Modeled dryer using an automatic control system for agricultural products

Oluyemisi Adeola Adejumo[1*], Adebayo Ojo Adebiyi[2], Aye Taiwo Ajiboye[3], Kayode Oje [3]

(1. National Centre for Agricultural Mechanization (NCAM), Idofian, Kwara State,
2. Nigerian Stored Products Research Institute, Km 3. Asa Dam Road, Ilorin Kwara State.
3. Faculty of Engineering and Technology, University of Ilorin, Kwara State.)

Abstract: A laboratory modeled dryer fully automated was fabricated for monitoring and controlling the drying of agricultural products. Instrumentations were installed for monitoring the rate of moisture remover using Aluminum Load Cell, interfaced to a personal computer at an interval of 30 seconds. A voltage/frequency AC motor speed controller for air flow rate, temperature controller thermocouples were installed for monitoring the temperature at 8 different points on the sample tray which were later logged and displayed on a personal computer via the thermocouple Logger. Five treatments of the cassava mash samples in three replicates were dried and monitored within the automatic control dryer. The result of the evaluation for drying kinetics of Industrial Cassava mash shows that, the system allowed the modeled dryer to operate at a constant temperature with desired airflow and also provided full control of the temperature and drying airflow. It also gave room for computerized real-time automatic control system to retain quality. The automatic control system was reliable for operation and easy maintenance.

Keywords: automatic control system, dryer, and quality

Citation: Adejumo, O. A., A. O. Adebiyi, A. T. Ajiboye, and K. Oje. 2022. Modeled dryer using an automatic control system for agricultural products. Agricultural Engineering International: CIGR Journal, 24 (2):239-247.

1 Introduction

Drying is one of the most widely used methods for preserving agricultural products or food. Other purpose for drying agricultural products is to reduce the water content to minimize microbial spoilage and deterioration potential during storage Jindarat et al. (2011). Drying also resulted into weight-loss which facilitate transportation of the dried product and extends the shelf-life. Among other benefits of drying are reliability and efficient form of preservation of agricultural products for further processing. Drying could be direct and indirect removal of moisture from agricultural products which reduces moisture-mediated degradation, chemical and enzymatic reactions (Anirban, 2016). Often with food products, owing to the relationship between temperature and moisture; majority of agricultural products are thermo-sensitive, their color, chemical and physical properties may change significantly because of excessive heat accumulation during drying (Jindarat et al., 2011). Due to the importance of quality preservation of final product, improved food process efficiency and reduced waste during drying process; automatic process control of drying conditions is important. The study on Automatic Process Control and Instrumentation (APC&I) is an important means of studying agricultural drying process control to the point at which it retains quality of products. The interaction of drying parameters in agricultural processes with computerized control

Received date: 2021-03-26 **Accepted date:** 2022-02-18

* **Corresponding author: O. A. Adejumo,** Ph.D., Associate Professor of National Centre for Agricultural Mechanization (NCAM), Idofian, Kwara state. Email: oluyemisi123@gmail.com, Tel: 08033928528.

systems would provide accurate data acquisition methods, and facilitates analysis and decision making with greater agility through automated systems, as well would ensure accuracy and uniformity of the product moisture content (Suhaimi et al., 2013). In Nigeria especially, most agricultural drying process/es still adopts manual control method which is unreliable, exhibit large dead time, long-time delay and poor stability therefore, the quality of output product cannot be ensured neither specific while the design of efficient controls for food drying process system becomes difficult (Tippayawong et al., 2008; Lamnatou et al., 2010).

The development of computer control drying systems has facilitated the study of physical principles involved in agricultural processes; which promotes the use of Automated Control drying (Vijayananth et al., 2016). More efficient drying systems can be achieved through Artificial Intelligent controls of the temperature and airflow used in drying (Srzednicki et al., 2006; Tippayawong et al., 2008); with some significant improvements there had been significant growths in development of computer-based agricultural material drying systems in recent years (Vijayananth et al., 2016). These are revealed through the effort of Mittal and Otten (1983), Byler et al. (1989), Omid 2004, Akpinar et al. (2003) and Pati et al. (2004). This system can provide such advantages as fast data acquisition during complex experimental conditions in drying, precise timing and triggering of simultaneous and sequential events, automatic control of numerous devices or operations, versatility of operation through software control and ease of interfacing to a variety of computer terminals, and digital recording systems for process monitoring and control of drying processes (Wafler and Warnock, 1982; Omid, 2004).

