pISSN 1993-4041 eISSN 3078-4840
Journal of Agricultural Machinery and Bioresources Engineering
Journal home page: https://journal.bau.edu.bd/index.php/jambe
Journal of Agricultural Machinery and Bioresources Engineering, 8(2): 53-61. https://doi.org/10.61361/jambe.v8i2.127

Research Article

No-load Testing of the Modified Auxiliary Heating System for BAU Solar Chimney Dryer

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Article Information

Received : 29 September 2024
Revised : 25 November 2024
Published: 07 December 2024

ABSTRACT

Experimental analysis was conducted to evaluate the performance of a modified electric auxiliary heating system for a natural convection solar dryer without load. The dryer operated using heat from two sources for drying operation. This study focused on describing the temperature profile inside the dryer and the airflow velocity of the modified auxiliary heating system at no-load. Microcontroller (ESP32) automation was integrated within the auxiliary heating system to maintain the recommended temperature range for drying agricultural products. The experiment was conducted during low sunshine season and the maximum solar radiation was 336.56 W/m². The average airflow velocity from each column of holes was found to be in the range of 2.33 m/s to 2.80 m/s. From the test, the obtained drying temperature was sufficiently higher above ambient air temperature to continue drying. A maximum rise of 29.7 °C above ambient was found at 2.00 pm. The second drying chamber had slightly high temperature values due to the stagnancy of hot air in it. The auxiliary heater showed promising performance towards a weather-independent drying operation. However, it needs to be improved in capacity to raise the air temperature to the required range. Further study on the dryer design for better exhaustion system alongside uniform airflow rate is also recommended. Integrating IoT-based solutions will make the drying process smarter and reduce drudgeries during the operation.

Keywords: Auxiliary heating, Electric heater, Automation, Solar dryer, No-load performance

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1. Introduction

Postharvest losses are one of the major problems in the present world and it is contributing to the rise in undernourishment and hunger amidst the global population. FAO et al., estimated that around 8.9 to 10.5% of the world's population faced hunger crisis in 2021 [1]. The prevalence of hunger has become acute not because of insufficient agricultural production, but because of the losses and waste in the food chain [2]. Food loss and waste majorly occur at several stages depending on the economic development of individual countries. The low-income and developing countries lose a large amount of their production during the harvesting and post-harvesting operations [3,4]. Technological and financial facilities play as crucial factors in this estimated food loss and waste. About one-third of the global food production is lost in postharvest operations, which sums up to approximately 1.3 billion tons of food produced [5]. This loss not only affects the global food and nutrition status but also leaves a deep mark on the lives of smallholder farmers [6]. Bangladesh is a South Asian developing country with an agriculture-dominant economy. Despite of being a small country, Bangladesh produces more than 90 varieties of vegetables and 60 varieties of fruits and is ranked third worldwide in vegetable production [7]. Though, this enormous production in Bangladesh suffers from a postharvest loss (PHL) of 23.6 to 43.5% of the total amount [8]. The PHL also takes a large share of money off the agricultural production chain. The PHL of fruits and vegetables occurs

Cite This Article
Roy, N. K., Nipa, N., J. Khatun, J., Tasnim, N., Sarkar, S., Hanif, M. A., and Saha, C. K. 2024. No-load testing of the modified auxiliary heating system for bau solar chimney dryer. *Journal of Agricultural Machinery and Bioresources Engineering,* 8(2):53-61. https://doi.org/10.61361/jambe.v8i2.127

primarily due to their high moisture level, joined in hands with insects and rodents' infestations, mechanical damages during postharvest handling, improper storage conditions, lack of processing and storage technologies, etc. [9].

