DESIGN AND FABRICATION OF SOLAR ASSISTED SPICE DRYER

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Abstract - *Spice drying using conventional methods like open air sun drying and smoke drying could lead to insufficient product quality. In order to be marketable, the product meant for sale should meet high quality standards. Solar drying improves the quality of the products in terms of colour, flavour and appearance, reduces the risk of microorganism growth, prevent insect infestation and contamination by foreign matters. The aim of the project is to design and manufacture a solar assisted spice dryer that can deliver good quality products. The preliminary aim is to dry nutmeg which is very sensitive to temperature, along with other fruits such as pepper, cardamom etc. The machine consist of a chamber for heating air, a blower, sieving system, and a solar flat plate collector system to reduce power consumption.*

Key Words: Solar, Nutmug mace, solar heat collector, Relative humidity, Temperature

1. INTRODUCTION

Drying is one of the most important post-harvest operations for herbs and spices. It is mainly aimed to reduce the moisture content for preservation .For some spices such as chilly, pepper, nutmeg mace etc., drying is not only for preservation purposes but also for controlling the taste and flavour in order to increase their market value. Natural sun drying method is commonly used for drying herbs and spices. Although negligible investment is required by this method, products being dried are usually contaminated by insects, birds and dusts and subject to improper and non-uniform drying (especially in rainy season). In this project we are going to take care of the draw backs of natural drying by developing a closed chamber solar assisted spice drying machine

1.1 Literature Review

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.

1.2 Problem Statement

Food scientists have found that by reducing the moisture content of food to between 10 and 20%, bacteria, yeast, mold and enzymes are prevented from spoiling it. The flavor and most of the nutritional value is preserved and concentrated [16].Wherever possible, it is traditional to harvest most grain crops during a dry period or season and simple drying methods such as sun drying are adequate. However, maturity of the crop does not always coincide with a suitably dry period. Furthermore, the introduction of high-yielding varieties, irrigation, and improved farming practices have led to the need for alternative drying practices to cope with the increased production and grain harvested during the wet season as a result of multi-cropping.

In the case of spices the drying helps in preserving its texture as well as its flavour.

2. METHODOLOGY

Design phase:

- Developed several methods
- Chosen the best alternative

- Prepared detailed design

Analysis:

- CFD Analysis

Fabrication:

- Procurement of components
- Fabrication and field testing

2.1 DESIGN

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 design is done based on the properties of Nutmug mace which is a main crop in the hilly areas of kerala.

Initial moisture content of nutmug mace=80%

Requied moisture content for safe storage=10%

Drying Temperature=60^{0}C

2.1.1 DESIGN OF DRYING CHAMBER

The design of the drying chamber is drawn on ANSYS 16.2.

The dimension of the dryer is taken in such a way that to dry 5Kg of nutmug mace.

The chamber dimensions are given below,

Length	70cm
Breadth	40cm
Height	50cm
No of trays	8
Tray size	30*40cm
Gap between trays	10cm

Table-1: Chamber Specifiation

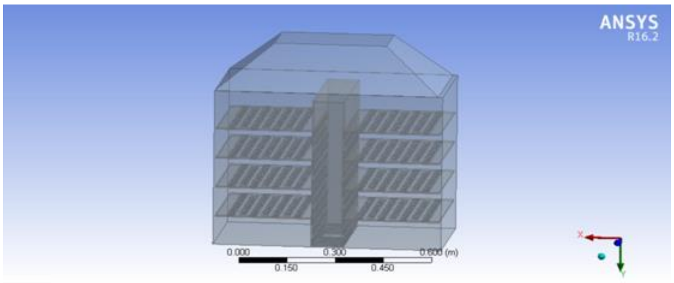


Fig-1: Drying Chamber

2.1.2 DESIGN OF SOLAR HEAT COLLECTOR

The solar heat collector is done based on two factors, the total energy required and the optimum temperature needed.