Effective control strategy and microcontroller appear capable of saving up to 30% in energy use compared with a nonautomatic control system (Bakker-Arkema, 1984). Omid et al. (2006) developed an automated type thin-layer dryer for drying agricultural materials, which was introduced in the literature for drying study of some vegetables and fruits including potato, red pepper, apple, strawberry, pumpkin and eggplants slices (Akpinar et al., 2003; Akpinar, 2006). Byler et al. (1989) constructed a microprocessor-based system to control experimental conditions in the study of the moisture content of agricultural products; while the study of (Rolle et al., 2015) optimized for Evolved Water Vapour (EWV) analysis for spray drying. The concept of a controlled drying process adopts the methodology of measurement and variation of drying parameters which include, temperature, relative humidity and airflow used in the drying process relative to the product being processed, increases the thermodynamic efficiency of the process, and preserving the maximum quality of the product. Shabde and Hoo, (2008) developed a control structure to regulate the spray dryer's, product properties and drying parameters.

The objective of this research work developed and evaluate a modeled dryer with automatic control system for studying the drying characteristics of agricultural materials.

2 Materials and methods

2.1 Theoretical analysis for moisture content determination

Moisture Content was determined as the quantity of water available in the product; using the dry basis Usman et al. (2015). The dry-weight basis is widely applicable to organic drying analysis because the dry weight of matters is almost constant during the process.

2.2 Experimental apparatus

2.2.1. Description of the dryer

The dryer shown in Figure 1 is a rectangular, cupboard shaped-like which consists of the following units: a drying chamber, the heating unit, the chimney and the Automatic Control System. The drying chamber consists of the plenum chamber and the heating chamber. The plenum chamber is the unit in which the blower injects the drying air before coming in contact with the materials (product) to be dried. The plenum was designed as a long, curved chute leading to the drying section from underneath in order to distribute the air uniformly through products to dry. The heating chamber has one electrical heating coils of 1.20 kW, when air is heated up, a backward curved centrifugal fan sucks the heated air into the plenum chamber while residual exits through the vents. The inside of the chamber allows a tray to be arranged at a time, it has one door to allow the tray to be placed inside when opened and closed after placed. The chimney serves as a vent through which the moisture from the product escapes to the atmosphere.

PARTS LIST

ITEM	QUANTITY	PARTS DESCRIPTION
1	1	Drying Structure
2	1	Loadstar
3	1	Loadcell Sensor
4	1	Chimney
5	1	Inverter Box
6	1	Temperature thermostat
7	1	Picolog
8	1	Heating Element or Heater
9	2	Drying Trays
10	1	Air Enclosure shut
11	1	Blower/Electric Motor
12	1	Frame/Stand
13	1	Gate or Door