Postharvest processing of perishable crops (fruits and vegetables) is performed to extend their shelf life [10]. It is primarily done either by storing them at a temperature where microbial activities cannot initiate (cold chain), or by reducing their high moisture level to safe moisture content (dry chain). The cold chain requires higher infrastructure, refrigeration, and energy costs, thus implying the dry chain is a better and more feasible solution in developing countries [11]. Drying is the ancient method of preserving agricultural produce. This method evaporates the water content from the perishable products through the active utilization of solar radiation [12]. Open sun drying is the most practiced method in conventional postharvest processing operations, and it has low-cost involvements [13]. But, solar drying technique has surpassed open sun drying in terms of product quality, drying rate, and operation controllability [14,15]. Albeit extreme dependency on sunlight makes the solar dryers ineffective at night or during adverse climatic conditions [16]. The intermittent behaviour of solar dryers can lead to regaining of moisture from the environment and initiate microbial contamination. These shortcomings have led scientific endeavours to develop the concept of solar hybrid dryers. Solar hybrid dryers use an additional heat source alongside solar energy, to increase the performance and overcome the intermittent operation of natural convection solar dryers. The additional heating facilitates drying operation even at night and when very low solar radiation is available (foggy weather and rainy days) [17]. Numerous designs of solar hybrid dryers equipped with an auxiliary heating system have been investigated around the world. Suherman et al. [18] studied a solar hybrid dryer integrated with an LPG burner to supply additional heat. The LPG burner helped the dryer to maintain the set temperature and obtained a faster drying of cassava starch. Ihoume et al. [19] developed a greenhouse solar dryer incorporating an electric heater to provide heat at night. Roy et al. [20] developed an electric auxiliary heating system for a solar dryer and was able to improve the average dryer temperature by 1.00–12.84°C during the off-sunshine hours. Other investigations on using biomass burners [21], infrared lamps [22], electric resistance systems [23], etc. as auxiliary heating systems have also been carried on.

The drying temperature is a crucial parameter of the drying operation. Exposure to excess temperature will discolour the product and affect its nutritional attributes and lower temperatures will consume higher drying time. Extensive research on suitable temperatures for drying perishable products has found the certain range of drying air temperatures which facilitates faster drying without affecting product quality. Lopez-Vidana et al. [17] experimented with a hybrid solar-gas dryer with a control action to maintain dryer internal temperature between 55 °C and 65 °C for drying tomatoes. To ensure a fast, continuous, and efficient drying operation, maintaining the drying temperature range is also essential.

Drying agricultural products at a fixed temperature range results in better-quality dried products. Sharma et al. [24] recommended drying temperature for several fruits and vegetables, i.e., 65 °C for pineapple and chillies: 75 °C for carrots and onions, etc. Development and adoption of an appropriate solar hybrid drying technology, with the ability to maintain the recommended drying temperature, can reduce the postharvest losses of perishable agricultural products efficiently and smartly. Although several types of solar dryers are being tested at the lab and field scale to check their viability, extensive studies on solar hybrid dryers are not being conducted as such in Bangladesh. A natural convection solar chimney dryer was previously developed for fruits and vegetables at the Department of Farm Power and Machinery, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh [25]. An auxiliary electric heating system was also constructed, modified, and automated to hybridize the solar chimney dryer. As consequence of the previous research studies, this study focuses on checking the functionality of the modified auxiliary heating system for drying different agricultural products. The specific objectives were to test the temperature profile of the dryer at the no-load condition with the modified auxiliary heating system and to analyze the ability of the auxiliary heating system to maintain the set temperature range.

2. Materials and Methods

2.1 Description of the solar chimney dryer

The BAU solar chimney dryer is a natural convection solar dryer designed for fruits and vegetables drying (Figure 1). The dryer's frame is built of galvanized iron (GI) and mild steel (MS) bars. The collector unit of the dryer is made of black painted PVC sheet covered with multi-wall polycarbonate sheet. It has adjustable inclination, to receive and trap maximum solar radiation. The drying chamber, which is similarly painted black, is separated into two parts, each with three movable trays (1.20 m x 0.60 m) for placing products in single-layer. These trays have MS steel skeletons with peripheral plastic nets and additional woven nets to prevent product loss during drying. The overall dimension of the dryer chamber is 0.90 m x 0.61 m x 0.12 m. The chamber base is made of plywood and the top is covered with multi-wall polycarbonate sheet. A chimney unit evacuates the hot, moist air and is protected by a cover to keep rain and debris out. An exhaust fan is installed at the chimney to facilitate the exhaustion of hot and humid air from the drying chambers.

