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Implementation of proportional–integral control in Baglog steamer temperature control

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ABSTRACT

Sterilization is the oyster mushroom cultivation process. Sterilization is used to kill nuisance microorganisms that can inhibit mushroom growth. The sterilization process is 8 hours at a temperature of 70–95 ºC. This process of frequent breakdown is caused by the unstable temperature sterilization space and is controlled manually. Based on these problems, the right solution is to use a steamer that can be controlled automatically using the proportional–integral (PI) control method. PI controller consists of proportional gain and integral gain. To determine the value of proportional gain and integral gain, this study used the Ziegler-Nichols tuning method using the S curve. The results of the PI control parameters obtained the value of Kp=25.2 and Ki = 0.302. Thus, producing a transient response graph with Mp=94.5; Os=0.45; PO=0.47; Tr=16,440 s. The system can work according to setpoint 95 ºC and maintain a stable temperature according to the setpoint with these results. And the sterilization time becomes fast from 8 hours to 6 hours.

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1. INTRODUCTION

Oyster mushroom (Pleurotus ostreatus) is a wood fungus that grows sideways on rotting wood [1]. This mushroom has a fruiting body that blooms to form a shallow funnel-like shellion. The white oyster mushroom is best known to be delicious and liked by the public [2]. Because it tastes like chicken meat, even this oyster mushroom is liked by most people in the world because of its distinctive taste and health benefits [3]. Oyster mushroom growing media or commonly called Baglog is an oyster mushroom growing medium consisting of a mixture of sawdust, bran, lime, and water [4].

Baglog is a growing medium from oyster mushrooms. Before entering the mushroom seeds, the Baglog must go through a sterilization process in the form of heating at high temperatures which aims to kill various pathogens and other microbes in the growing media [5]. Baglog that has been packaged is then sterilized so that the media can meet the nutritional needs of the [6]. Media sterilization is one of the most important processes in the cultivation of oyster mushrooms because the media that has been made usually still contains many microbes, especially wild mushrooms [7]. Conventional sterilization is generally carried out for 8 hours at a temperature of 70–95 ºC [8]. Oyster mushroom cultivation of them, can be done with a steam technique using the drum. Commonly used fuel is firewood which could be assisted by using coal or kerosene or liquefied petroleum gas (LPG) gas [9].

The mushroom cultivation process currently still relies on a conventional system, the process of using firewood to boil water so that the weathering process occurs evenly, the Baglog must be turned manually, so it takes a long process [10]. The conventional system is considered to have many weaknesses, it is necessary to develop it using a modern control system to speed up the sterilization process. In the sterilization process, this process becomes important because the development of the fungus depends on the conditions of the Baglog. One application of the automatic control system is in controlling the temperature of the Baglog steamer. The control system used is a proportional–integral (PI) control, where the PI control can maintain a steady-state value in the disturbance response [11].

2. METHOD

In this study, the controller used is Arduino Mega 2560. This controller is the main component to regulate the temperature of the steamer with the PI method programmed on the Arduino Mega 2560. In this design, the Baglog steamer system can be controlled automatically according to a predetermined setpoint.

2.1. Previous research

The theoretical basis for the implementation of this final project is the cascade control implementation on Baglog steamer temperature control using programmable logic controller (PLC) and human machine interface (HMI). In this study, the steamer can be controlled automatically by cascade control with the proportional integral derivative (PID) control method. In temperature readings, PT100 is used and monitored with an actuator in the form of a DC motor [12]. In previous studies, Baglog capacity was only 80 pieces shelling use of 1 drum. In the current study, 4 drums are used to produce up to 320 Baglogs. Moreover, the selection of PI control is supported by research on the process of designing and manufacturing automatic expansion valve controls using a PI control system, to control the process of controlling the temperature of the evaporator chamber to obtain more optimal heating results. Where the results of this study are the PI control system on the automatic expansion valve, the heater process is faster and the energy required is much more efficient [13].

