CFD and Experimental Evaluation of Solar Seed Dryer

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Abstract : Solar energy is the most promising of the renewable energy sources in view of its apparent limitless potential. Direct solar energy has been applied to grain drying for years. The sun and wind dry crops in the field, stack or window. Artificial drying has supplemented this process to increase the harvest rate during inclement weather or to minimize field losses. This article investigates solar grain drying as one alternative. Radiant energy from the sun reaching the earth surface is known as shortwave radiation, solar radiation, solar energy or isolation. The total radiation may be direct from the sun; diffuse, scattered by the atmosphere or reflected, from adjacent surfaces.The dryer temperature and drying rate were found to be higher than the natural open sun drying method. The results showed a considerable advantage of solar dryer over the traditional open sun drying method in term of drying rate and less risk for spoilage.

***Keywords*–Solar seed dryer, exhaust fan, Solar energy,Drying, CFD.**

1. INTRODUCTION

Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting. Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications requiring low to moderate temperature below 80°C, such as crop drying and space heating. Drying is the oldest preservation technique of agricultural products and it is an energy intensive process. High prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources. Drying of agricultural products using renewable energy such as solar energy is environmental friendly and has less environmental impact.

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. 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.

One basic disadvantage of forced convection dryers lies in their requirement of electrical power to run the fan. Since the rural or remote areas of many developing countries are not connected to the national electric grids, the use of these dryers is limited to electrified urban areas. Even in the urban areas with grid-connected electricity, the service is unreliable. In view of the prevailing economic difficulties in most of these countries, this situation is not expected to change in the foreseen able future. The use of natural convection solar dryer could boost the dissemination of solar dryers in the developing countries. Therefore, experimental performance of solar dryer has been evaluated in this project.

This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the 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 and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74% for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

2. LITERATURE REVIEW:

HOSSAIN et al.(2006) investigate that a mixed mode type forced convection solar tunnel drier was used to dry hot red and green chillies under the tropical weather conditions of Bangladesh. The drier consisted of transparent plastic covered flat-plate collector and a drying tunnel connected in series to supply hot air directly into the drying tunnel using two fans operated by a photovoltaic module. The drier had a loading capacity of 80 kg of fresh chillies. Moisture content of red chilli was reduced from 2.85 to 0.05 kg kg^{-1} (db) in 20 h in solar tunnel drier and it took 32 h to reduce the moisture content to 0.09 and 0.40 kg kg^{-1} (db) in improved and conventional sun drying methods, respectively. In case of green chilli, about 0.06 kg kg^{-1} (db) moisture content was obtained from an initial moisture content of

7.6 kg kg^{-1}(db) in 22 h in solar tunnel drier and 35 h to reach the moisture content to 0.10 and 0.70 kg kg^{-1} (db) in improved and conventional sun drying methods, respectively.LMRE et al.(2007)investigate that importance of Solar Drying is increasing worldwide, especially in areas where the use of the abundant, renewable and clean solar energy is essentially advantageous. In the developing countries and in rural areas the traditional open-air drying methods should be substituted by the more effective and more economic solar drying technologies. RBD needs should be considered in the basic research and experimental fields; in performance measurement; in the modelling simulation- design and testing. The international co-operation of experts should be improved and more efforts would be needed in the policy and in the public information.KOBAYASHI et al.(2007) investigate that Seeds with high moisture content are easily attacked and damaged by microorganisms. It is important to reduce the moisture content to a safe level for storage. Soybean seeds, directly mixed with silica gel in different mass ratios, were dried in static beds at different environmental temperatures. The drying kinetics were compared and analyzed. A diffusion type model was used to simulate the sorption drying process with success. Simple relations have been developed for sorption isotherms of both soybean and silica gel. A mass diffusivity equation for soybean drying was supplied in Arrhenius type.