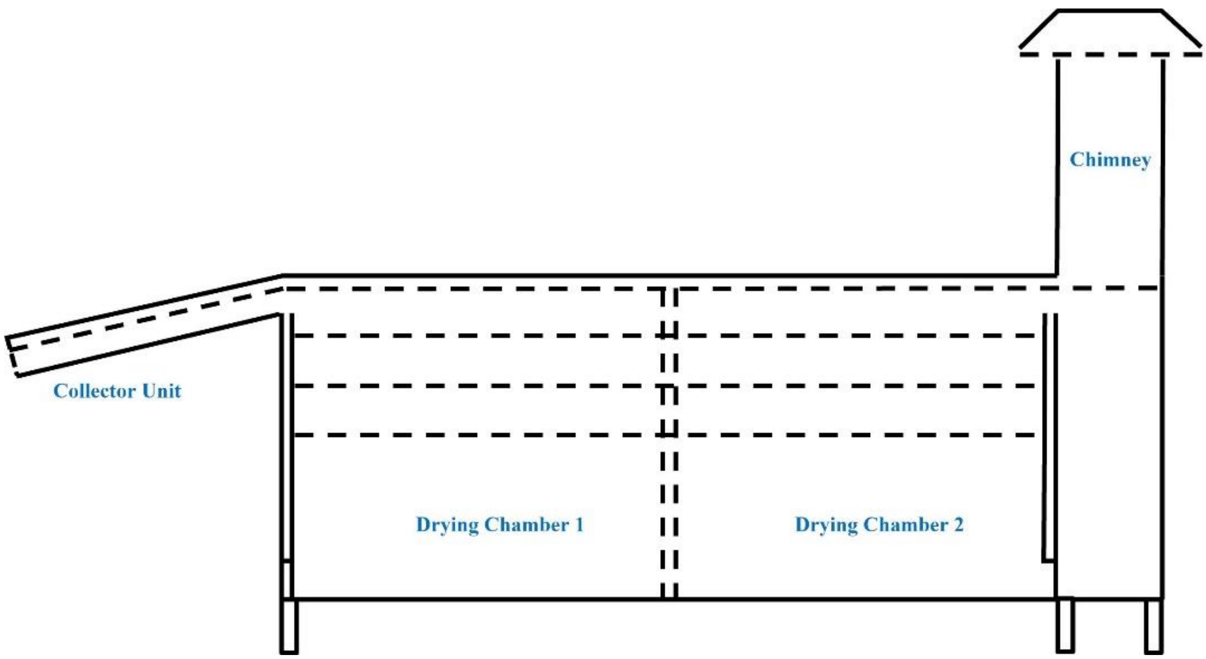

Figure 1. Schematic diagram of the solar chimney dryer

2.2 Auxiliary heating system

An electric auxiliary heating system was designed an incorporated with the solar chimney dryer. It has 3 sections: (a) the heating section, (b) control section, and (c) hot air distributor bed.

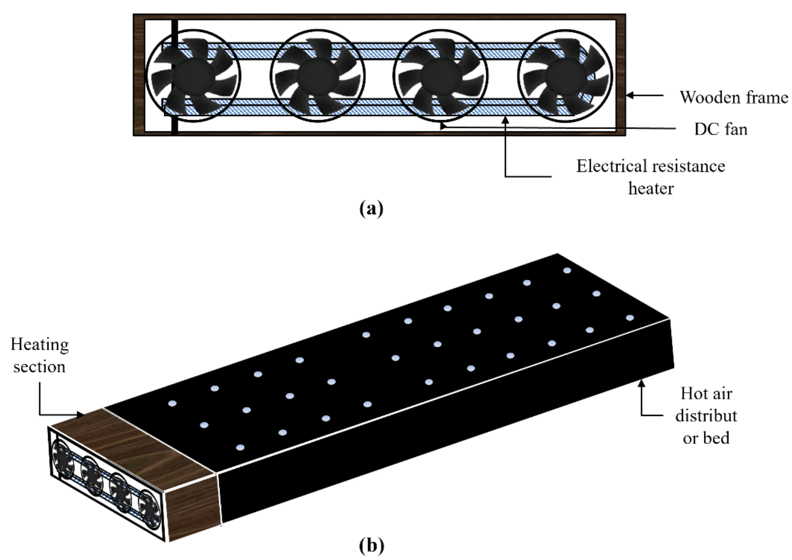

Figure 2. Schematic views of (a) heating section and (b) modified auxiliary heating system

A 3.3 kW electric resistance heater was used as the auxiliary heat source to ensure a continuous drying operation. It operates through connection with the grid electricity. Selection of the electric heater was done by estimating the amount of heat required for drying a 12 kg batch of products. The heating section was accompanied by 4 DC blower fans, so that hot air travels from end to end of the distributor bed. The DC fans could provide variable rate airflow according to the control setting. A wood casing was provided to place the heater for a safe operation. A control mechanism was integrated within the system to automate the heater. A microcontroller unit (ESP32) was used in the control section, and it regulated when to start the heater and when to stop. The ESP32 module was selected as the microcontroller because of its high performance and built-in WiFi and Bluetooth connectivity option which eases the monitoring of data. Holes were drilled in the hot air distributor bed to ensure the flow of hot air into the drying chamber. The hot air distributor bed had 3 column of holes and 10 holes per column. Figure 2 shows the schematics of the modified auxiliary heating system. BAU Solar Chimney Dryer with the modified heating system is shown in Figure 3.

