A Review on Computational Fluid Dynamics Analysis on Greenhouse Dryer

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Abstract. Over the decades Solar energy has been utilizing for the conservation of various agricultural products at different zones in the world. Existing literature reveals that open dehydrating is the mostly followed for the desired application and its efficiency limited to certain extent. In order to overcome the limitations, solar dehydrating is proposed and implemented by various researchers. Greenhouse dryer found to be most appropriate technique to preserve different kinds of fruits, vegetables and grain products. In recent years, a great deal of research has been focused to enhance the performance of the selected method. Traditionally it is confined to empirical form and later it is extended to CFD analysis to obtain effective results through simulations. The present article presents the extensive survey over empirical and CFD analysis of Green house dryer application on dehydrating in both active and passive mode of convections.

Keywords: Solar greenhouse dryer; In-direct type greenhouse dryer; Computational Fluid Dynamics; Natural Convection; Forced Convection; Open Sun Dehydrating.

1. Introduction
Greenhouse dryer in agricultural applications widely used to harvest the crops from the preserved condition and protect from the affect made by bug and maladies. Also it serves as a yield dryer to various applications due it robust structure and lesser operating and low maintenance cost compared to other existing dryers. Dehydrating is a process of reducing the moisture content in the food products either by forced or natural convection. Solar dehydrating is unique over the other due to direct exposure of sun light supplies adequate amount of thermal radiation at probable surface area helps essential buoyancy effect to carry out desired effect. The rate of moisture content reduction signifies the effect of the process which involves enormous calculations to draw the relation over the influencing variables at various conditions.

Multiple sensors are used to fix at different locations of the dryer to test air flow. CFD offers greater work space to conduct various simulations for estimating the air velocity in the drying chamber which is very expensive and difficult in practical experimentations. Developing the relations the between obtained results of numerical and experimental leads to develop new theories and further insights in the field. The further sections intend to explain various research approaches in numerical and experimental by different researchers.

2. Review
CFD is most versatile software for the design and performance investigation of green house dryers. It overcomes the traditional complexities of green house dryers with minimal cost and resulting with greater outputs even at which the practical tests are almost impractical [1-3]. Based on the results obtained through CFD, it extremely supports to modify the design parameters to obtain desirable temperature and air flow
based atmosphere [4]. It anticipates mass transfer conduct in food items since the estimated greenhouse dryer microclimate with respect to its design descriptions and utilized apparatus [5-10].

The utilization of the 3D CFD model permits getting a real picture of the whole volume of the greenhouse dryer, including at overhang level. As to outcomes acquired in the past works, numerous investigations have concentrated on the impact of the air flow difference from the temperature appropriation inside the greenhouse [11-13]. Manoj and Manivannan built up a MATLAB-based modelling and simulation framework to predict the wind stream properties, equilibrium wetness substance of the sun based dryer techniques as shown in Fig. 1. Greenhouse dryer is considered for investigation. Wetness expulsion process was investigated for 7 days and 7% of weight decrease was noticed. The performed on MATLAB program and the 3-D model has been created on procedure. The Crank-Nicholson expression has been connected to thermal and FD technique has been utilized to produce for dehydrating cocoa bean. These outcomes demonstrate a period of dehydrating decreases the wetness contains for 50 to 7% and 60 to 8% of wetness removed of dehydrated bean[14]. Mabrouk et al. [15] observed a empirical model for temperature and mass exchange of granular items in a fixed-bed greenhouse tunnel dryer.

![Figure 1. 2D of Green House Solar Dryer [14].](image)