On drying 5kg of nutmeg mace, water removed is 3kg and dried mace is 2kg

Heat required = $mC_p\Delta T + mC_f$

= 3*4200*30+3*110*1000

= 708 KJ

708 KJ is supplied in 8 hour

Heat supplied per second $= \frac{708\times1000}{8\times3600} =$ 24.5 watts

Heat acquired from solar collector

$$U_L = (\alpha\tau)I_T A_c - U_L A_L (T_c - T_a)$$

$$30 = A_c[\alpha\tau I_T - U_L(T_c - T_a)$$

$$A_c = \text{0.8 * 0.9* 800 - 18.5 * 30}$$

$$= 0.5203\, m^2$$

Heating Coil Design

708KJ = V* I* T

= 230 * I * 8 *3600

I = 0.107A

708KJ $= I^2 \times$ R $\times 8 \times 3600$

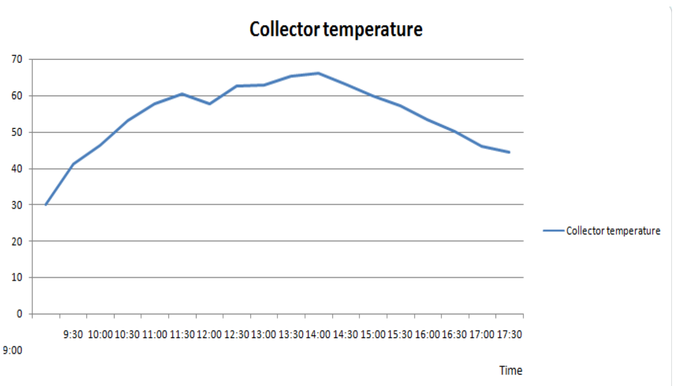
R = 2147.5Ω

Since manufacturing of heating coil based exactly on our specification is difficult, a suitable heating coil, available in market is selected

Based on the above calculations, solar heat collector is designed

Fig-2: Solar Collector

The shown model is fabricated and tested, a maximum temperature of 65^0



Graph -1: Collector temperature

2.1.3 DESIGN OF ELECTRONIC CIRCUIT

Electronic circuit is designed in order to maintain an optimum drying temperature throughout the drying process. The electronic circuit design is given below :

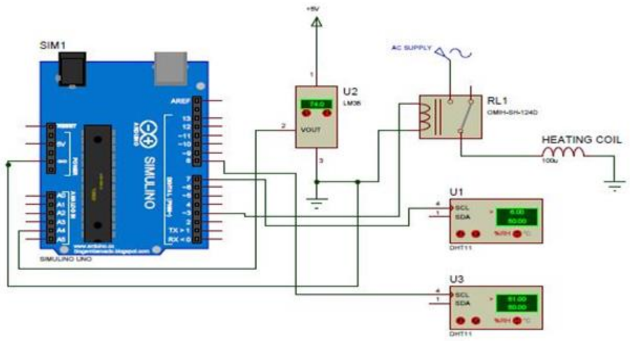


Fig 3 : Electronic circuit design

This electronic circuit works based on the program given below along with its flow chart.

```
#define TempPin A4

int TempValue=0;
const int fan = 4;
const int heater = 3;
void setup()
{
pinMode(fan, OUTPUT);
pinMode(heater, OUTPUT);
digitalWrite(fan,LOW);
digitalWrite(heater,LOW);
Serial.begin(9600); // Initializing Serial Port:-baud rate
}
```

```
void loop()
{
TempValue = analogRead(TempPin); // Getting LM35 value and saving it in variable
float TempCel = ( TempValue/1024.0)*300; // Getting the celsius value from 10 bit analog value

if(TempCel<50)
digitalWrite(heater,HIGH);
else
digitalWrite(heater,LOW);

if(TempCel>60)
digitalWrite(fan,HIGH);
else
digitalWrite(fan,LOW);
}
```

3. ANALYSIS

The analysis of drying chamber is done with the help of ANSYS 16.2 Fluent software. The result obtained is clearly says that an effective heat distribution is obtained in the chamber.

The meshed geometry and the temperature contour obtained are shown below.