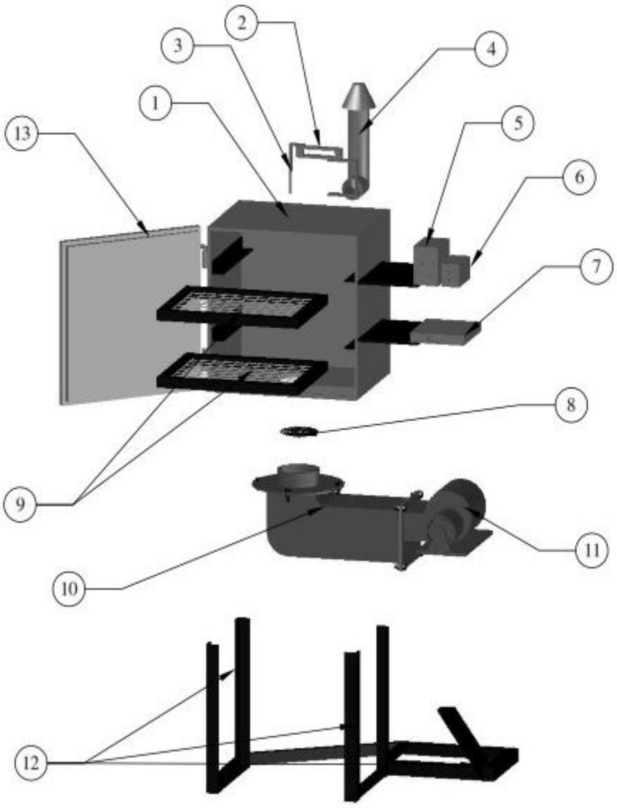

Figure 1 Exploded diagram of dryer with associated instrumentation

2.2.2. Description of the prototype control system

The Experimental Laboratory Model Dryer (ELMD) is a fully automated dryer with Aluminium Load Cell (OIML) Figure 2 is for monitoring of the weight and moisture removed per time and was interface to a personal computer; to log at an interval of 30 seconds. It consists of a sample tray which was hung to the load cell Figure 3, a voltage/frequency AC motor speed controller for measuring the variation of air flow rate, a temperature controller K – type model (WRX – 31) for measuring the variation in the dryer temperature and the 8-channels K-type thermocouples for monitoring the temperature of the sample at 8 different points on the sample tray. The temperature sensed by the thermocouples were logged into the personal computer via the TC-08 Thermocouple Data Logger as shown in Figure 4 and 5. The power rating of the dryer fan motor is 0.75 kW. The heat source is from 2 kW electric heater powered by 230 Volt AC supply via the temperature controller.

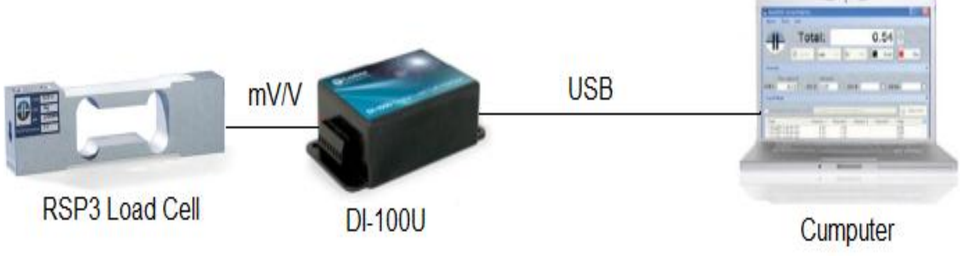

Figure 2 Connection of load cell, interface device and laptop computer

Figure 3 V/F control AC motor speed controller

Figure 4 The TC-08 thermocouple data logger

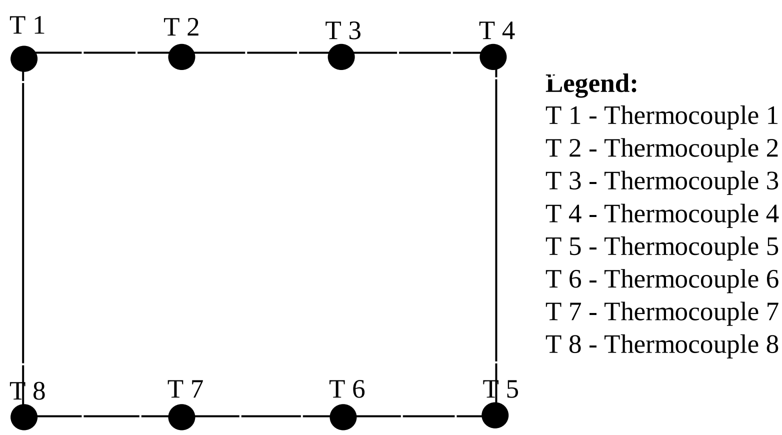

Figure 5 Arrangement of the thermocouples on the sample tray

Figure 6 The sensitive weighing scale

3 Procedure

Drying experiments on the system developed was carried out using grated unfermented cassava mash samples as shown in Figure 6 in the drying medium. The experiment was conducted between 12th April to 27th June, 2017. Cassava mash was processed from cassava tubers harvested from farm management unit of; the National Centre for Agricultural Mechanization (NCAM) Ilorin. Site location is 8° 22′ 59″ North and 4° 43′ 0″ East. They were peeled, washed, grated into mash and dewatered for a very short period of 1 hour in order to disallow fermentation and to retain quality required for an industrial purpose.