Figure 3. BAU Solar Chimney Dryer with modified auxiliary heating system

2.3 Experimental procedure

The no-load experiment was conducted on 11 January 2024, from 2.00 pm to 7.00 pm at the Engineering Workshop, Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh-2202.

Figure 4. Sensor placement locations for the no-load test

The airflow distribution of the modified auxiliary heating system was evaluated using a handheld anemometer, and an average velocity of each column of holes was determined. To check the temperature distribution profile inside the dryer, 15 k-type thermocouple sensors were placed at different positions inside the dryer (Figure 4).

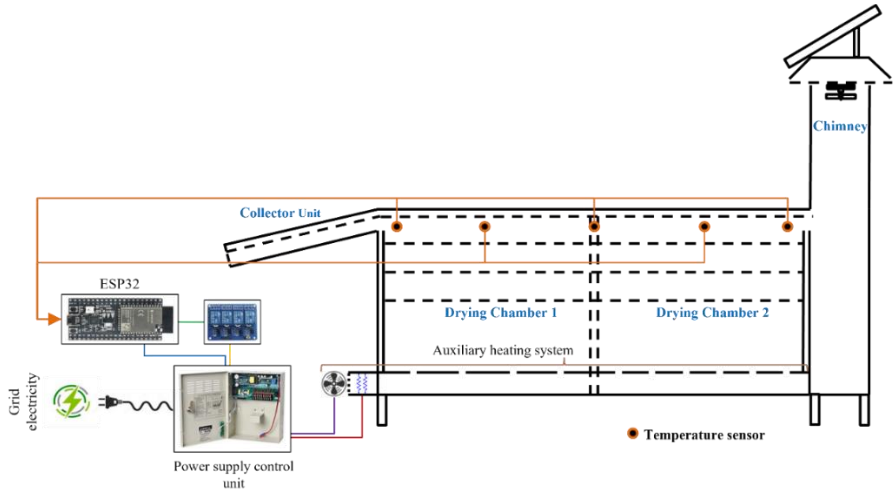

Figure 5. Automation system schematic of the auxiliary heating system

The ESP32 microcontroller was used to set the desired temperature range (45 to 55 °C during day, 34 to 44 °C at night) during the test. It was connected to 5 temperature sensors placed just above the top trays (Figure 5). If any of the temperature sensors read temperature higher than the set value, the microcontroller switches the heater off through relay modules. The hot air is then removed rapidly through the work of the exhaust fan at the chimney and reduces the dryer inside temperature. Again, when the temperature sensors record a value less than the desired, the control system turns the auxiliary heater on, thus maintaining the internal temperature of the dryer within the set range. The basic algorithm of the control system is shown in Figure 6. Two more sensors were placed at the distributor bed level to check the variance of temperature between the top and bottom portions of the dryer. The temperatures at different points were recorded using a Hydra FLUKE data logger. The solar radiation data was recorded at one-minute interval through a HOBO Micro Station data logger.

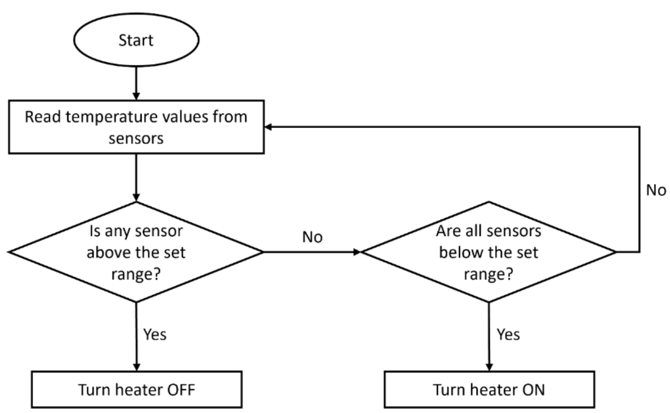

Figure 6. Automation system control algorithm used in the study

3. Results and Discussion

3.1 Airflow distribution

The airflow of the modified system was recorded at each hole to check whether a uniform distribution is maintained by the system or not.