2.2. Baglog planting media

Baglog as Figure 1 is an oyster mushroom growing medium applied by mushroom farmers by using sawdust as a planting medium. Before planting (inoculation) seeds into the planting medium, it is necessary to prepare tools and materials. Then sterilize at a predetermined temperature [14]. The materials used in the activity are gleam wood sawdust, rice bran, corn bran, agricultural lime ($CaCO_3$), oyster mushroom seeds, gypsum, 70% alcohol, and spirit [15].

Figure 1. Baglog

2.3. Steamer

In Figure 2 is a steamer, steam is the technical language of water vapor, which is the gas phase of water that is formed when water boils [16]. To change water from the liquid phase (liquid) to the gas phase (steam) heat energy is needed to raise the temperature of the water which is commonly referred to as "sensible heat" [17]. A steamer is a tool used for Baglog sterilization. Sterilization is done to kill nuisance microorganisms that can inhibit the growth of fungi.

Figure 2. Steamer

2.4. RTD–PT100

Resistance temperature detector (RTD) as shown in Figure 3 is a temperature sensor whose measurements use the principle of change of resistance or resistance metallic electricity which is affected by temperature changes. PT100 is one type of temperature sensor which is famous for its accuracy [18]. The most exact temperature measurement can be made by using platinum sensors. Temperatures from -254.3 °C up to +850 °C can be measured with a P100 sensor [19]. Hence the name begins with "PT." Called PT100 because this sensor was calibrated at 0 °C at a resistance value of 100 ohms [20]. Temperature calibration in the form of PT100 can use the method of comparison of measurement results on PT100 with a thermometer. The comparison method is used by comparing standard calibrators in the form of ice cubes or boiling water [21].

Figure 3. PT100

2.5. PI control system

PI controller in Figure 4 is a combination of proportional (Kp) and integral (Ki) [22]. The advantage of the combination of proportional and integral control is to speed up the reaction of a system and eliminate offsets [23]. A controller with proportional control is added with an integral controller whose relationship is u(t) as the controller and e(t) is the error signal [24]. PI control is carried out if the response results do not have an overshoot belonging to the first-order system ($zero\ of - set\%\ Ess\ =\ 0\%$) [25]. PI controller that has good performance is obtained by providing accurate controller tuning parameters [26]. Tuning controlling parameters is the process of setting control parameters to produce desired control system [27]. One of the controlling parameter tuning methods is the Ziegler Nichols Tuning method. Method Ziegler Nichols tuning consists of the reaction curve method (open-loop control) and oscillation method (closed-loop control). The Ziegler Nichols tuning method is faster than the trial and error method because has a specific formula for finding controller tuning [28]. The characteristics of the control system response can be known by looking for the parameters written:

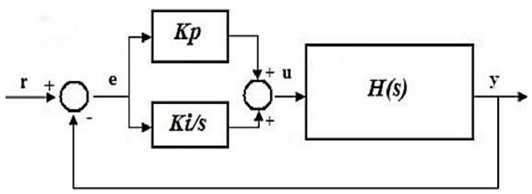

Figure 4. PI controller

Maximum overshoot (Mp) is the peak value of the unit's measurable response curve. If the final value of the deaf state of the response is far from one. Overshoot (Os) is a relative value that expresses the maximum price ratio of a response that exceeds the steady-state price compared to the steady-state value.

$$Os = Mp - Sp\ (Celcius) \tag{1}$$

Percentage of overshoot (PO) is the number of waves that overshoot the steady-state or final value at peak time, expressed in the form of a percentage of the steady-state value. Overshoot in units (%):

$$PO = \frac{Os}{Sp} x\ 100\% \tag{2}$$

rise time (Tr) is the time reached by the system when the system reaches 90% of the setpoint. Peak time (Tp) is the time reached by the system when the system reaches the max temperature state from the first run. Settling time (Ts) is the time reached by the system when the system reaches a steady state.