Aghbashlo et al. [16] inspected a greenhouse dryer for chamomile blooms, and they utilized TRNSYS programming. They composed a program in Compaq visual FORTRAN programming language. RMSD was under 9.3% and found that TRNSYS is a decent apparatus for simulation of sun powered dryers. Chen et al. [17] suggest by REA for clarifying distinctive testing of dehydrating techniques. These techniques followed the essential guidelines of chemical reaction engineering to show the physical changes characters of dehydrating [18]. It is demonstrated that the REA techniques is a basic, exact and strong method for displaying the convective dehydrating of eaten and non-eaten materials under state steady natural conditions [19]. Technique likewise utilized for modelling different intermittent dehydrating [20]. Mohammadi et al. [21] have examined about the significance of greenhouse solar dryer. The investigators examined about the controlled strategy, for example, versatile, input and intelligent control for their introduction. The investigators have modeled & numerically valuated within condition of semi solar greenhouse dryer. It has been reported that the dynamic model with beginning qualities used to predict within air and soil temperature. As per the outcomes, the connection between the consequences of dynamic model with experimental value according to RMSE, MAPE and EF demonstrated that, the dynamic
technique can gauge within air and soil temperature with 5.3°C, 10.2 %, 0.78 % and obtained 3.45°C, 7.7 %, 0.86 %, separately also similar comparative strategy can be utilized to item fuel utilization in greenhouse.

Simulation output results from CFD should be compared with real dehydrating investigations and if there is an understanding among anticipated and empirical results, at that point the CFD code might be apply for other dehydrating conditions to upgrade the dehydrating execution of the dryer. These have been demonstrated by investigation of numerous analysts [22-28] then demonstrate that the execution of new dryer plans can be anticipated by CFD Simulation output. These examinations additionally demonstrated that the CFD reproduction result is practically identical with real conditions. Taki et al [29] evaluated three dissimilar variables – inside air, soil and plant temperature utilizing ANN & SVM. The investigators have considers influence within temperature as shown in Fig. 2. Among 13 unique calculations along these lines the investigators has determined the best model for gauge of real value in greenhouse which can similar exchange actuality and predict power lost.

Figure 2. Type of selected greenhouse at Shahreza city [29].

Arunsanddeep et al [30] simulated heat and mass exchange for sun based dehydrating of circular items, for example, green peas. FD technique with implicit method has been utilized for exposition. The arrangement of FD conditions was resolved by TMA and PC codes in MATLAB were created to explain them. Outcome has been compared for dehydrating rate with the empirical value from the survey and both are noticed to be in better understanding.

Chauhan et al. [31] examined the regions of programming use for sun powered dryer operation. Elements of fluid can be possible by ANSYS and FLUENT. MATLAB and FORTRAN can be useful in numerical demonstrating. For measurable investigation SPSS can be utilized. Malekjani and Jafari et al. [5] studied about the components basic the dehydrating operations in dehydrating out of food and agricultural items. The writers have created propelled modelling of simulation procedures for new dryers. It has been called attention to that nourishment quality is most significant parameters amid dehydrating. It has been reasoned that CFD can be utilized to forecast fluid flow, temperature and mass transfer in dryers. The approval issue of CFD outcomes is additionally exists in the light of complexity of gaining empirical
information in some dryer structures and conditions. Coupling of CFD with recent methods, for example, response designing methodology discrete component technique as profitable. Kumar et al [32] have utilized CFD to deal with indenting temperature conveyance with keep up in greenhouse dehydrating. CREO 5.0 has been utilized for geometric modelling as shown in Fig. 3. The examination has been done in familiar for forced and natural circulation. Numerically acquired outcomes have been compared shaped and works and with be in correlation.

![Figure 3](image)

**Figure 3.** Greenhouse jaggery dehydrating under natural convection mode [32].

Prakash et al. [33] observed on various systems of sunlight based dehydrating where proficiency of dehydrating, expectation of temperature, wetness in yield, rate of dehydrating, fluctuated hues and different in harvests and their quality were examined. CFD software is used for investigation by ANFIS programming. Numerically modelling suggests better results.

By utilizing CFD method, the miniature can be simulated to contemplate the attributes of temperature, air velocity conveyances and heat transfer in the dryer [34-35]. Miniature methods such as fuzzy, artificial neural system, etc can be effective for anticipating the data of reaction factors [36]. Numerical miniatures and simulation procedures are helpful for inspecting the impact of input factors on the yield responses [37]. Harjunowibowo et al. has observed that recent developments in greenhouses for vitality sparing purposes. It has been recommended that fitting greenhouse with LEDs can save power by 75% when compared with expense of artificial lights. It is reported to control framework that introducing automatic framework in greenhouse dryer would create a steady and cost-effective microclimate, subsequently ensuring the quality and amount of the yield [38]. Gupta et al [39] have done CFD investigation of greenhouse dryer as shown Fig. 4. Past exploratory information has been utilized as boundary condition for recreation. Temperature circulation and wind flow example have been investigated about and reported that numerically acquired outcome elucidate local parameter.
Figure 4. Geometric Modeling For Direct Type Solar Greenhouse Dryer [39].