Figure 7 shows the velocity profile of hot air from the distributor bed at varied lengths. From the experiment it was noticed that the average airflow velocity for each column of holes ranged between 2.33 to 2.80 m/s. The higher values of air velocity were obtained at the holes near the heating section and vice versa at the distant holes. Pagukuman and Ibrahim [26] recommended a velocity of 1 to 2 m/s for optimum drying of agricultural products. The developed heating system here needs to optimize the velocity of air from the blower fans to maintain the recommended range.

The discrepancy in the airflow velocity of different column of holes is 0.47 m/s on average. The result justifies the need to provide more holes in the second drying chamber for ensuring the supply of uniform amount of air to both chambers.

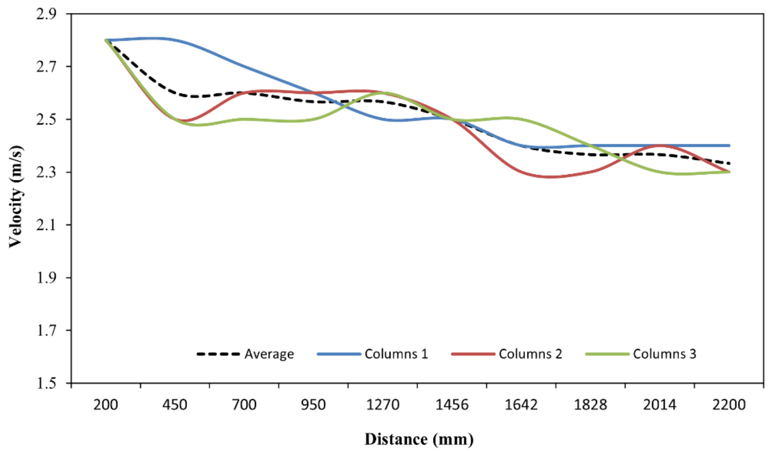

Figure 7. Airflow distribution of the auxiliary heating system

3.2 Distribution of solar radiation

The solar radiation plays a key role in solar hybrid dryers. Consumption of additional energy depends upon the availability of sunlight and how much solar energy is being consumed. The distribution of solar radiation during the test day is represented in Figure 8. At this period, the solar radiation was found between 59.02 W/m^2 (5.00 pm) to 336.56 W/m^2 (3.00 pm) (Figure 8). After 5.00 pm the solar radiation went to negligible level. Since the solar radiation was not present in higher magnitudes, the temperature rise inside the dryer was found as a major contribution of the modified auxiliary heaters.

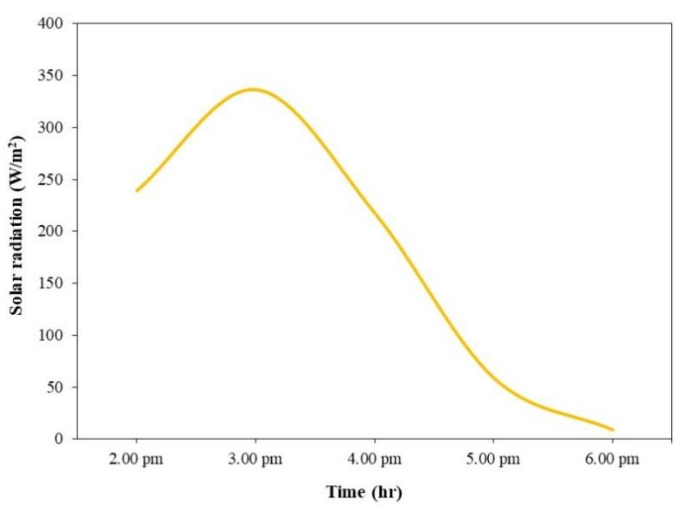

Figure 8. Distribution of solar radiation during the no-load rest

3.3 Spatial and temporal distribution of temperature

The temperature profile obtained from the no-load test provides an overview of the auxiliary heating systems capability to dry products even when no or low solar radiation is available. Figure 7 provides a graphical overview of the temperature profile inside the dryer during the no load test. The test results show that at bed level the temperature ranged 57.03°C (7.00 pm) to 62.24°C (2.00 pm) in first drying chamber, and 51.46°C (7.00 pm) to 54.62°C (6.00 pm) in second chamber. In the top layer, the temperature ranged between 35.46°C (7.00 pm, first chamber) to 52.04°C (2.00 pm, second chamber). The temperature rise was slightly higher in the second chamber, because of the hot air getting stuck in the top layer of the second chamber during the exhaustion through chimney. Similar trend was noticed in the lower levels side the dryer (second and third tray). In the second and third tray level the maximum temperature was found as 49.86°C and 52.14°C, both at the second drying chamber. During the test time, the ambient temperature varied between 16.25°C and 22.45°C. The average temperature of the drying chambers at that time was recorded between 34.06°C-46.39°C (first chamber), and 42.75 °C-51.75 °C (second chamber). During the test after sunset, the average ambient temperature was 16.83°C, whereas the average temperatures inside the drying chambers with electric heater were found to be 34.61°C (first chamber) and 43.46°C (second chamber). So, an average rise of 17.78°C to 26.63°C above the ambient was recorded during the no-load test (Figure 9).