2.6. System block diagram

Based on the block diagram system in Figure 5, the first block in the input sections contains a temperature sensor that uses resistance temperature detector (RTD) PT100 to measure the temperature in the steamer. Before the temperature sensor can work, signal conditioning must be connected in PT100 because the electronic circuit is a converter of the output temperature sensor and pressure sensor in the form of resistance. After the resistance value is converted into a voltage value, the temperature sensor can be processed by Arduino Mega 2560. The second block is real-time clock (RTC). RTC is a timer process sterilization while the system is on processing, RTC duration has been set through the Arduino program that is for 6 hours. Further in the process section, Arduino Mega 2560 is the main controller for data processing with the PI method. Then in output sections, the motor driver functions to change the rotation of the solenoid valve. The solenoid valve is a steam door flow, so if the temperature has not reached the setpoint, the valve will open and vice versa. During the process, liquid crystal display (LCD) will show the temperature of each drum and the time remaining for the sterilization process.

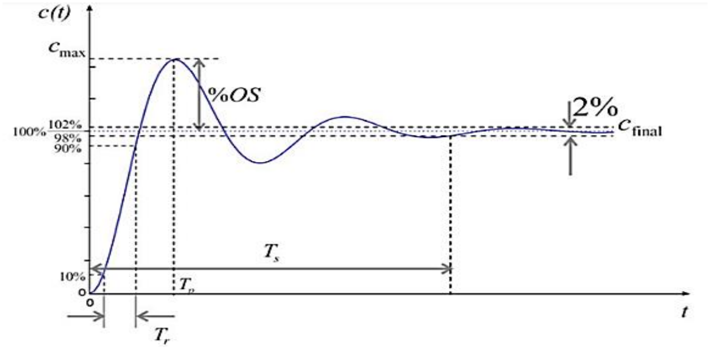

Figure 5. Second order response

2.7. Work principle

The working principle of the Baglog steamer is to keep the temperature in the steamer constant or stable by the given set point. This steamer can be run when the temperature in the boiler has reached 110 ^{o}C. Then the steam valve will open to provide a water vapor supply to the steamer. When the temperature in the steamer has reached the setpoint, which is 95 ^{o}C, the PI will adjust, and the valve will close when the steam needs of the steamer have been met. When the evaporation process lasts for 6 hours, but the temperature in the steamer has decreased, the PI will continue to work, the valve will open and the opening will be following the feedback sent by the temperature sensor. After reaching the setpoint, the valve will close, and vice versa.

2.8. PI method design

The first explanation of the elements in Figure 6 is the setpoint value that has been determined, namely 95 ^{o}C, then processed by the PI controller. PI control functions to adjust the ignition timing of the steamer according to the temperature sensor feedback that is read on the steamer. The setting is done by entering the appropriate Kp and Ki values so that a stable system response and more efficient time are obtained. From the temperature that has been read, the temperature data will be processed by the controller to be used as a comparison with the setpoint value, in which the control results are given to the system. Then, the temperature sensor functions to read the temperature value on the steamer which will be displayed on the LCD.

In the design of the PI control in Figure 7, it will be processed using a formula, it takes feedback from the PT100 temperature sensor reading which will later become the formula for calculating the response curve method in the program. The PI controller has two influential parameters: the proportional constant (Kp) and the constant (Ki).

To meet the values of Kp and Ki, tuning is needed so that the response curve of the system as shown in Figure 8, without a controller is obtained and then the PI parameter equation is sought from the results of the system response curve using the Ziegler Nichols method. The first step in getting the PI parameter value is to take the response from the plant that has been experimented with by entering it in the form of a unit step, to get the value of the delay time L and the time constant T. The values of L and T are obtained from the S-shaped curve, which is determined by drawing a tangent line at the point of the curve and finding the tangent's intersection to the time axis and the steady-state line.

