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Automatic Tobacco Dryer Refrigeration System Optimization Using PLC and SCADA

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Abstract

In many cases, tobacco leaves are still dried using conventional methods, which relies merely on sunlight, thus making it difficult for farmers to dry them in the rainy season. Tobacco leaves rot easily, so alternative drying methods that are not weather dependent are required. Our research offers a solution by making a tobacco leaf drying machine with a refrigeration system. This tool can accommodate 5 kg of tobacco and can be controlled by a PLC and monitored using SCADA. The drying test was carried out at a temperature setting of 40°C–50°C and a humidity of around 25%–55%. The first test was drying 1 kg of tobacco leaves with a moisture content of 30%, which required a drying time of up to 2 hours and 40 minutes. After the drying process, the average weight of tobacco leaves became 287.8 g with a moisture content of 12%. The second test was the drying of 5 kg of tobacco leaves with a moisture content of 30%, which required a drying time of up to 4 hours and 15 minutes. After the drying process, the weight of the tobacco leaves was 880 g and the moisture content was 11.5%. The test results show that tobacco leaves can be dried without changing their original color and shape, even though they had experienced a decrease in mass and water content.

Keywords:
Tobacco Leaves, refrigeration system, PLC, SCADA

1 Introduction

Tobacco is a strategic plantation commodity due to its high competitiveness and substantial contribution to the national economy. Until now, Indonesian farmers have relied solely on the sun's heat to dry their tobacco leaves, resulting in difficulties during the rainy season. Numerous variables, including climate and raw materials, must be considered in this process, as they will affect drying time and earnings. Both natural and artificial forms of drying exist. For natural drying, the hot sun is utilized, whereas machines are used for artificial drying. In comparison to overcoming the effects of natural relativity, weather, and humidity, artificial drying has advantages.

Many cases in Indonesia, tobacco leaf drying still uses the traditional method by drying tobacco leaves under the hot sun, although economically the production costs are considered cheap, but this method becomes an obstacle for production in the rainy season and causes no production in the rainy season [1], [2]. Drying

Drying using a machine that does not depend on the weather is needed to be an alternative solution to the problem of drying grain [3], [12], [13]. Controlling temperature, moisture content and appropriate humidity is the

Researchers have conducted research in 2016, As depicted in Fig. 2. There is a description of previous research, Design of Telemetering

using a machine that does not depend on the weather is needed to be an alternative solution to the problem of drying tobacco leaves. Controlling temperature, moisture content and appropriate humidity is the key in the drying process using this artificial dryer. For this reason, the application of sensor and dryer technology with low operating costs is very important [3].

Tobacco (Nicotiana tabacum L.) has big role in the economy national through excise and taxes, provision of employment and multiple impacts (multiplier) effect) tobacco procurement and trade [1], [2], [4]. 40–80 percent of farmers' income is derived from tobacco farming. With area ownership, the cultivation area of each farmer is 0.25 to 0.50 ha, and the area growing tobacco each year is an additional 200,000 ha; therefore, there are 400–800 million farmers whose income is 40 to 80 percent dependent on tobacco products. Using the sun's heat, tobacco products are chopped and dried during processing. In wet weather, however, the process of chopping tobacco cannot be carried out, and despite the fact that the cigarette industry is primarily interested in chopped tobacco that has been exposed to rain, the price will be extremely low. During the rainy season, tobacco farmers are unable to produce, and the weather will have an effect on the already low price of chopped tobacco. Given the aforementioned issues, it is urgent to develop a technology for drying chopped tobacco.

In [5], The process of drying harvested crops using the sun's heat source has the potential to be developed, but the adoption rate is still hampered because the energy of the sun fluctuates with the seasons. The disadvantages of drying with solar energy can be covered by the use of an in-store system (using a heat exchanger) was revealed [6]. The system is more profitable because it produces good quality but at a slightly higher cost.

In drying agricultural products, several important parameters that need to be considered are expressed by [5], [7], [8] which states that the humidity in the media or drying chamber affects the speed of the drying process of agricultural products, while [8] state that drying time depending on the thickness of the material being dried.

Research on tobacco drying has been conducted by [9], which aims to engineer and test solar collectors and LPG stoves for virginia tobacco ovens. In this study, a tobacco leaf oven was powered by LPG and topped with a solar collector. The oven used is 4 m x 4 m x 7 m in size and has a capacity of two tons of LPG tobacco leaves, which are burned with a BAT/Balittas-1 stove designed specifically for Virginia tobacco ovens. The oven method adheres to the prevalent practice, and the evaluation of the research results is based on technical and economic considerations. The experimental location at P.T. Sadhana Arif Nusa, East Lombok, and West Nusa Tenggara. Using LPG fuel and solar collectors as energy sources, the oven phases can achieve the desired temperature range (300C–700C). While [1] in his research on the tobacco drying process using combined heat energy from solar energy and a heat exchanger stated that the drying process with the combined system was more profitable than drying with sunlight alone and drying with a heat exchanger alone. reliability that does not depend on time and at a relatively low cost.