The apparatus model was assessed by exploitation and victimization commercially which as accessible by CFD code in order to handle the mass and heat transfer inside the apparatus. Natural convection was the sole technique of temperature transportation plan of getting a simple style. A biomass burner was incorporated into the star apparatus intended to oblige the further effect of low buoyancy found in natural convective driers[40]. Numerical simulation of the wind flow inside a half and half sunlight based electrical drier, utilizing a business CFD bundle was showed. With recommended temperature and velocities, the miniature predicts the conduct of the wind flow inside the system [41]. Chauhan et al [42] has concentrated on the expanding ecologically concerns and concentrated on utilization of sun powered vitality as a substitute source. The investigators have recommended utilization of sun powered dryer coordinated with heat energy storage framework. Utilization of intelligent mirror, improvement in the geometry of level plate collector to build heat exchange zone and utilization of selective coatings on safeguard plate to enhance accumulation of sunlight based radiation can improve the thermal performance of the dryer. Mujumdar and Wu [43] have stressed that the CFD approach is the cost-effective arrangements that can push advancement and innovativeness in dehydrating structure and improvement. Since the dehydrating procedure, particularly for huge scale dryer, estimation of air speeds and temperature is tedious, since a few sensors should have been install at different areas and directions of wind flow, along these lines CFD software might be utilized to predict the air speeds and temperature in the dehydrating chamber. Jyoti et al. [44] described about the utilization of parabolic trough in sunlight based collector. It is reported that the effectiveness of this type of collector rely upon the heat power of sun. Survey on the parabolic trough sunlight based collector has been introduced. It is reported that the investigators have utilized different advancement method, and approved the same by utilization of devices likes ANSYS, Fluent and so forth.

Designing appropriate geometric arrangements of the dehydrating chamber, the forecast of the wind stream and temperature inside the dryer streamlines the structure and improving the dehydrating procedure before the real dryer was assembled. Numerical strategies have been utilized to numerically show the conduct of the wind stream inside a few sorts of dryers [15, 45 & 46]. This procedure is tedious and includes a complex scientific definition. CFD is a broadly acknowledged procedure and instrument for numerical
recreations of such frameworks. CFD had been demonstrated as an powerful computational device for anticipating the flow behaviour and mass transfers happening in multi-part frameworks in numerous enterprises [47-48]. Kant et al [49] have described about the power storage materials sunlight based dryer. The investigators have detailed that different investigations have been done in most recent couple of decades for the equivalent. It has been reported that for better heat execution of sun powered dryers, a PCM with high latent temperature of fusion and with a vast ground zone for thermal exchange is required and is as of now being investigated broadly. Comsol Multi-Physics, CFX advanced solver technology, FORTRAN programming language, Open FOAM and Fluent – Ansys, to improve the dryer configuration similar utilization of business bundle.

Purusothaman and Valarmathi [50] have performed CFD investigation of greenhouse dryer when communicated to surface temperature on a hot bright day with the expectation of forced convection and natural convection forms as shown Fig. 5. The variation has been made in thickness of shut material and mass stream rate. It is reported that the sun radiation expanded shapely from 10am to early afternoon. Higher temperature is seen in forced convection then natural convection by 41%.

Ingle et al [51] has been numerically simulated sun based collector for grape dehydrating. The investigators have utilized CFD to see better heat transfer capacity. Unstructured framework has been created utilizing ICEM CFD. For investigation Fluent bundle has been utilized. They acquired an arrangement of non-linear partial differential conditions and numerically fathomed them by a FV technique. Significant examinations on reproduction of natural convection sun based dehydrating of farming items and improvement have additionally been accounted [52-53]. Sanghi et al [7] have elaborated CFD model to simulate the corn dehydrating operation in a sun powered dryer. The execution of the dryer has been simulate at reasonable and over-cast climate conditions. Temperature, air speed profiles and humidity in the dryer have been showed. The outcome has been approved with numerical information. The simulated outcome over anticipate the factors, such as temperature and wetness.