Nwakuba et al. [27] did a no-load study of an Arduino-primed solar-electric dryer and found that the minimum heat-up time of the drying chamber occurred at a 70°C set temperature and 2 m/s airflow rate, with maximum internal temperatures reaching 31.8°C in solar mode and 92.5°C in hybrid mode. Yassen et al. [28] conducted a no-load trail on a solar-biomass hybrid dryer, where solar-mode raised the inside temperature to 63°C. The temperature rise by the hybrid mode depended on the biomass feed rate (80°C at 490 g/hr and 62°C at 278 g/hr). In our experiment, the temperature rise was less than these studies because of the low solar radiation and low heater capacity. The heater automation was checked and found that whenever the temperature at the top level went below 34°C at night, the heater was switched on automatically through the microcontroller action. A Bluetooth-based connection enabled the ease of data monitoring in a smart phone. But maintaining the recommended temperature range was not fully possible as the weather condition was not favourable, and thus the air temperature did not rise to required degrees.

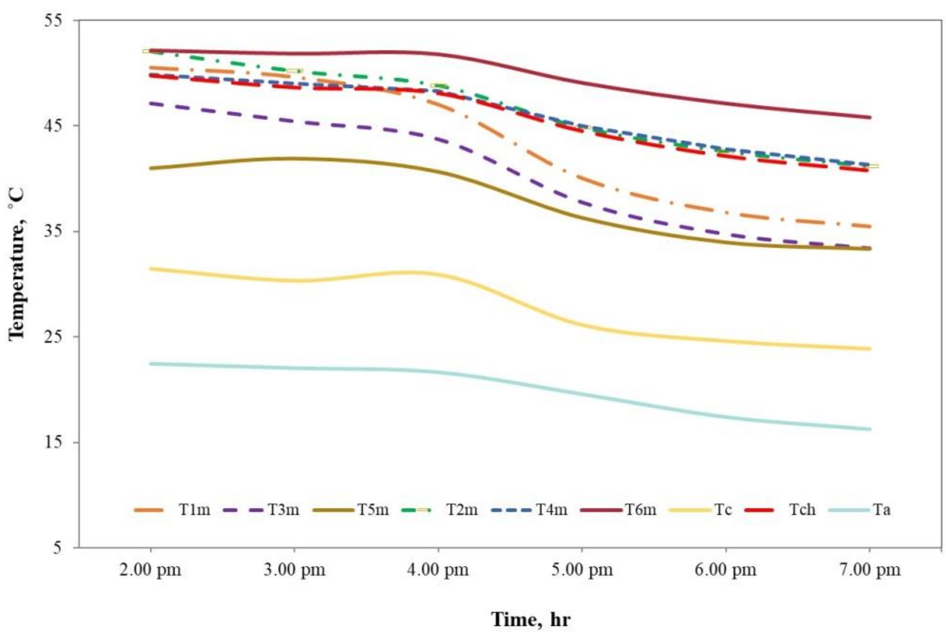

Figure 9. Temperature distribution in and out of the dryer during the no-load testing, where T1m= Tray 1 middle temperature; T2m= Tray 2 middle temperature; T3m= Tray 3 middle temperature; T4m= Tray 4 middle temperature; T5m= Tray 5 middle temperature; T6m= Tray 6 middle temperature; Tc= Collector temperature; Tch= Temperature at chimney; Ta= Ambient temperature

4. Conclusions

Performance of the modified and automated auxiliary heating system for BAU solar chimney dryer, at no-load condition, was investigated and analyzed. The auxiliary heating system used grid electricity connection to supply additional heat energy inside the dryer. The airflow rate of the modified system was found in the higher range (2.33 to 2.80 m/s, on average from each column) with minimal deviations (0.47 m/s). The highest temperature inside the dryer was found to be 52.14 °C (at T6m, 2.00 pm) when the ambient temperature was 22.45 °C. The temperature was found to be higher in the second chamber than the first one, this is because of the unavailability of a smooth passage for the hot air to and through the chimney. The temperature profile showed the potentiality of the modified auxiliary heating system in continuing drying more effeciently with the support of solar radiation. But, to dry products within the recommended temperature range for different perishable agricultural products, the capacity of the heater needs to be improved. The airflow velocity from the auxiliary heating system also needs to be reduced to the suggested limit. Furthermore, the dryer design should be improved and modified to allow a natural passage of the hot and humid drying air. An IoT-based monitoring solution will help the farmers and operators to carry out drying more efficiently.