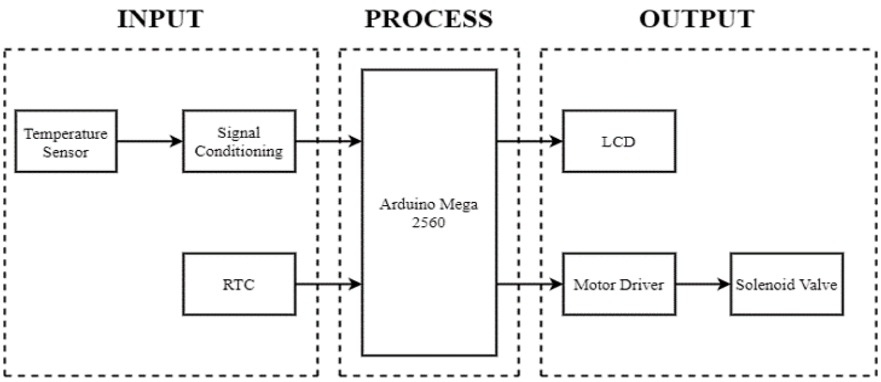

Figure 6. Block diagram system

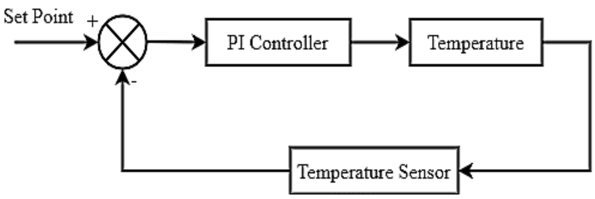

Figure 7. PI method design

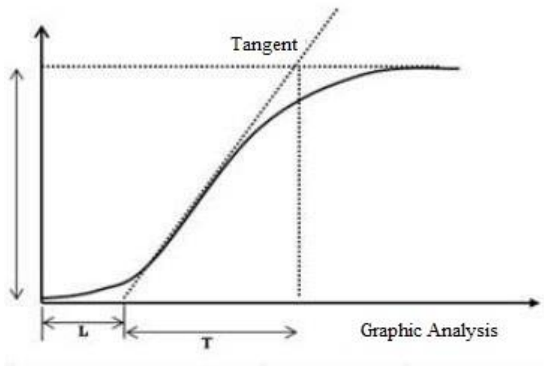

Figure 8. Ziegler Nichols graphical analysis S curve

Here are the results of the response of the Baglog steamer temperature without control Based on Figure 4, it is known that the plant response is in the form of an S curve, so in this design the Ziegler Nichols I method is used. Then look for the L (dead time) and T (delay time) values from the system response graph, then the L value is 25 and T is 700. After obtaining a response in the form of a unit step, the next step is to enter the values of L and T into the PI parameter formula in the Ziegler Nichols tuning rule used as shown in Table 1.

Table 1. PI control formula

Controller type	Kp	Ki	Td
P	T/L	~	0
PI	0,9 T/L	L/0,3	0

Based on Table 1 to obtain the values of Kp and Ki, (3)-(5) is obtained and Ti is obtained by (4) as shown in:

$$Kp = 0{,}9\ x\ T/L \tag{3}$$

$$Ti = L/0{,}3 \quad (4)$$

$$Ki = Kp/Ti \quad (5)$$

From the calculation results obtained from (3), the Kp value is 25.2 and the Ti value is obtained from (4), which is 83.3, while the Ki value is obtained from (5), which is 0.302. So that the transfer function of the PI plant control parameters obtained the value of $Kp = 25.2$, $Ki = 0.302$.

