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Experimental and Simulated Investigation of Solar Greenhouse Dryer for Drying Fenugreek Leaves using Computational Fluid Dynamics

Soumya Hublikar[1] and Dr.T.R.Anil[2]
[1]Department of Mechanical Engineering, Sanjay Bhokare Group of Institutes Miraj India,
Email:hublikarsn@sbgimiraj.org
[2]Department of Aeronautical Engineering, Gogte Institute of Technology Belagavi India,
Email:tranil@git.edu

***Abstract*—Preservation of fenugreek leaves is the important post-harvest in the food industry. Traditional methods of drying are not efficient [Oluwasanmi Iyiola Alonge,2019]. In this work greenhouse dryer is developed and fabricated to dry fenugreek leaves [Petros Demissie, 2018]. Experimentation is done by placing 1 Kg of fenugreek leaves in the drying unit and the parameters like temperature, humidity, weight of samples are recorded at 15 minutes interval of time. The modeling was done using Computational Fluid Dynamics for simulating the temperature and solar radiation distributions throughout the drying unit. [Oluwasanmi Iyiola Alonge,2019].Experimental and simulation results are in good agreement.**

***Index Terms*— Greenhouse dryer, Computational fluid dynamics, Fenugreek leaves, Simulation, Drying.**

I. INTRODUCTION

Drying is the oldest preservation technique for agricultural products and an energy-intensive process. High prices and the scarcity of fossil fuels have placed an emphasis on the use of alternative sources of renewable energy. [B K Bala, 2013]. Drying agricultural products with renewable energy such as solar energy is environmentally friendly and protects the environment. Drying is very important as this helps in better enzymatic action and also in grinding and also enables storability of products under ambient temperatures. Different drying methods are available for drying of the agricultural crops. Fenugreek leaves are good sources of vitamins and minerals and are available only for a short period but can be dried for storage. Dehydrated leaves are rich sources of β-carotene and iron and can be used in off seasons [B.K.Bala,2013].The time required for drying the fenugreek leaves was observed to decrease with increase in drying air temperature [P. D. Jawake]. S.R Navale et.al developed solar cabinet dryer and compared it with open sun drying for drying fenugreek leaves. The study that the sample dried in cabinet solar dryer took four hours while open sun took seven hours to dry at 87% (wb) moisture content. Kumar et al (2013) developed greenhouse dryer and measured the atmospheric air temperature, relative humidity, air velocity, solar radiation in no load conditions. It is observed from the experiments that drying conditions in natural convection greenhouse drying are not favorable because of high relative humidity inside the dryer so a forced convection type dryer has been proposed.

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Computational fluid dynamics simulations are widely used because of their ability to solve equations for the conservation of mass, momentum, and energy using numerical methods to predict temperature, velocity, and pressure profiles in the drying chamber. (Suhaimi et al., 2013). Computational performance of the ISD solar energy system was evaluated using MATLAB Simulink. The estimated air mass flow in the inlet of the ISD was 0.75 kg/s. Purusothaman & Valarmathi et al (2018) have performed Computational fluid dynamics(CFD) analysis of greenhouse dryer in which higher temperature is observed in forced convection then natural convection by 41%. Sanghi et al (2018) have simulated the corn drying process in a solar cabinet dryer. The result has been validated with experimental data.

Many researches have been done in the field of analyzing dryers. Mixed mode type solar greenhouse dryer has been suggested and for obtaining the better results it has been proposed simulate the model using Computational Fluid Dynamics.[Ravi Kumar Sahu,2018].In this paper experimentation and simulation of a greenhouse type indirect solar dryer is done for predicting the air flow and temperature distribution [Oluwasanmi Iyiola Alonge,2019].

II. Materials And Methods

A. Description of the dryer

Greenhouse Dryer has a collector and an insulated drying chamber provided with exhaust fans. The size of the solar collector is 1.22 x 0.99 x 0.18(all in meters) and it consists of copper sheet (1.17m x 0.9m) coloured with black paint. The collector box was made with a 5mm thick structural steel frame. The copper foil was supported by plywood and the thermocol was placed on the side walls. A 4mm thick single window glass was attached to a hopper frame at a distance of 0.1mm above the copper foil. The hopper was tilted at an angle of 32 ° to the surface of the earth. 0.23m × 1m × 0.25m drying chamber was developed from the GI sheet. A tray (on which the product was placed) was stacked. The frame of each tray (1.13 mx 0.9 m) was made of mild steel. Atmospheric air enters the collector and then flows up through the items to be dried in the drying chamber. The chamber was insulated on all sides except the top, which had extractor. A 30 watt-solar cell module was used to power a dc fan for ventilating the dryer. Experiments were performed by placing fenugreek leaves on the trays during February 2019, data of temperature, air velocity, humidity and weight of samples were collected using thermocouples, anemometer, hygrometer and weighing machine respectively.

