substituting (3) in (1)

1600.6848 x 0.12 = 0.65 x 5.669 x 10-8 (Tcollector plate$^4$ – 308$^4$)

Tcollector plate = 72.2735° C

Where,

G= solar constant.

*σ= stefan boltzmann constant = 5.669 x 10-8 W/m²*

$\alpha_{copper}$= absorptivity of copper.

*τ*= transmitivity of glass.

### B. TIME REQUIRED TO REACH THE CALCULATED TEMPERATURE

$$\frac{Tt - Ta}{Ti - Ta} = e^{\frac{-hAs}{\rho Vc}}$$

$$\frac{70 - 35}{25 - 35} = e^{\frac{-9.81 \times 2.2048 \times t}{850 \times 0.22048 \times 386}}$$

$-3.5 = e^{-0.8947\,t}$

Taking log on both sides and solving,

t = 75.28 minutes

Where,

Tt = Temperature at't' sec (°C)

Ta = Ambient temperature (°C)

Ti = Initial temperature (°C)

h = convective heat transfer coefficient = 9.1 W/m2

As = Surface Area (m²)

ρ = Density (Kg/m³)

V = Volume (m³)

C = Specific heat (J/Kg/K)

### C. RATE OF HEAT TRANSFER

$Q_c = h_c(T_{air} - T_s).A$--------------------------------------(1)

$T_{air} = T_{ch} = 72°$ C = 345K

$T_{surface} = 35°$ C = 308K

$A_s = 0.3326m^2$

$q_c = h_c(345 – 308).0.3326$

$\mathbf{q_c = 123.062\ W/m^2/K}$

Radiative heat transfer is given by,

$Q_r = h_r(T_{ch} - T_s).A$---------------------------------------(2)

$$h_r = \frac{\varepsilon.\sigma\,(T_{ch}+273)^4 - (T_s+273)^4}{(T_{ch}+273) - (T_s+273)}\text{----------------------(3)}$$

$$= \frac{0.95 \times 5.67 \times 10^{-8}\,(72+273)^4 - (35+273)^4}{(72+273) - (35+273)}$$

= 7.5233 W/m/K

From (2)

$q_r = 7.59(345 - 308).0.3326$

$\mathbf{q_r = 92.58\ W/m^2/K}$

**Where,**

*Tair = Sourrounding Hot air Temperature*

*Tsurface = Food grain surface temperature*

*A = Surface area of the product*

*hc = Convective heat transfer coefficient (W/m²/K) = 10 W/m²/K*

*ε = emmisivity of food grain = 0.95*

*σ = stefan boltzmann constant = 5.669 x 10-8 W/m²*

## 10. ADVANTAGES AND LIMITATIONS

### ADVANTAGES

- The High temperature movement of air and lower humidity increases the rate of drying.
- Since food is kept in a chamber, it is safe from contamination by rodents, birds, insects, animals and dust.
- Higher productivity as the result of higher drying rate.
- Drying can be done in the small area.
- The dried products can be stored for a longer period of time due to better drying process.

### LIMITATIONS

- There is no definite control over the temperature attained in the collector.
- The food grains may be over heated and may lose their properties.
- Less efficient on cloudy days, and operates only in daytime.

- Quality of food may be affected, if overheated.

## 11. APPLICATIONS OF THE EQUIPMENT

- We see the application of this project widely in the agricultural sector, directly by the farmer who produces it, or by the processing industries.
- It can be used in preservation of organic edible produce (food grains), for packaging.
- Packed food items, which would range from ready to eat food to ready vegetables and grains, suitably packed for prolonged storage by the consumer, before using it, and is now a thriving industry owing to busy lives of people.
- Many Food Processing industries on a very small scale, to very big industries, involving mass production, would also benefit from the machine

## 12. OPERATION

The grains to be dried are fed in through the hopper. The flow rate can be controlled by a slider arrangement provided. The grains, at a controlled flow rate, falls onto the feeder tray, and move down by gravity. The grains fall on the copper trays, which are inclined in two directions. The sideways inclinations, follow a zigzag pattern, hence the grains flow along the tray, fall from the provided opening, onto the next tray, and fall off the opening of that tray, which would be cut in the opposite end of the previous tray. The last tray empties the grains onto a grain collector bin, which can be unloaded, once filled. The solar radiation is incident on the tempered glass, which allows the radiation to seep in. The radiation is trapped inside, due to the Rockwool insulation, reflective covering on the sides, and the glass itself. The building up temperature, heats up the trays, and hence the grains directly. The provided exhaust fans draw in air through the equipment, which also gets heated up. This air heats up the food grains along with direct drying, drying and carrying the moisture content along with it, like in a hot air dryer. The combined effect of direct solar drying, and hot air drying, reduces the moisture content of the food grains, aiding in its preservation.

## 13. CONCLUSION

The equipment will help in disinfecting all types of food grain, which the farmer would produce. The equipment would provide results by removing just requisite amount of moisture. The farmer would benefit from the machine, as it minimizes the use of electricity and uses abundantly, naturally available solar energy. He should be able to disinfect the food grains by removing moisture, so that the pathogens would not thrive. There would be no harmful effluents from the machine, and is environmentally safe. The use of this equipment will help to have savings in power consumption, disinfestations time and rate of disinfestations

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## REFERENCES

[1] Ms. Vaishnavi Bharat Chougule et al, “Design and fabrication of a solar drying system for food preservation”, ijret 11th and 12th march.
[2] Mangesh Gavhale et al, “Design and development of solar seed dryer”, ijiset volume 2 issues 4, april 2015.
[3] Ashish D. Chaudhari, “A review of solar dryer technologies”, international journal of research in advent technology, volume 2 february 2014.
[4] Anupam Tiwari, “A review on solar drying of agricultural produce”, journal of food
[5] Umesh Toshniwal and S.R Karale, “A review paper on solar dryer”, ijera, volume 3 issue 2 march-april 2013
[6] A.A. El-Sebaii and S.M. Shalaby, “Solar drying of agricultural products: a review”, renewable and sustainable energy reviews 16(2012)37-43.
[7] A.K. Kamble et al, “Drying of chilli using solar cabinet dryer coupled with gravel bed heat storage system” journal of food research and technology volume 1 issue 2 october- december 2013
[8] Megha S. Sontakke1 and Prof. Sanjay P., “Solar drying technologies: a review”, irjes volume 4, issue 4 april 2014.
[9] Grain storage management in india, m. Esther magdalene sharon, et al., journal of postharvest technology.
[10] Prashant Pandharinath Said, et al., “Food grain storage practices-a review”, journal of grain processing and storage
[11] Megha S. Sontakke, et al., “Solar drying technologies: a review”, international refereed journal of engineering and science.
[12] Ganesh Hegde, et al., “Scope for solar energy in kerala and karnataka”, presented at: lake 2012 - national conference on conservation and management of wetland ecosystems, school of environmental sciences, mahatma gandhi university, kottayam.
[13] Global Energy Network Institute , “Overview of renewable energy potential of india”.
[14] Sagar Kapadiya, et al., “Solar drying of natural and food products: a review”, international journal of agriculture and food science technology

[15] Debabandya Mohapatra, et al. "Current trends in drying and dehydration of foods", food engineering, nova science publishers, inc
[16] Ashish D. Chaudhari, "A review of solar dryer technologies", international journal of research in advent technology, volume 2 february 2014.
[17] Kathiravan Krishnamurthy, et al, "Infrared heating in food processing: an overview", comprehensive reviews in food science and food safety.
[18] Manish Joshi, et al , "Preservation of food items using solar dryers: a review", International journal of engineering research and application.

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