ADENIYI et al. (2012) investigate that A growing preservation technique in western part of Nigeria is the use of solar dryer box. Conventionally, exposure to direct sun light has been the practice to preserving farm produce because majority of the farmers cannot afford advanced techniques that may depend on electricity supply from the national grid. Recent studies have shown that alternatives to direct exposure to the sun are preferable for vitamin preservation. A simulation of a solar box design for such purpose is presented for temperature distribution based on sun direct solar irradiation of 1423W/m^2 of Akure (5.304º Latitude 7.258º Longitude). Results compare well with experiment.KUMAR et al. (2014) investigate that for the drying agriculture product, solar dryer with natural convection is presented. Mostly agriculture products are dry in the winter season. Solar radiations play the important role in the drying process, because in the winter season the environment temperature observed less as compare to rest of the year. So it is necessary to optimize the design of the solar dryer for better results. For the better efficiency of the dryer some parameters play important role like material of the absorber plate, gap between glass and absorber plate, hole-size and heat loss. To optimize the design of solar dryer experimental data analyzed in CFD tool to achieve better efficiency of solar dryer. YALDYZ et al.(2014) investigate that a solar cabinet dryer consisting of a solar air heater and a drying cabinet, was used in drying experiments.Our results revealed that drying air temperature could increase up to about 46°C. Drying air velocity had an important effect on drying process. Drying time changed between 30.29 and 90.43 hours for different vegetables by the solar drying. This drying time was between 48.59 and 121.81 hours for the natural sun drying. Drying curves could be explained by determined thin layer drying models satisfactorily with high determinant ion coefficients.

SONTAKKE et al.(2015) investigate that Solar drying is one of the application of solar energy. Drying means moisture removal from the product. Drying is helpful in preserving food product for long time; it prevent product from contamination. Direct solar drying, indirect solar drying, and mixed mode solar drying these are different solar drying methods. Primarily open to the sun or direct sun drying technique is used. However, it has some disadvantages. These disadvantages can be eliminated by indirect type of dryer which is used for drying products as application of solar energy. In this paper, we studied the different technique of drying and various modes of solar drying. KUMAR et al. (2015) investigate uncertain price rise and rapid depletion of fossil fuels accelerated the development of renewable energy in the form of alternative power sources. Solar is an abundant, renewable and sustainable energy source that attracted many eminent researchers across the world to work in the field of solar energy applications.RAHMAN et al.(2015)investigate that Particularly in the low drying temperature drying is an energy intensive process and requires a suitable optimization technique. This work represents the kinetic simulation and energy efficient optimization technique for drying long grain, i.e. rice. At 30–60◦C temperature the grains have been dried in a solar powered air dryer. After certain time interval the enzymatic activity and the moisture content have been measured. Genetic Algorithm (GA) has been used for the simulation and the optimization process while the experimental data have been used to fit the thin layer drying model. The results indicate that between 40 and 50◦C temperature and the 1.3–1.5 m/s air flow rate the drying time for the rice is around 120–180 min.ABDELGAIED et al.(2016) investigate the effect of rotary desiccant wheel on the thermal performance of the solar dryer unit is numerically investigated. The solar dryer unit integrated with rotary desiccant wheel consists of rotary desiccant wheel, solar air collector, and drying unit. The theoretical models of the desiccant wheel and solar collector have been validated using an experimental data. Also, the effects of desiccant wheel rotation speed on the performance of this system are investigated.AMBESANGE, et al. (2017) investigate that Energy is a crucial input in the process of economic, social and industrial development of any nation. Some important applications of solar energy are solar water heating, solar space heating/cooling, solar cooking, solar crop drying, solar power generation etc. Simplest method to utilize solar radiation is to convert it into thermal energy for heating applications by using solar collectors. Solar air Dryer because of their inherent simplicity are cheap and are used for many domestic and commercial applications like space heating, crop drying, wood seasoning etc. In this paper the objective of the CFD flow study is to design, test and optimize flow-conditioning devices, as appropriate, to guide the gas flow through the duct. In this a two-dimensional numerical simulation of the heat transfer, Nussult number, Velocity and temperature was conducted using the CFD code FLUENT VERSION 14.5. The CFD modeling involves numerical solutions of the conservation equations for mass, momentum and energy. TOMAR et al.(2017) investigate that Drying reduces the moisture content of harvested crops thus slowing decay processes to enable longer term storage. Solar dryers contain the crop being dried, to enhance solar energy collection incurring lower crop losses than are associated with open-sun drying and recurrent costs than are inherent to uses of fossil-fuels for drying. The influences of key environmental, operational and design parameters for solar dryers are discussed including: (i) psychrometry of drying processes and ambient conditions, (ii) how initial crop properties are converted to final desired product attributes, (iii) feasibility of using powered components such as fans and (iv) air-heating solar collector selection.