B. CFD Modelling

The geometry of greenhouse dryer consists of collector and dryer. Each region was modelled and then exported to FLUENT for mesh development.

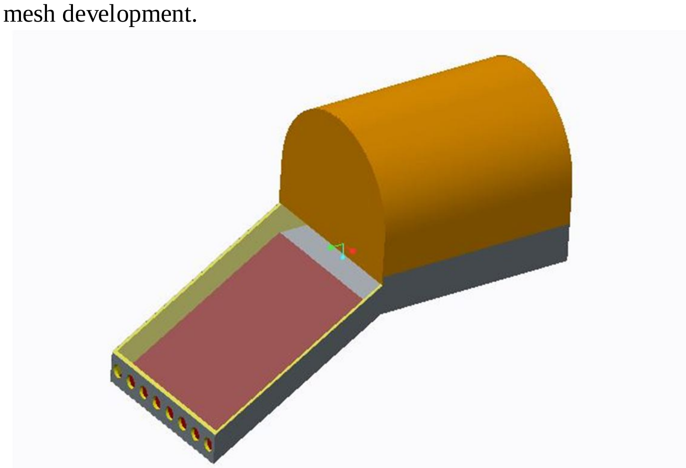


Figure 1: Geometric Modeling of Solar Dryer

Generation of grid is the next step for the validation of the dryer. For this geometry, tetrahedral unstructured mesh is used. Total number of nodes is 125370 and elements are 667090.

The boundary conditions are specified in the pre-processing stage in CFD. [Miguel Andrés Daza Gómez,2018]. The inlet and outlet are modeled as mass flow and pressure respectively and transient system with a flow regime turbulence that is exemplified with the K-ε model. The velocity is modeled at 1 m/s.

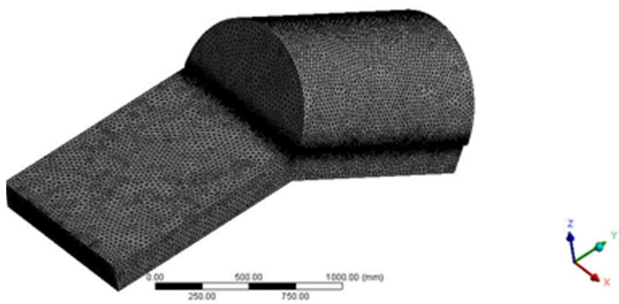


Figure 2: Meshing of the Domain

II. Results And Discussions

A. Experimental Results

Figure 3 shows the variations of ambient air temperature and solar dryer temperature with respect to solar radiations during experimentation period. The solar intensity varied from 547W/m2 at 11.00am to maximum of 957 W/m2 at 2.00 pm. The atmospheric air temperature varied between 32 ℃ to 41 ℃ while the temperature inside the solar dryer varied from 38 ℃ to 55 ℃. From figure it is clear that dryer temperature was 15 ℃ to 20 ℃ more than the ambient temperature. The experiment suggests that the product kept inside the dryer is dried efficiently. Also the dryer temperature varied according to the solar intensity during this experimental period.

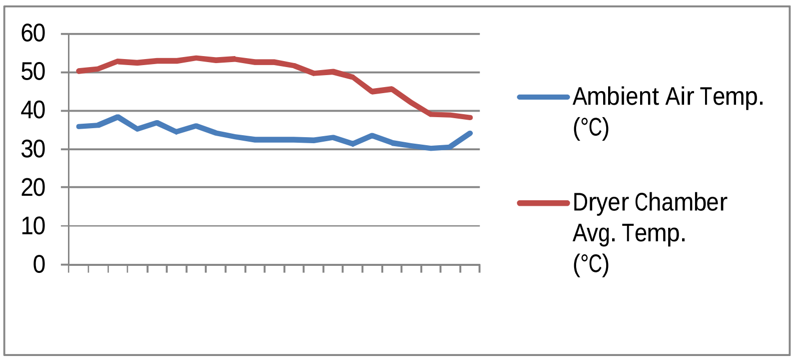


Figure 3: Variation of dryer chamber temperature with respect to drying time for fenugreek leaves

B. Simulation Results

The velocity and temperature distributions are obtained from the CFD analysis. It is observed that velocity is uniform throughout the dryer as shown below.