Author Contributions: Conceptualization, C.K.S., S.S and N.K.R.; methodology, N.K.R., S.S., and C.K.S.; software, N.K.R.; validation, C.K.S., N.K.R. and S.S.; formal analysis, N.K.R., N.J.N., J.K., and N.T.; investigation, N.J.N, J.K., N.T., and N.K.R.; resources, C.K.S.; data curation, M. A. H., N.J.N., J.K. and N.T.; writing—original draft preparation, N.K.R.; writing—review and editing, C.K.S., M.A.H., and N.K.R.; visualization, N.K.R. and N.J.N.; supervision, C.K.S.; project administration, C.K.S; funding acquisition, C.K.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Mercantile Bank PLC-CSR Grant for Technology Incubation in Agriculture (MBPLC-CSR GraTA).

Acknowledgments: This research was made possible by the support of the Department of Farm Power and Machinery, Bangladesh Agricultural University, and the financial support of Mercantile Bank PLC, Bangladesh.

References

1. FAO; IFAD; UNICEF; WFP; WHO. The State of Food Security and Nutrition in the World 2022. Repurposing Food and Agricultural Policies to Make Healthy Diets More Affordable.; FAO: Rome, **2022**; ISBN 9789251364994.
2. Matavel, C.; Hoffmann, H.; Rybak, C.; Sieber, S.; Müller, K.; Brüntrup, M.; Salavessa, J. Passive Solar Dryers as Sustainable Alternatives for Drying Agricultural Produce in Sub-Saharan Africa: Advances and Challenges. Discov. Sustain. **2021**, 2, doi:10.1007/s43621-021-00049-4.
3. FAO Global Initiative on Food Loss and Waste Reduction; FAO. Rome. Retrieved from: www.fao.org/publications**, 2015**.
4. Parthasarathy, P.; Pambudi, N.A. Performance Study of a Solar Chimney Air Heater. Case Stud. Therm. Eng. **2019**, 14, https://doi.org/10.1016/j.csite.2019.100437.
5. FAO Global Food Losses and Food Waste – Extent, Causes and Prevention; FAO: Rome, **2011;** ISBN 9789251072059.
6. Kumar, D.; Kalita, P. Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. Foods **2017**, 6, 1–22, doi:10.3390/foods6010008.
7. Pamuk, H.; Alam, M.J.; Tichar, T. Scoping Study on Fruits and Vegetables: Results from Bangladesh; Wageningen Economic Research: Waginingen, **2021**; ISBN 9789463959933.
8. Hossain, M.; Khatun, M.; Matin, M.; Dewan, M. Postharvest Loss Assessment of Major Fruits Grown in Hill Regions of Bangladesh. Bangladesh J. Agric. Res. **2017**, 42, 171–184, doi:10.3329/bjar.v42i1.31989.
9. Etefa, O.F.; Forsido, S.F.; Kebede, M.T. Postharvest Loss, Causes, and Handling Practices of Fruits and Vegetables in Ethiopia: Scoping Review. J. Hortic. Res. **2022**, 30, doi:10.2478/johr-2022-0002.
10. Desa, W.N.Y.M.; Fudholi, A.; Yaakob, Z. Energy-Economic-Environmental Analysis of Solar Drying System : A Review. Int. J. Power Electron. Drive Syst. **2020**, 11, 1011–1018, doi:10.11591/ijpeds.v11.i2.pp1011-1018.
11. Bradford, K.J.; Dahal, P.; Van Asbrouck, J.; Kunusoth, K.; Bello, P.; Thompson, J.; Wu, F. The Dry Chain: Reducing Postharvest Losses and Improving Food Safety in Humid Climates. Trends Food Sci. Technol. **2017**, 71, 84–93, doi:10.1016/j.tifs.2017.11.002.

12. Tiwari, A. A Review on Solar Drying of Agricultural Produce. J. Food Process. Technol. **2016**, 7, doi:10.4172/2157-7110.1000623.