3. EXPERIMENTAL SETUP AND CFD ANALYSIS:

(A)

(B)

Figure1.Experimental setup (A) Front view (B) Side view

➢ **CFD ANALYSIS:**

A 3-D model of solar dryer geometry was created using solid woks version 2016 SP with a coreo7 system, speed 3.0 GHz, 6GB ram and 1TB hard disk. Solid works 2016 SP4.0 flow Simulation results provides sufficient practical information to identifying the low temperature spot of the system and consequently this will be useful for improvement of the dryer designs. Solid works does not consider heat transfer effects in solids. Solid works computes the correct temperature distribution in the fluid, but there is no option to view the result. Velocity, mass flow rate, volume flow rate, or pressure (static and total) boundary conditions are specified at models' inlets and outlets. Flow Simulation using Solid works involves the following procedure:-

- Setting up the flow simulation project for internal flow analysis,
- Setting up a 3D flow condition,
- Initializing the mesh,
- Applying boundary conditions,
- Meshing the model. This is a series of automatic steps in which the code subdivides the model and computational domain into computational cells,
- Running the flow simulation and check for convergence,
- Visualize the temperature flow field.

Table 1.Material Properties

Properties	**Air**	**Glass**
Density, ρ	1.225 Kg/m^3	2321 Kg/m^3
Thermal Conductivity, K	0.0242 W/m-K	571 W/m-K
Specific Heat, C_p	1006.43 J/Kg-K	1.15 J/Kg-K
Viscosity, μ	1.7894×10^{-5}	-------------

Table 2.Material Properties

Properties	**Laminated Sheet**
Thickness, t	3.00 mm(±0.1)
Resistance to Surface wear	≥350 (revolutions)
Resistance to immersion in boiling water mass increase (%)	10.0%(Max)
Resistance to immersion in boiling water thickness increase (%)	1.7894×10^{-5}
Resistance to dry heat	180°C

Table 3.Boundary Condition

Boundary Conditions	**Governing Equations**
Inlet	Air with varying velocity for different cases
Outlet	Pressure with value 1 atm
Outer Wall 1	Solid