The temperature of 40°C, 55°C, 70°C, 85°C, 100°C and varied air velocity levels of 1.0 m s^{-1},1.5 m s^{-1}, 2.0 m s^{-1}, 2.5 m s^{-1} and 3.0 m s^{-1} were also investigated. The dewatered mash was placed on a stainless-steel drying tray which was suspended from the load cell. The experiment continued until the weight of mash sample became constant and the results were used for further processing. A 5^3 factorial experimental design in a Complete Randomized Block Design was used with the following combine effects of three independent variables. Figure 7 represented the drying rate of the dewatered cassava mash at velocity of 1.0 m s^{-1} at temperatures levels of 40°C, 55°C, 70°C, 85°C and 100°C. An inverse relationship effect was noticed between the air temperatures and the drying time.

To evaluate the interaction effect between the air temperature and the drying time, IBM SPSS 2016 was employed. This phenomenal was observed for other velocity levels which were shown as presented in Figures 8 - 11. This thus indicates that the reduction of the moisture content of the grated unfermented cassava mash was not affected by the air velocity inject by the automated model dryer, showing that the air velocity of the control system performed satisfactorily and adjustment of the velocity to the desired value would be necessary because at the air velocity levels of 1.0 m s^{-1}, 1.5 m s^{-1}, 2.0 m s^{-1}, 2.5 m s^{-1} and 3.0 m s^{-1} the same trend was exhibited by the temperatures supporting the fact that at any of this air velocity levels, drying process of unfermented grated cassava mash will occur. IBM SPSS 2016 statistical package was utilized for the determination of interaction between the variables at different levels. The study using different velocities reveals no significant effect on the drying rate and this is coherent to the work carried out by Amnart and Pongjet (2006), and Amin et al. (2011). This observation is a general report for other food products e.g. mulberry, eggplant, tomatoes, sweet pepper, cassava chips and peach slices (Doymaz, 2004; Ertekin and Yaldiz, 2004; Doymaz, 2007; Kingsly et al., 2007; Caparanga et al., 2017).