13. Parvin, M.; Saha, C.K.; Nandi, R.; Alam, M.M. Solar Conduction Dryer for Drying of Fruit and Vegetables in Bangladesh. J. Food Process. Preserv. **2021**, 45, 1–15, doi:10.1111/jfpp.16102.

14. Poonia, S.; Singh, A.K.; Jain, D. Techno-Economic Analysis of Inclined Solar Dryer for Carrot (Daucus Carota L.). Ann. Arid Zone **2021**, 60.

15. Olaoye, S.A.; Oyekoge, O.O.; Owoseni, O.T.; Adesuyi, D.O.; Oladele, S.O.; Isa, J.; Olalusi, A.P. Developmental Trend of Hybrid Solar Dryer: A Comprehensive Review. J. Eng. Res. Reports **2023**, 24, 1–19, doi:10.9734/JERR/2023/v24i1793.

16. Prakash, O.; Kumar, A. Historical Review and Recent Trends in Solar Drying Systems. Int. J. Green Energy **2013**, 10, 690–738, doi:10.1080/15435075.2012.727113.

17. Lopez-Vidana, E.C.; Mendez-Lagunas, L.L.; Rodriguez-Ramirez, J. Efficiency of a Hybrid Solar – Gas Dryer. Sol. Energy **2013**, 93, 23–31, doi:10.1016/j.solener.2013.01.027.

18. Suherman, S.; Susanto, E.E.; Zardani, A.W.; Dewi, N.H.R. Performance Study of Hybrid Solar Dryer for Cassava Starch. AIP Conf. Proc. Proc. 2nd Int. Conf. Chem. Process Prod. Eng. 2019 **2020**, 2197, doi:10.1063/1.5140943.

19. Ihoume, I.; Tadili, R.; Arbaoui, N.; Daoudi, M.; Selim, A. Enhancing Grape Drying Efficiency: A Thermo-Ecological Analysis of a Hybrid Solar Greenhouse Dryer. Adv. Transdiscipl. Eng. **2023**, 38, 11–17, doi:10.3233/ATDE230267.

20. Roy, N. K.; Tasnim, N.; Saha, C. K.; Mimmi, S. F.; Kabir, M. Development of an auxiliary heating system for a solar dryer in Bangladesh. *J. Food Process Eng.* ***2024***, 47(8), e14705. https://doi.org/10.1111/jfpe.14705

21. Tarigan, E.; Tekasakul, P. A Mixed-Mode Natural Convection Solar Dryer with Biomass Burner and Heat Storage Back-up Heater. Proc. ISES World Congr. 2007 (Vol. I – Vol. V) **2009**, doi:10.1007/978-3-540-75997-3.

22. Ragasudha, R.; Karthickumar, P.; Murali, S.; Pradeep, R.; Rathnakumar, K.; Mercy Amrita, C.; Babiyola, D.; Manimehalai, N. Design and Performance Analysis of a PV-Powered Solar-Infrared Hybrid Dryer for Anchovy Fish Drying. Biomass Convers. Biorefinery **2023**, doi:10.1007/s13399-023-03944-0.

23. Taşkin, O.; Izli, N.; Vardar, A. Analysis on Photovoltaic Energy-Assisted Drying of Green Peas. Int. J. Photoenergy **2016**, doi:10.1155/2016/3814262.

24. Sharma, A.; Chen, C.R.; Vu Lan, N. Solar-Energy Drying Systems: A Review. Renew. Sustain. Energy Rev. **2009**, 13, 1185–1210, doi:10.1016/j.rser.2008.08.015.

25. Akter, T. Development and Evaluation of a Solar Dryer for Drying Pineapple in Bangladesh, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh, **2022**.

26. Pagukuman, B.N.D.; Ibrahim, M.K.W. A Review of the Significance Effect of External Factors of the Solar Dyer Design to Dried Foods Product Quality. J. Eng. Des. Technol. **2021**, 20, 1765–1786, doi:10.1108/JEDT-01-2021-0033.

27. Nwakuba, N.R.; Chukwuezie, C.O.; Asoegwu, S.N.; Nwaigwe, K.N. No-Load Performance Testing of an Arduino-Primed Hybrid Solar-Electric Crop Dryer. In Proceedings of the ASABE 2017 Annual International Meeting; **2017**.

28. Yassen, T.A.; Al-Kayiem, H.H.; Habib, K. Evaluation of Hybrid Solar - Biomass Dryer with No Load. MATEC Web Conf. **2014**, 13, doi:10.1051/matecconf/20141306007.