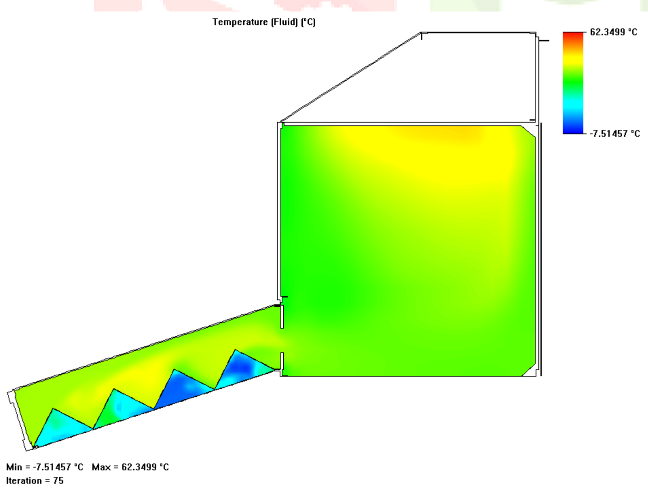


Figure2.Temperature variations on solar seed dryer at 9 am

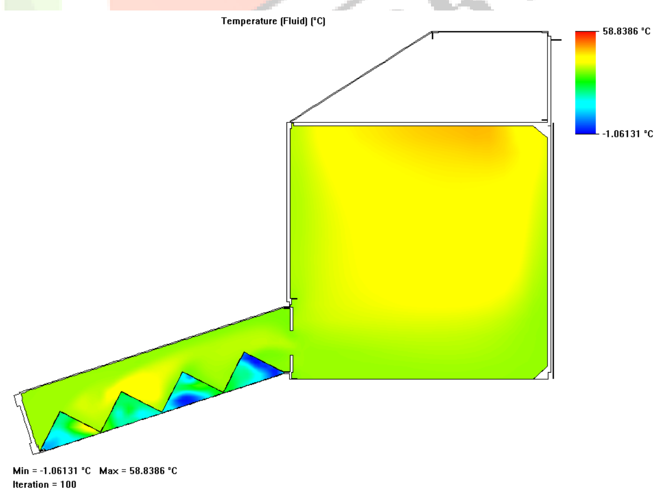


Figure 3.Temperature variations on solar seed dryer at 10 am

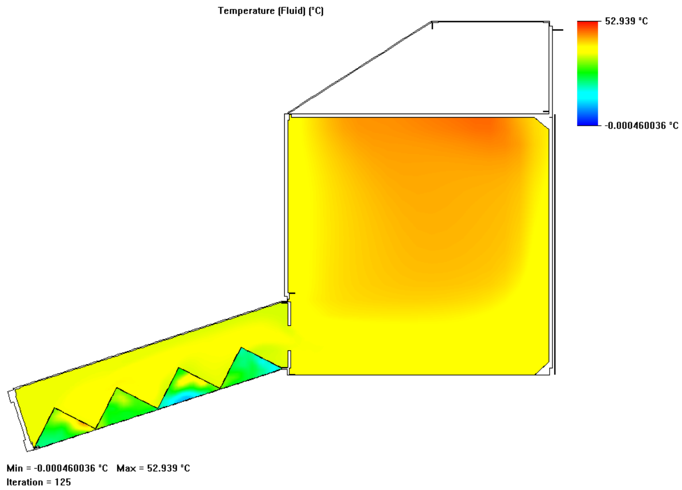


Figure 4.Temperature variations on solar seed dryer at 11 am