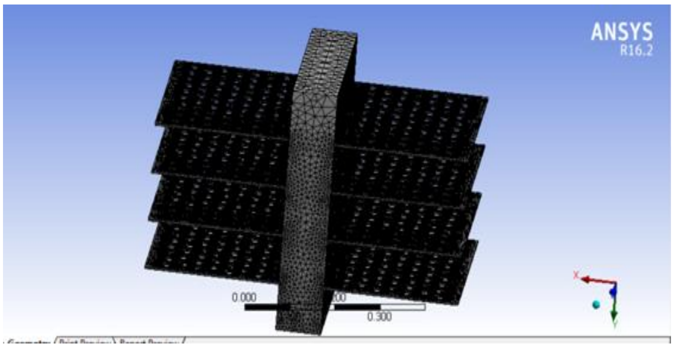
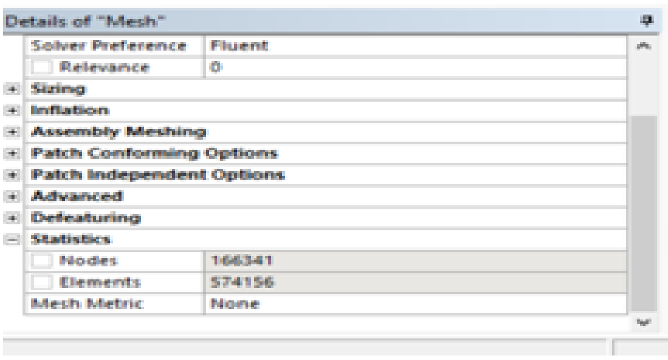


Fig-4 : Mesh of the chamber



Details of "Mesh"	
Solver Preference	Fluent
Relevance	0
Sizing	
Inflation	
Assembly Meshing	
Patch Conforming Options	
Patch Independent Options	
Advanced	
Defeaturing	
Statistics	
Nodes	166341
Elements	574156
Mesh Metric	None

Fig-5 : Statistics of mesh

3.1 TEMPERATURE CONTOUR

Temperature contour shows the heat distribution inside the drying chamber. The inlet conditions are given as follows, Inlet Temperature=60^{0}C

Inlet velocity =1.5m/s

Inlet pressure=1 bar

As per the inlet conditions the software will produce a temperature distribution. The result obtained as per our conditions says that the design is well enough the heat is available at every at the required space.

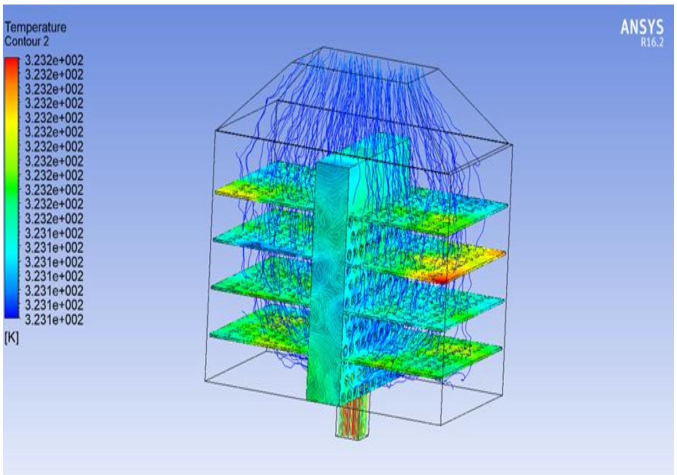


Fig-6 : Temperature contour

4. FABRICATION

The design was analysed and approved, then we started the fabrication part. The fabrication includes the fabrication of Solar heat collector and the drying chamber.