3. RESULTS AND DISCUSSION

3.1. RTD–PT100

In Table 2 the test results of the PT100 temperature sensor provide optimal performance by resistance measurements using a temperature measuring instrument, namely a digital multimeter. The results obtained are quite accurate, it can be seen from the error value.

$$E = \frac{\Sigma e}{n} \quad (6)$$

Based on the test results of the PT100, the sensor detects the temperature as needed and the error ratio between the use of a thermometer and a digital multimeter is obtained with a minimum error of 0.222%

Table 2. Temperature sensor resistance test graph

No	Temperature (°C)	Temperature sensor measurement PT100 (Ω)	Sensor datasheet PT100 temperature (Ω)	Error (%)
1	50	120	119,73	0,22
2	55	122,1	121,69	0,33
3	60	123,8	123,64	0,13
4	65	125,8	125,59	0,17
5	70	127,4	127,54	0,11
6	75	129,4	129,48	0,06
7	80	131,1	131,43	0,25
8	85	133,0	133,36	0,27
9	90	135	135,3	0,22
10	95	136,6	137,23	0,46

3.2. PI control

This PI control test refers to the Ziegler-Nichols PI design to achieve a temperature setpoint of 95 °C as show in Figure 9. This test is done by looking at the PI tuning response in each PI block, from the calculation results of the PI parameters that have been implemented in the plant. The graph results below are tested through the PT 100 sensor reader.

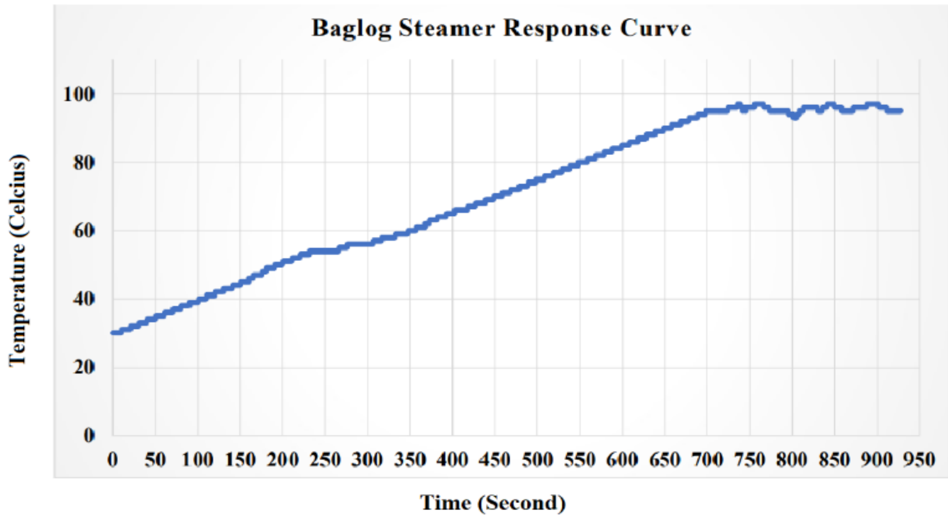

Figure 9. Baglog steamer without response curve

Based on the results of the PI control test, the system response graph parameters were obtained with a setpoint of 95 °C. PI control has an output in the form of feedback from the sensor if given an input value. PI control test, it is obtained that the control time is faster and the PI control can control the valve opening. The response results from Figure 10 show that the Mp value is 94.45 C, the overshoot value is 0.45 C, the Percentage of overshoot value is 0.47%, and the rise time value is 16.440 seconds where the results of the parameter values obtained that this tool has reached the setpoint value so that it does not cause excessive heat in the steamer. If the temperature has not reached the setpoint then the valve will open, but if the temperature has reached the setpoint then the valve will close. PI response at Figure 10 as in the picture.