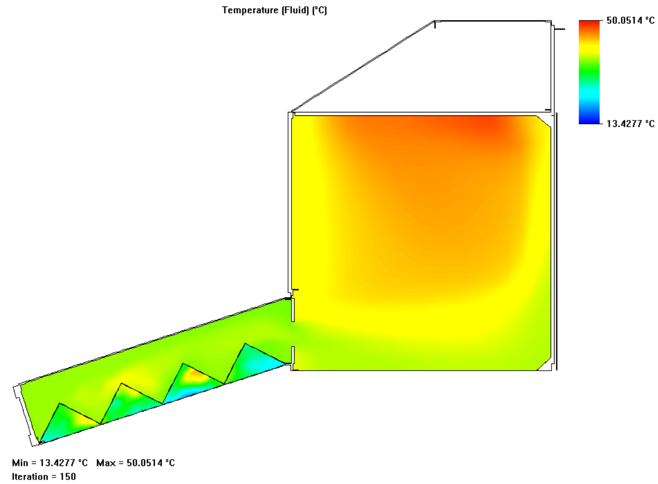


Figure 5.Temperature variations on solar seed dryer at 12 pm

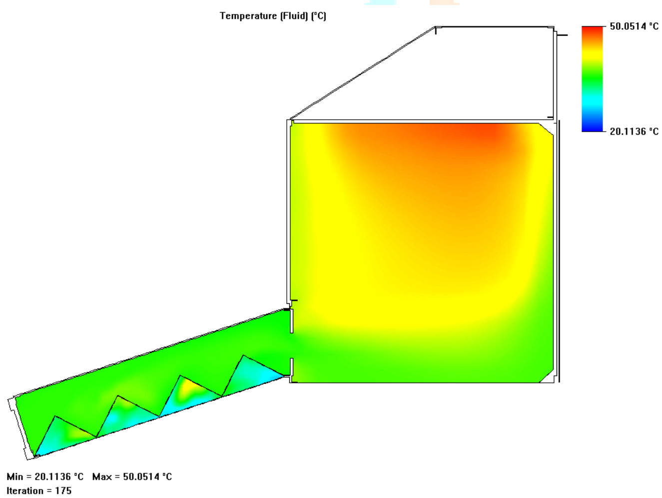


Figure 6.Temperature variations on solar seed dryer at 1 pm

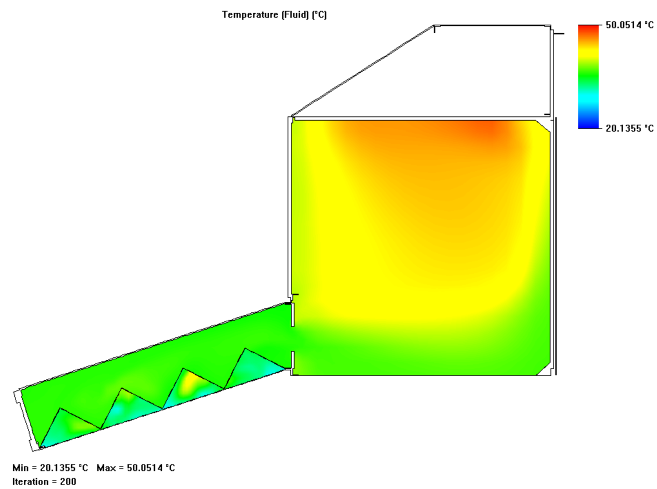


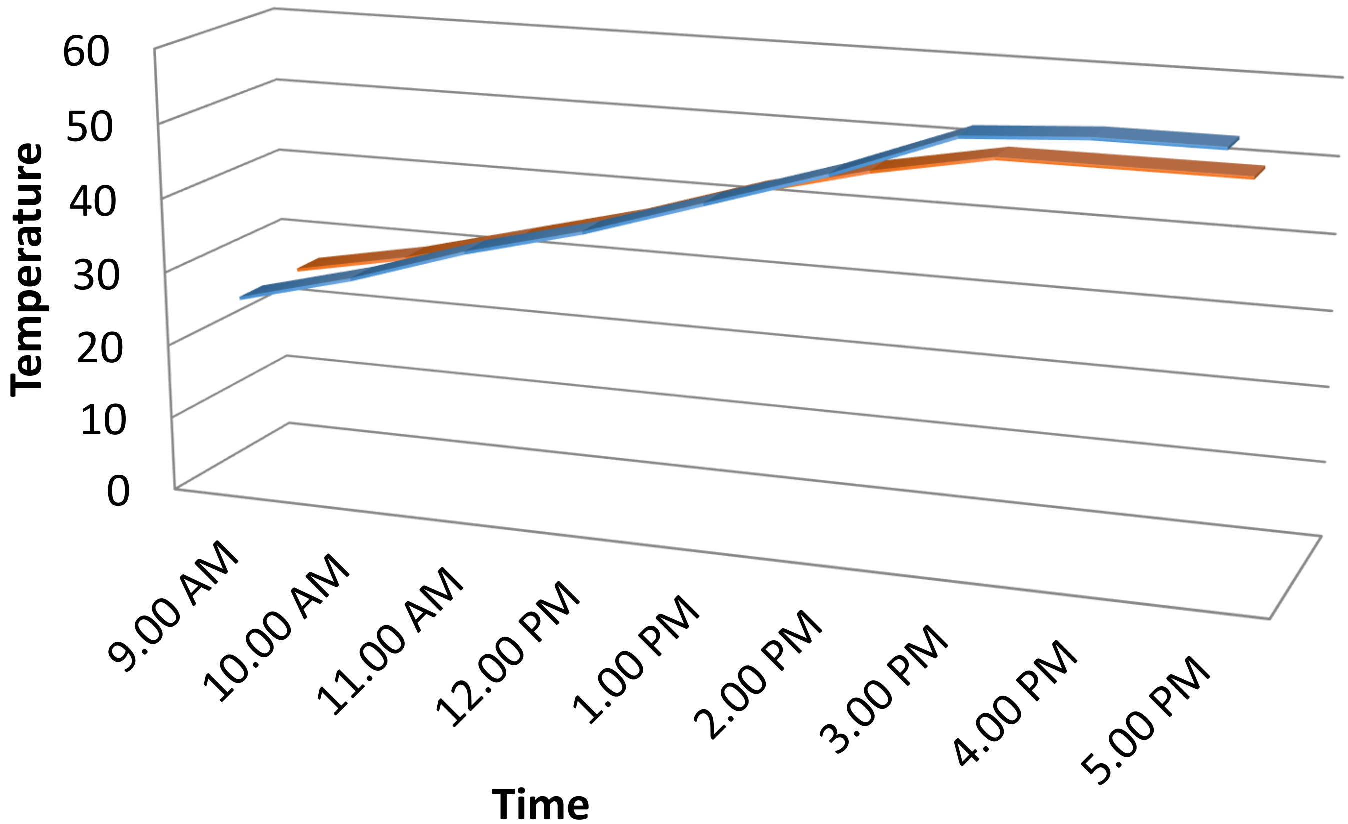
Figure 7.Temperature variations on solar seed dryer at 2 pm