Prakash and Kumar at el [54] have utilized ANSYS to anticipate the conduct of slightly modified greenhouse dryer under dynamic mode in no-load conditions. Climate condition have been taken has
information, for example, Adaptive Neuro Fuzzy Inference framework (ANFIS). Warmth, surrounding temperature surrounding RH, solar radiation and period of experimentation. As yield greenhouse air temperature and relative moistness have been acquired. Outcomes from ANSYS model has been found to be in a decent understanding. Kumar and Tiwari [55] revealed thermal modelling of jiggery samples dehydrating in a natural convective greenhouse dryer. The miniature was customized in MATLAB, and anticipated data well. Khaldi et al [56] have empirical study of indirect sun based dryer incorporated with heat storage for dehydrating figs. Unsteady turbulent wind flow and thermal exchange utilizing two-dimensional model has been completed. The investigators have considered the impact of air channel estimate and thickness of backed bed on conduct of dryer. It is directed that the way of flow determined local parameters.

Janjai et al. [57] detailed an exploratory act of a Photovoltaic ventilated greenhouse dryer for dehydrating of chilies. Barnwal and Tiwari [58] revealed sun based dehydrating of grapes utilizing a hybrid PV-warm (PV/T) dryer and fabricated a multi linear equation to foresee wetness dissipation amid dehydrating. Kokate et al. [59] fabricated a sun powered dryer to help plastic industry as shown in Fig. 6. For preconditioning and lack of hydration of Nylon–6 and Polypropylene (PP) about 3–5% of all out power was required. For Polypropylene material the most extreme temperature rise up to 71°C henceforth with a similar dryer configuration preheating is possible. They formulated a numerical model of sun based dryer. Numerous parameters were in charge of predicting air temperature. Psychrometric curve was utilized to clarify it. The temperature of 55to 60°C was accomplished inside the dryer. The accompanying parameters to be specific sunlight based power and the outside wind speed of safeguard were in charge of inside air dehydrating temperature.

![Figure 6. Pictorial view of solar dryer [59].](image)

Dorouzi et al. [60] has fabricated liquid desiccant-helped sun based dryer for dehydrating of tomato samples. A photovoltaic warm sun powered collector has been utilized to supply the electrical power. Hue examination of dehydrated tomato samples was completed and it was incorporated that the expansion in the warmth of the dehydrating air expanded the gentility, and yellowness esteems, yet the expansion in the Relative humidity diminished the estimations of softness and redness. The temperature of 60°C & RH of 23 % were prescribed for tomato samples in the reported dryer.

3. Conclusion
In this article a survey on solar green house drying is presented and different approaches followed by the researchers are explained. Solar based Photo Voltaic fan usage as assistant connection to provide forced air circulation inside the dryer has been proposed to accomplish the higher dehydrating rates. For getting the better drying rate of dryer and investigation of dryer by using Computational Fluid Dynamics. The simulation output by CFD might be tried with actual drying tests and on the off chance that there is an understanding among predicted and test results, at that point the CFD code might be reapplied for other drying conditions to optimizing the drying performance of the unit. The CFD might be along these lines utilized as a drying optimization device.

Nomenclature

1. FDM       Finite Difference Method
2. TRNSYS    Simulation Program
3. RMSD      Root-Mean-Square Deviation
4. REA       Reacting Engineering Approach
5. EF        Model Efficiency
6. MAPE      Mean Absolute Percentage Error
7. ANN       Artificial Neural Network
8. SVM       Support Vector Machine
9. ANFIS     Adaptive Neuro Fuzzy Inference framework
10. LED      Light-Emitting Diode
11. RH       Relative Humidity
12. FVM      Finite Volume Method
13. PV       Photo Voltaics
14. TMA      Tridiagonal Matrix Algorithm

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