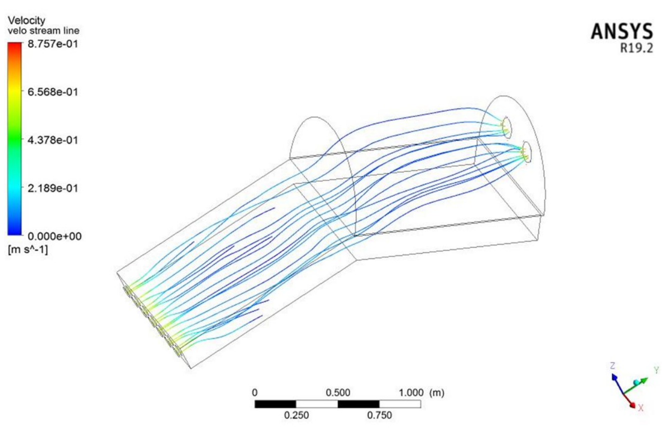
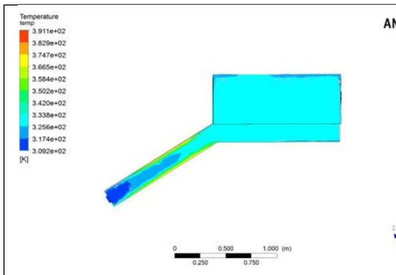
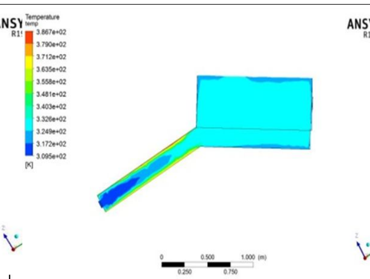


Figure 4: Profile of velocity of air stream

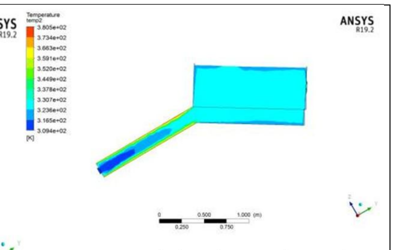
Temperature distributions is obtained at different times 12 noon, 1 pm,2pm, 3pm and at 4 pm and temperature was 56°C, 55°C, 54°C, 51°C and 47°C respectively as shown below. Sun rays are almost perpendicular over the greenhouse dryer and tray at 12 noon. So, highest temperature is observed during this time period.



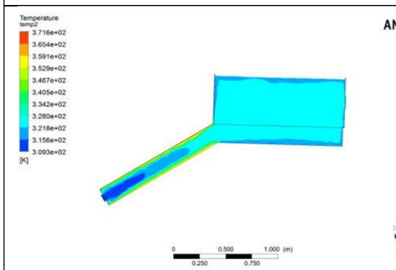
Temperature variations in solar greenhouse dryer at 12 noon



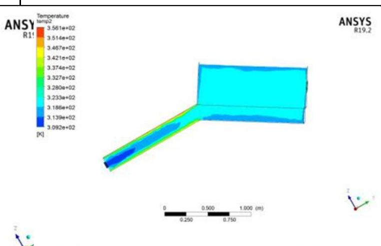
Temperature variations in dryer chamber at 1 pm



Temperature variations in greenhouse dryer at 2 p



Temperature variations in greenhouse dryer at 3 pm



Temperature variations in greenhouse dryer at 4 pm

Figure 5: Temperature profiles at different time intervals

III. Conclusion

Experimentation and simulation of solar greenhouse dryer has been conducted. Experiments are performed outdoors in February 2019 and recorded various parameters like temperature, humidity and weight of the samples at different time intervals. For the simulation purpose, the geometry has been modelled in CREO 2.0 and analysis has been done using Fluent 14.0. Numerically obtained results are in good agreement with experimental results.

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