4. RESULTS AND DISCUSSION:

The simulation was carried out and the temperature distribution obtained for solar dryer is presented in Fig 2. It can be seen that air enters into solar collector at an ambient temperature and being heated by solar collector. The temperature at the start of drying is equal to that of the ambient and increases towards the top of the collector. Since this temperature is higher than that in the ambient, it increases the thermal buoyancy. It could be seen that the highest temperature is concentrated at the top of the solar collector which is around 340 K to 348 K. The heat was transferred from solar collector to the drying chamber by natural convection. The temperatures inside the drying chamber are in the range of 50-20°C, except for the top portion of the drying chamber. The bottom and middle portion of the drying chamber recorded the highest temperature around 338K since it is exposed to the high temperature air flow. However, as the location of the tray become farther, the temperature decreases due to the heat losses to the surroundings and to heat up the lower trays. The lowest temperature was spotted just above the top tray and it represents the exhaust air temperature which flow out of the dryer.

- **Comparison of experimental and simulation results:**

The comparison of experimental and simulation results in natural convection solar dryer are listed in Fig. The results indicate that the average temperature of drying air is in good agreement for the top, middle and bottom portion of the drying chamber.



	9.00 AM	10.00 AM	11.00 AM	12.00 PM	1.00 PM	2.00 PM	3.00 PM	4.00 PM	5.00 PM
Experiments	26	30	35	39	44	49	55	56	56
Simulation	26	29	33	37	42	46	49	49	49

Figure 8.Temperature vs Time chart

➢ **Result Summary:**

The objective of the simulation of the dryer is to find the most efficient design and operation mode for optimum temperature distribution. The numerical simulation of the temperature inside the solar dryer was performed with Solid works. Experimental data was used for the boundary conditions and numerical validation. The following key conclusions are made from the analysis.

- The simulation results were validated with the real experimental data and there was no significant difference between real and simulated temperature inside the drying chamber.
- The simulated 3D model of hybrid dryer using Solid works was capable of predicting the system behavior in real situations.
- The temperature profiles of the dryer operation achieved reasonable temperature required for drying.
- Further study on other modeling software is needed to uphold confidence in numerical simulation of drying process.

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