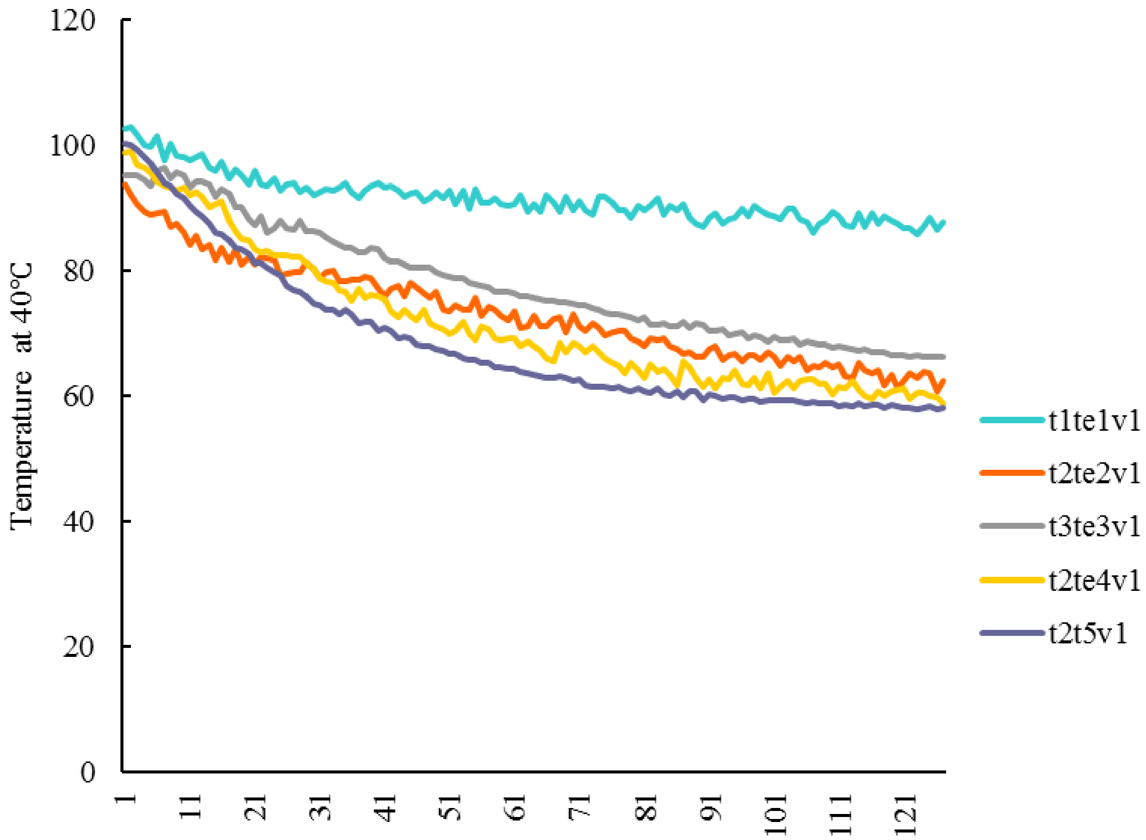

Figure 7 At velocity 1.0 m s^{-1}

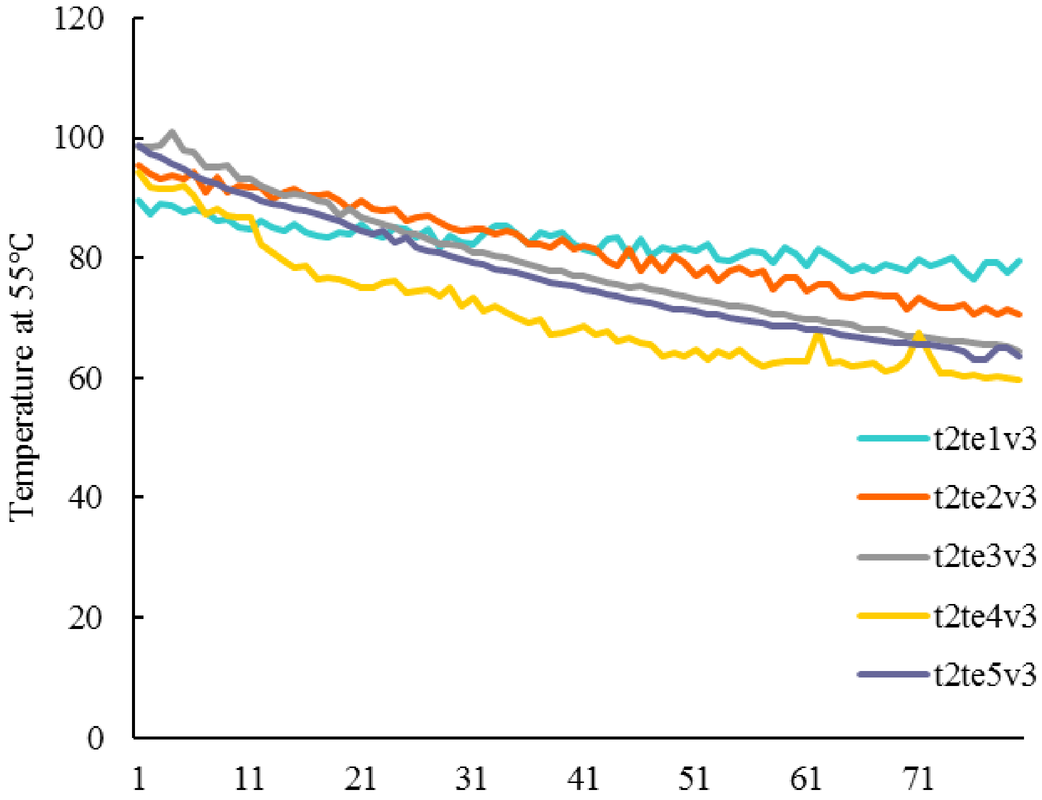

Figure 8 At velocity 1.5 m s^{-1}

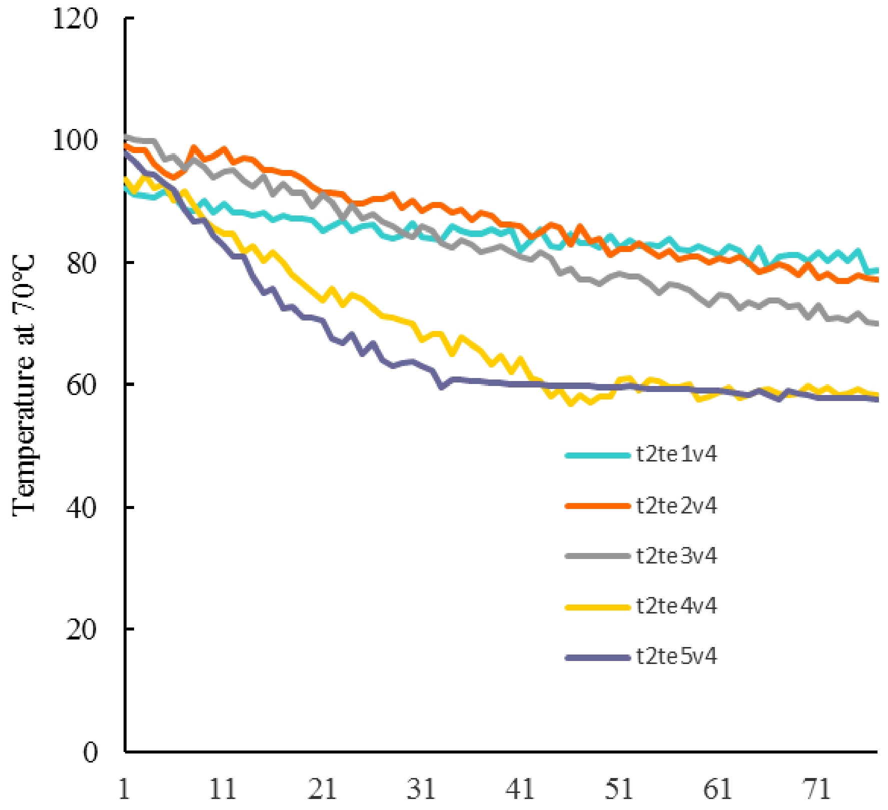

Figure 9 At velocity 2.0 m s-1

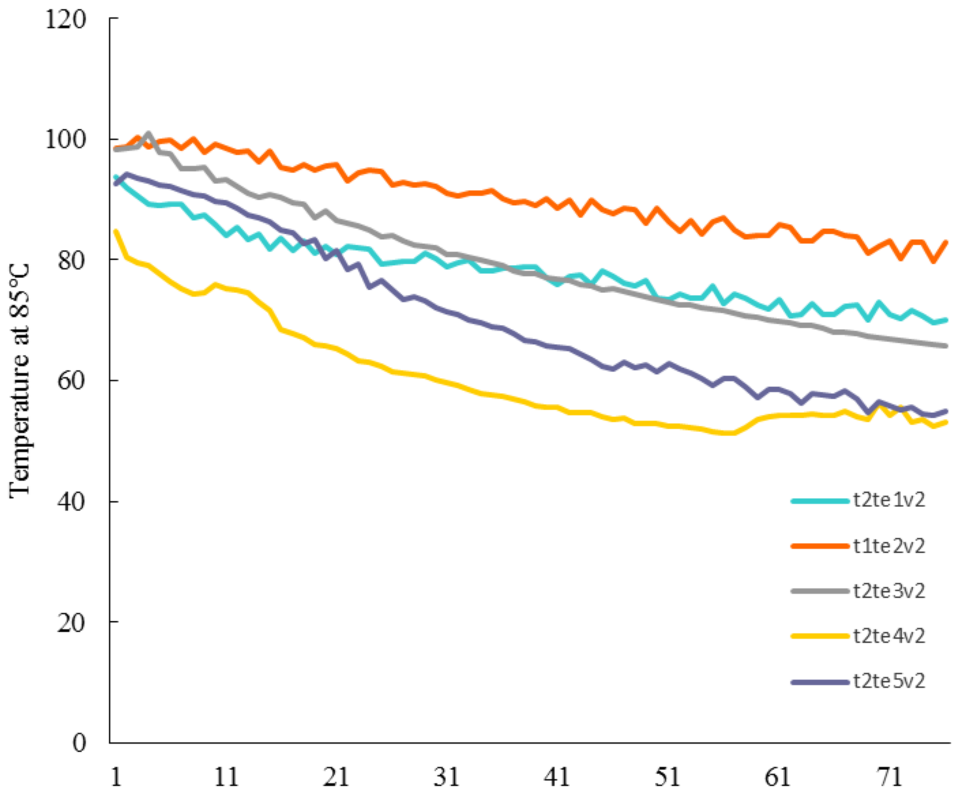

Figure 10 At velocity 2.5 m s-1

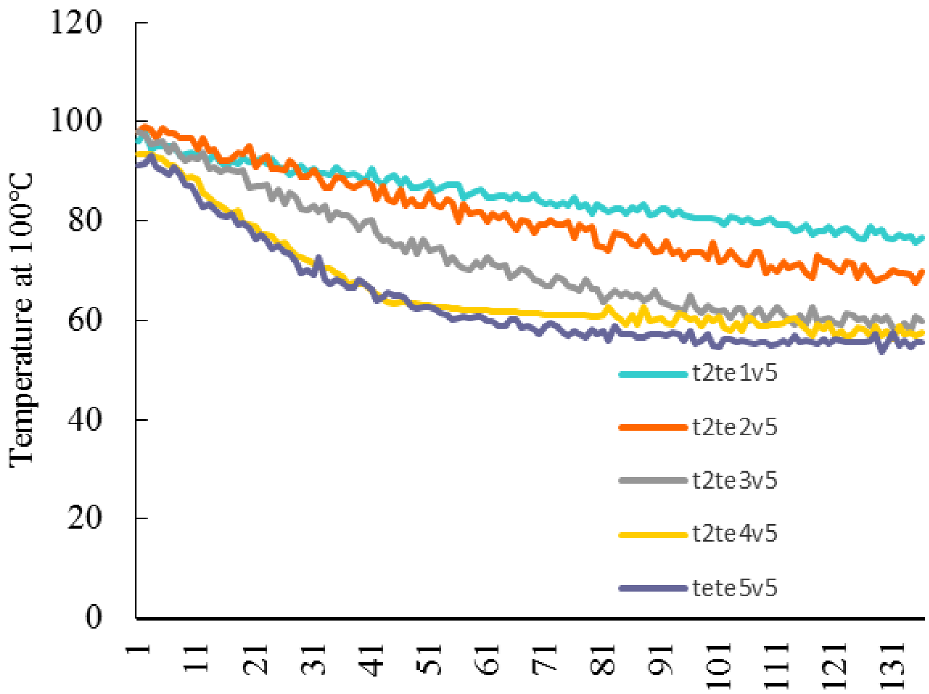

Figure 11 At velocity 3.0 m s^{-1}

4 Conclusions

The automatic instrumentation system enables the dryer to operate at a constant temperature of the drying air and desired drying airflow. In addition to the automatic control modelling, the system performed real time data acquisition, generating charts, graphs and log reports in the format of excel and text files. The result of the experimental study of moisture content reduction during drying industrial cassava mash using the experimental model dryer with fully automatic control system (ACS) shows that