4.1 MATERIALS USED

MATERIAL	MATERIAL
ASBESTOS	IRON SHEET
ALUMINIUM GRILL	SHUTTER FAN
ALUMINIUM NET	CAST IRON SQUARE PIPE
DC FAN	MS ANGLE
HEATING COIL	RUBBER HOSE
PLYWOOD	REGULATOR
ALUMINIUM TUBE	TEMPERATURE SENSOR
MATTE BLACK PAINT	ARDUINO
ALUMINIUM FOIL	GUM
	HINGE

Table-2: Material chart

4.2 FABRICATED MODEL

This is the fabricated model of solar assisted spice dryer. Here solar heat collector, drying chamber, heat carrying passage and the electronic components are all interconnected in such a way that it works effectively as a spice dryer.

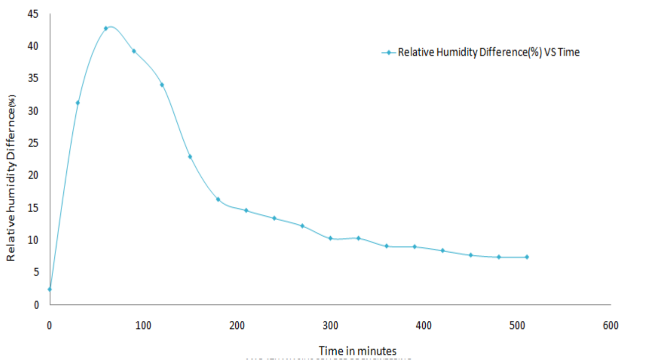
Fig-6: Fabricated model

5. EXPERIMENT AND RESULTS

After the completion of the fabrication the system had been tested for a week and the readings were noted and the drying time was observed as 8 hours. The relative humidity, temperature etc were noted and the graphs were plotted.

	A	B	C	D	E	F	G	H	I	J	K
1	sl no	measuring interval	interval in min	Relative Humidity	Collector temperature	tempereture i	Relative Humidity 2	Temperature 2	Relative Humidity defference	Energy meter reading	difference
2	vertical	for 60°C(open cycle)		RH1	T	T1	RH2	T2	RH2-RH1	initial raeading: 181.1	
3	1	9:00	0	35.4	30.1	40	37.8	30.2	2.4	181.1	0
4	2	9:30	30	25	41.26	54	56.2	33.5	31.2	181.4	0.3
5	3	10:00	60	21.1	46.34	59.58	63.8	36.8	42.7	181.5	0.1
6	4	10:30	90	21	53.24	60.1	60.2	38.13	39.2	181.5	0
7	5	11:00	120	20.9	57.62	58.51	54.9	36.9	34	181.5	0
8	6	11:30	150	20.7	60.32	60.49	43.6	47.5	22.9	181.5	0
9	7	12:00	180	20.8	57.62	58.34	37.1	40.25	16.3	181.5	0
10	8	12:30	210	21	62.58	62.58	35.6	45.8	14.6	181.5	0
11	9	13:00	240	21.1	63.01	63.01	34.5	49.5	13.4	181.5	0
12	10	13:30	270	20.6	65.43	64.32	32.8	49.7	12.2	181.5	0
13	11	14:00	300	20.9	66.14	64.58	31.2	49.8	10.3	181.5	0
14	12	14:30	330	20.7	63.2	60.26	31	50.7	10.3	181.5	0
15	13	15:00	360	20.7	59.95	59.8	29.8	51	9.1	181.5	0
16	14	15:30	390	20.7	57.24	56.24	29.7	51.2	9	181.5	0
17	15	16:00	420	20.6	53.5	58.54	29	51.3	8.4	181.6	0.1
18	16	16:30	450	20.7	50.08	59.95	28.4	51.4	7.7	181.9	0.3
19	17	17:00	480	20.7	46.01	60.01	28.1	51.4	7.4	182	0.1
20	18	17:30	510	20.7	44.54	56.02	28.1	51.4	7.4	182.3	0.3

Table-3 : Observattions



Graph-2 : Relative humidity vs time

3. CONCLUSION

Designed, manufactured and tested the solar assisted spice drier successfully. It is observed that the drying time is about 8 hours. When compared to conventional drying process, it is two times more efficient. Also when compared to electrical drier, it takes 2 hours more, but the working cost is much less.

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