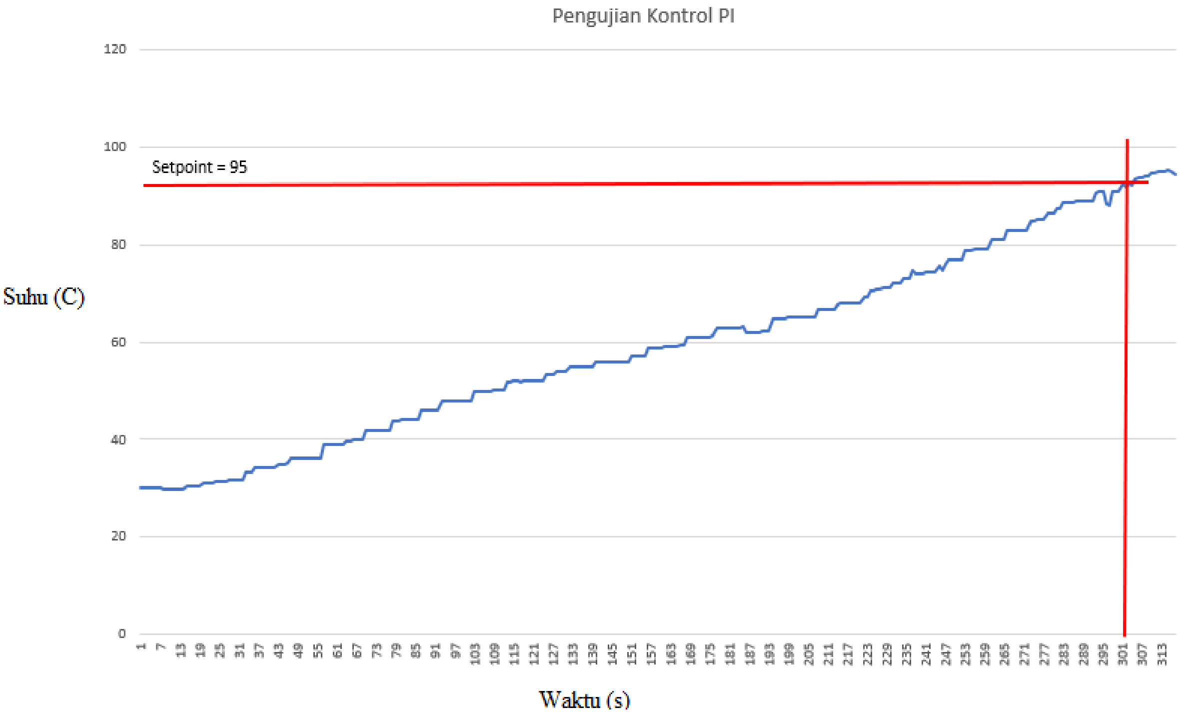

Figure 10. Response with PI control

4. CONCLUSION

Based on the results of the tests and analyzes that have been carried out on the Baglog steamer, the following conclusion can be drawn: i) baglog steamer automation using Arduino Mega 2560 can work according to the setpoint value of 95 °C, This microcontroller can provide good performance while the tool is working, ii) the results of the real test of the tool obtained that the PT100 temperature sensor was able to reach the setpoint temperature of 95 °C, iii) by controlling the PI method, it affects the performance of the system which previously used manuals that took quite a long time, iv) with the PI control used, it can move the valve when the temperature has reached the setpoint. If the temperature is less than the setpoint, the valve will open and if the temperature has reached the setpoint, the valve will close, v) the application of PI control can speed up production time if the conventional system takes 8 hours. With the automatic system, Baglog sterilization becomes 6 hours, vi) the performance of the tool after being controlled using the PI method obtained the value of Mp = 94.5; Os =0.45; PO =0.47; and Tr =16,440.

REFERENCES

[1] G. P. Cikarge and F. Arifin, ‘‘Oyster mushrooms humidity control based on fuzzy logic by using Arduino ATMega238 microcontroller,’’ in *Journal of Physics: Conference Series*, vol. 1140, no. 1, p. 012002, Dec 2018, doi: 10.1088/1742-6596/1140/1/012002.

[2] I. P. A. K. Surya, ‘‘Chemical on pleurotusostreatus,’’ *International Journal of Chemical and Material Sciences*, vol. 2, no. 1, pp. 8-13, 2019, doi: 10.31295/ijcms.v2n1.72.