the velocity control system performed very well when adjusted to the desired levels. The automatic control system was reliable and of easy implementation and maintenance. The use of automatic control (AC) allowed full control of the temperature and drying airflow in a wide range of values (40°C, 55°C, 70°C, 85°C, 100°C. and 1.0 m s^{-1}, 1.5 m s^{-1}, 2.0 m s^{-1}, 2.5 m s^{-1} and 3.0 m s^{-1}, respectively) therefore, monitoring the rate of moisture removal per time on the computer interface gave room for computerized real-time automatic control system of drying agricultural products in order to maintain agricultural product quality.

References

Amin, T., R. Shahin, and K. Alireza. 2011. Effect of temperature, relative humidity and air velocity on drying kinetics and drying rate of basil leave. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, vol. 10(4): 2075 -2080.

Amnart, B., and Pongjet. 2006. Drying kinetic of pepper corn in a fluidized bed with helical distributor plate. In *The 2nd Joint International Conference on Sustainable Energy and Environment*, Bangkok, Thailand, 21 – 23 November, 1 - 4.

Anirban, N.,2016. Analysis of Drying Parameters for Different Agricultural Products. Available at: https://www.researchgate.net/publication/316688367. Accessed in December 2017.

Akpinar, E., Y. Bicer, and A. Midilli. 2003. Modeling and experimental study on drying of apple slices in a convective cyclone dryer. *Journal of Food Process Engineering*, 26(6): 515.

Akpinar, E. 2006. Determination of suitable thin layer drying curve model for some vegetables and fruits. *Journal of Food Engineering*, 73(1): 75–84.

Bakker-Arkema, F. W. 1984. Selected aspects of crop processing and storage: a review. *Journal of The British Agricultural Engineering Research*, 1984(30): 1-22.