[3] I. Taskirawati, ‘‘The effect of the addition of promoting microbes (PROMI) in making media of pleurotus ostreatus,’’ *Journal of Sylva Indonesiana*, vol. 3, no. 02, pp. 68-77, 2020, doi: 10.32734/jsi.v3i02.2844.

[4] Y. Syahputri, A. G. Dalimunthe, and M. Usman, ‘‘Added value analysis of oil palm frond waste into the white oyster mushroom (Pleurotus ostreatus) growing media to increasing business opportunities in sampali village, Percut Seituan, Deli Serdang regency,’’ *Accounting and Business Journal*, vol. 3, no. 2, pp. 145-154, 2021, doi: 10.54248/abj.v3i2.3923.

[5] A. Abdurrahman *et al*., ‘‘Optimization and interpretation of heat distribution in sterilization room using convection pipe,’’ *Indonesian Journal of Science & Technology*, vol. 4, no. 2, pp. 204-219, 2019, doi: 10.17509/ijost.v4i2.18177.
[6] F. Alfianti, S. Sutarman, A. C. Murti, and M. B. Adenan, ‘‘Pasteurization of coconut water and rice washing water as a supplement for extending the life of oyster mushroom cultivation media,’’ *Agritech: Jurnal Fakultas Pertanian Universitas Muhammadiyah Purwokerto*, vol. 23, no. 1, 2021, doi: 10.30595/agritech.v23i1.10194.
[7] C. Sánchez, ‘‘Cultivation of Pleurotus ostreatus and other edible mushrooms,’’ *Applied microbiology and biotechnology*, vol. 85, no. 5, pp. 1321-1337, 2010, doi: 10.1007/s00253-009-2343-7.
[8] N. A., Gowda and D. Manvi, “Agro-residues disinfection methods for mushroom cultivation,” *Agricultural Reviews*, vol. 40, no. 2, pp: 93-103, doi: 10.18805/ag.R-1735.
[9] C. F. Munyeza, A. M. Osano, J. K. Maghanga, and P. B. Forbes, ‘‘Polycyclic aromatic hydrocarbon gaseous emissions from household cooking devices: a Kenyan case study,’’ *Environmental toxicology and chemistry*, vol. 39, no. 3, pp. 538-547, 2020, doi: 10.1002/etc.4648.
[10] M. A. M. Ariffin et al., "Automatic Climate Control for Mushroom Cultivation using IoT Approach," 2020 *IEEE 10th International Conference on System Engineering and Technology (ICSET)*, 2020, pp. 123-128, doi: 10.1109/ICSET51301.2020.9265383.
[11] L. S. P. Lawrence, Z. E. Nelson, E. Mallada, and J. W. Simpson-Porco, "Optimal steady-state control for linear time-invariant systems," *2018 IEEE Conference on Decision and Control (CDC)*, 2018, pp. 3251-3257, doi: 10.1109/CDC.2018.8619812.
[12] H. Ma, X. Song, R. Ding, and C. Hou, “Parameters Optimization Algorithm on the PID-P Cascade Controller of Flue Gas Heat Exchange System Based on Improved Particle Swarm,” 2021, doi: 10.2139/ssrn.3909864.
[13] S. S. Franco, J. R. Henríquez, A. A. V. Ochoa, J. A. P da Costa, and K. A. Ferraz, “Thermal analysis and development of PID control for electronic expansion device of vapor compression refrigeration systems,” *Applied Thermal Engineering*, vol. 206, p. 118130, 2022, doi: 10.1016/j.applthermaleng.2022.118130.
[14] R. Rambey, I. D. B. Sitepu, and E. B. M. Siregar, ‘‘Productivity of oyster mushrooms (Pleurotus ostreatus) on media corncobs mixed with sawdust,’’ *IOP Conference Series: Earth and Environmental Science*, vol. 260, no. 1, p. 012076, 2019, doi: 10.1088/1755-1315/260/1/012076.
[15] E. Baysal, H. Peker, M. K. Yalinkiliç, and A. Temiz, ‘‘Cultivation of oyster mushroom on waste paper with some added supplementary materials,’’ *Bioresource Technology*, vol. 89, no. 1, pp. 95-97, 2003, doi: 10.1016/S0960-8524(03)00028-2.
[16] R. W. Falta, K. Pruess, I. Javandel, and P. A. Witherspoon, ‘‘Numerical modeling of steam injection for the removal of nonaqueous phase liquids from the subsurface: 1. Numerical formulation,’’ *Water resources research*, vol. 28, no. 2, pp. 433-449, 1992, doi: 10.1029/91WR02526.
[17] W. D. Steinmann and M. Eck, ‘‘Buffer storage for direct steam generation,’’ *Solar Energy*, vol. 80, no. 10, pp. 1277-1282, 2006, doi: 10.1016/j.solener.2005.05.013.
[18] A. Tong, ‘‘Improving the accuracy of temperature measurements,’’ *Sensor Review*, 2001, doi: 10.1108/02602280110398044.
[19] R. Radetić, M. Pavlov-Kagadejev, and N. Milivojević, ‘‘The analog linearization of Pt100 working characteristic,’’ *Serbian Journal of Electrical Engineering*, vol. 12, no. 3, pp. 345-357, 2015, doi: 10.2298/SJEE1503345R.
[20] L. Parali, F. Durmaz, and O. Aydin, ‘‘Calibration of a platinum resistance thermometer (pt-100) and its measurement uncertainty analysis,’’ *Celal Bayar University Journal of Science*, vol. 14, no. 1, pp. 41-49, 2018, doi: 10.18466/cbayarfbe.334988.
[21] J. A. Prakosa, Purwowibowo, and D. Larassati, "Development of simple method for quality testing of PT100 sensors due to temperature coefficient of resistance measurement," *2021 International Symposium on Electronics and Smart Devices (ISESD)*, 2021, pp. 1-5, doi: 10.1109/ISESD53023.2021.9501552.
[22] J J. Alshehri, A. Alzahrani, M. Khalid, and F. Alismail, "Optimal control of a microgrid with distributed renewable generation and battery energy storage," *2020 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)*, 2020, pp. 1-5, doi: 10.1109/ISGT45199.2020.9087685.
[23] Q. Fei, Y. Deng, H. Li, J. Liu, and M. Shao, "Speed ripple minimization of permanent magnet synchronous motor based on model predictive and iterative learning controls," in *IEEE Access*, vol. 7, pp. 31791-31800, 2019, doi: 10.1109/ACCESS.2019.2902888.
[24] M. Chevalier, M. G. Schiavon, A. H. Ng and H. E. Samad, “Design and analysis of a proportional-integral-derivative controller with biological molecules,” *Cell systems*, vol. 9, no. 4, pp. 338-353, doi: https://Doi.org/10.1016/j.cels.2019.08.010.
[25] K. Ogata, “*Modern control engineering fifth edition*,” New York: Prentice-Hall, Inc. 2010.
[26] W. Taha, A. R. Beig, and I. Boiko, ‘‘Quasi optimum PI controller tuning rules for a grid-connected three-phase AC to DC PWM rectifier,’’ *International Journal of Electrical Power & Energy Systems*, vol. 96, pp. 74-85, 2018, doi: 10.1016/j.ijepes.2017.09.027.
[27] S. Srivastava and V. S. Pandit, ‘‘A PI/PID controller for time-delay systems with desired closed-loop time response and guaranteed gain and phase margins,’’ *Journal of Process Control*, vol. 37, pp. 70-77, pp. 70-77, doi: 10.1016/j.jprocont.2015.11.001.
[28] S. M. Othman *et al*., ‘‘Position tracking performance with fine tune Ziegler-Nichols PID controller for the electro-hydraulic actuator in an aerospace vehicle model,’’ in *Journal of Physics: Conference Series*, vol. 2107, no. 1, p. 012064, 2021, doi: 10.1088/1742-6596/2107/1/012064.

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