Byler, R., B. Gerrish, and C. Brook. 1989. Data acquisition and control system for experimental thin-layer drying study. *Computers and Electronics in Agriculture*, 3(1): 225-241.

Caparanga, A., R. Reye, R. Rivas, and F. De-Vera. 2017. Effect of air temperature and velocity on the drying kinetics and product particles size of starch from arrowroot. (Maranta

Arundinacea). *The European Physical Journal Conferences*, 162(2). Avillion Port Dickson, Malaysia, 9-10 August.

Doymaz, I. 2004. Convective air-drying characteristics of thin layer carrots. *Journal of Food Engineering*, 61(3): 359-364.

Doymaz, I. 2007. Air-drying characteristics of tomatoes. *Journal of Food Engineering*, 78(4): 1291-1297.

Ertekin, C., and O. Yaldiz. 2004. Drying of eggplant and selection of a suitable thin layer drying model. *Journal of Food Engineering*, 63(3): 349–359.

Kingsly, A., R. Singh, K. Goyal, and D. B. Singh. 2007. Thin-layer drying behaviour of organically produced tomato. *Am. Journal of Food Technology*, 2(2): 71-78.

Lamnatou, C., E. Papanicolaou, V. Belessiotis, and N. Kyriakis. 2010. Finite-volume modelling of heat and mass transfer during convective drying of porous bodies – non-conjugate and conjugate formulations involving the aerodynamic effects. *Renewable Energy*, 35(7): 1395–1402.

Mittal, G. S., and L. Otten. 1983. Microprocessor controlled low-temperature corn drying systems. *Agricultural Systems*, 10(1): 1-19.

Jindarat, W., P. Rattanadecho, and S. Vongpradubchai. 2011. Analysis of energy consumption in microwave and convective drying process of multi-layered porous material inside a rectangular wave guide. *Experimental Thermal and Fluid Science*, 35(4): 728-737.

Omid, M. 2004. A computer-based monitoring system to maintain optimum air temperature and relative humidity in Greenhouses. *International Journal of Agriculture and Biology*, 6(6): 1084-1088.

Omid, M., A. Yadollahinia, and S. Rafiee. 2006. A thin-layer drying model for paddy dryer. In *Proceedings of the International conference on Innovations in Food and Bioprocess Technologies, 202-209. AIT, Pathumthani, Thailand 12th–14th December.*

Pati, U. C., M. K. Ghosh, S. Bal, and G. Panda. 2004. Design and fabrication of a computer automated dryer for thin layer grain drying. *Journal of the Instrument Society of India*, 34(3): 187-194

Rolle, F., G. Beltramino, V. Fernicola, M. Sega, and A.Verdoja. 2015. Moisture determination for food quality assessment. In *17 International Congress of Metrology*, 100(205). Paris, France, 21 – 24 September.

Shabde, V., and K. Hoo. 2008. Optimum controller design for a spray drying process. *Control Engineering Practice*, 16(5): 541-552.

Srzednicki, G. S., Hou, R., and R. H. Driscoll. 2006. Development of a control system for in-store drying of paddy in Northeast China. *Journal of Food Engineering*, 77(2) 368-377.

Suhaimi, M., M. Sohif, R. Mohd, S. Kamaruzzaman, and S. Elias. 2013. The prediction of drying uniformity in tray dryer system using CFD simulation. *International Journal of Machine Learning and Computing*, 3(5): 419 – 423.

Tippayawong, N., C. Tantakitti, and S. Thavornun. 2008. Energy efficiency improvements in longan drying practice. *Energy*, 33(7): 1137-1143.

Usman, A. K., M. Salamdin., B., Mahajan and M. Alam. 2015. Grain moisture measuring techniques - a review of Agricultural engineering today; a technical publication of Indian society of agricultural engineers., 39(2): 13-18.

Vijayananth, D., V. M. Sivakumar, S. Ramkumar, and M. Thirumarimurugan. 2016. Control of tray dryer using PID controller. In *Middle-East Journal of Scientific Research*, 24(IIECS.23169): *254-258*.

Wafler, P., and W. Warnock. 1982. A microprocessor-controlled crossflow grain dryer test unit. ASAE Paper No. 82-3009. St. Joseph, Mich.: ASAE.