Drying with a hybrid system, which utilizes sunlight and hot air obtained from burning sogol, is able to reduce water content by about 64% in a period of 140 minutes [10].

In [11], has conducted a study to dry tea leaves with a refrigeration system which obtained test results. Drying green tea leaves for 5 hours with a temperature setting of 35-43ºC obtained a percentage of dryness rate of 44.7%. With a temperature setting of 37 – 45ºC, the percentage of dryness is 47.9%. With a temperature setting of 38.5 – 49.5ºC, the percentage of dryness is 52.8%.

key in the drying process using this dryer. Therefore, the application of sensor and dryer technology with low operating costs is very important [14]. The grain dryer made is as shown in Fig. 1.

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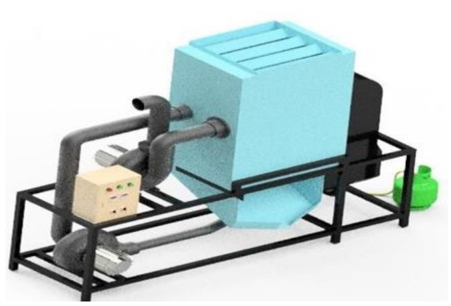

Fig. 1. Grain dryer tool

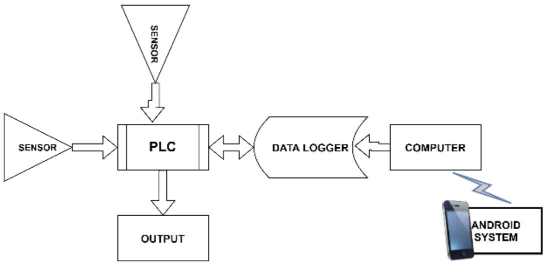

Fig. 2. Electrical power monitoring design diagram [11].

In 2020, researchers performed community service by creating rice dryers with on-off control but without PLC controllers. Fig. 3 depicts the controller created in the previous activity: the reason for conducting this research is the lack of use of a refrigeration system[15] to be implemented into a drying machine especially for tobacco dryers.

Fig. 3. Design of the on off rice dryer control panel [12].

The objectives of this research are developing a tobacco drying process control system and creating innovation and developing science and technology.

2 Research Method

The steps taken to achieve satisfactory results in this study are described in the methods as shown in Fig. 4.

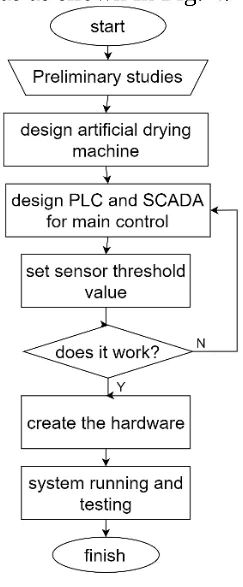

Fig. 4: Research flowchart

2.1 Preparation

At this preparatory stage, a literature study was carried out related to research that had been done in the tobacco drying process. methods and methods of drying tobacco were the focus of this initial study.

2.2 Design and manufacture of tobacco dryers with refrigeration systems

The design and manufacture of this tobacco dryer is carried out to control and monitor the tobacco drying process in the Electrical Engineering workshop. The design and manufacture process is divided into two, software design and hardware design.

2.2.1 Hardware Design

The following are the parts of a tobacco drying machine with a refrigeration system as shown in Fig. 5. Parts of the dryer are:

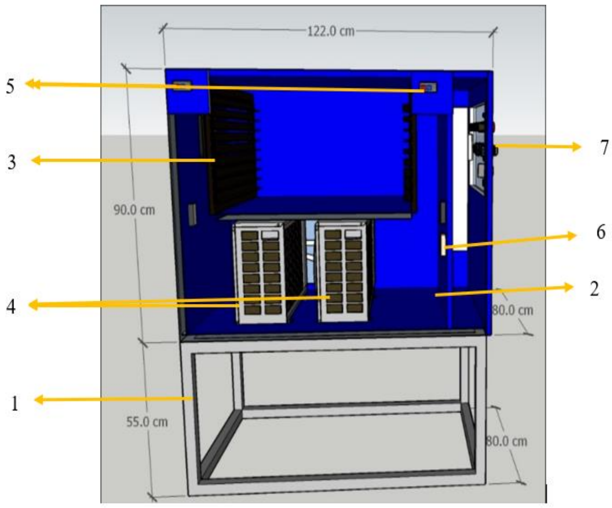

Fig. 5: Tobacco dryer machine design with refrigeration system

1. Buffer. The buffer is made of mild steel with dimensions of 122 cm x 55 cm x 80 cm and assembled to support the drying chamber.
2. Chamber. Chamber is constructed from plywood board measuring 122 cm x 90 cm x 80 cm and shaped into a beam resembling a chamber in general. As a medium for air exchange in a closed space, it can cause leaf drying, which is characterized by a decrease in tobacco leaf moisture content. There are also shelves for drying tobacco leaves in the chamber.
3. Shelf. The shelf is made of woven bamboo measuring 70 cm x 40 cm and is shaped in such a way that it forms a rectangular frame to expand the cross section, and facilitate the placement of leaves.
4. Split AC. Split AC components, of which there are four core components: the compressor, condenser, capillary tube, and evaporator. serves to exchange hot and cold air, which can reduce humidity or moisture content in tobacco leaves.
5. STC-3028. STC-3028 is a Temperature and Humidity Control function for measuring or controlling the heating process's temperature. The heating process's temperature will be displayed on the display of the temperature and humidity control. The desired temperature and relative humidity for the drying process are 40°C to 50°C and 25% to 32%, respectively.
6. XY-MD02. XY-MD02 is a component that is used to measure the temperature and humidity in the chamber which further readings will affect the performance of the compressor, condenser fan, and ventilation fan.
7. Control Panel. The control panel, is the part where the selector switch, push button, and indicator light are. Inside the control panel itself contains PLC, MCB, relays, power supply, and line terminals. All components are connected by conducting cables.

The input, controller and output devices are described as shown in Fig. 6.

1. Input devices: Push Switch On/Off and 2. Temperature and Humidity Control
2. Output Devices: Compressor, Evaporator, Condenser, Fan and. Ventilation Fan
3. Other Equipment: Modbus RTU RS485 SHT20 Temperature Humidity Transmitter, Power Supply, Pilot Lamp, Relay, and MCB
4. PLC Controller

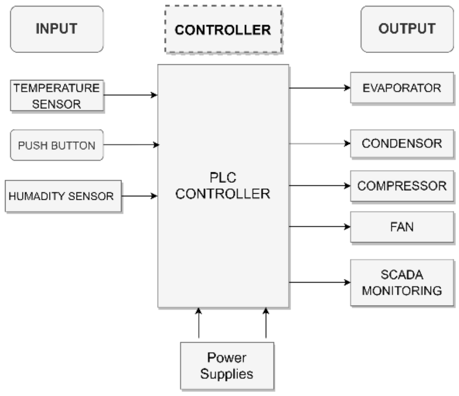

Fig. 6. Input, controller and output devices

PLC used is PLC Modicon TM221CE24T that shows on fig. 7. This PLC is a product of Schneider Electric. This PLC has 14 digital inputs, 10 digital outputs, 2 analog inputs, 1 serial line port, 1 ethernet port, and a 24 VDC power supply controller.

Fig. 7. PLC modicon TM221CE24T

Control design is used to make a tobacco dryer control system, for the control itself is controlled by a PLC mounted on the panel (Fig. 8).

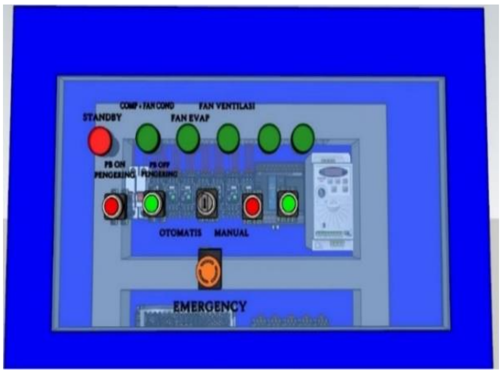

Fig. 8. TM221CE24T PLC control panel design

2.2.2 Software Design

Design software or this software is software used to create programs and animations. There are several tools used, such as the EcoStruxure Machine Expert Basic program which functions to create PLC control programs. PLC control program using ladder diagram shows on fig. 9.

The next step is to create a SCADA system for monitoring the tobacco drying process in real time using the Vijeo Citec software. the results of the design of the SCADA system as shown in Fig. 10

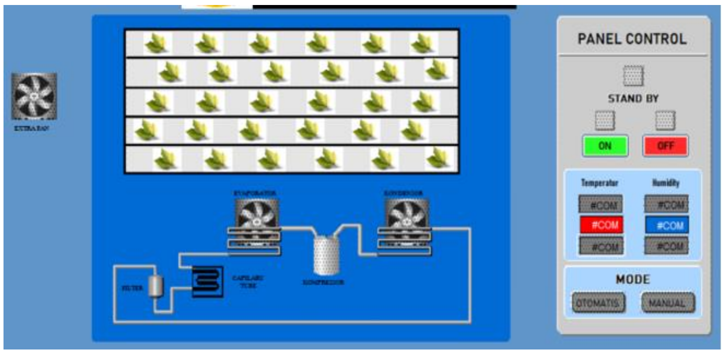

Fig. 10. Result of design SCADA system

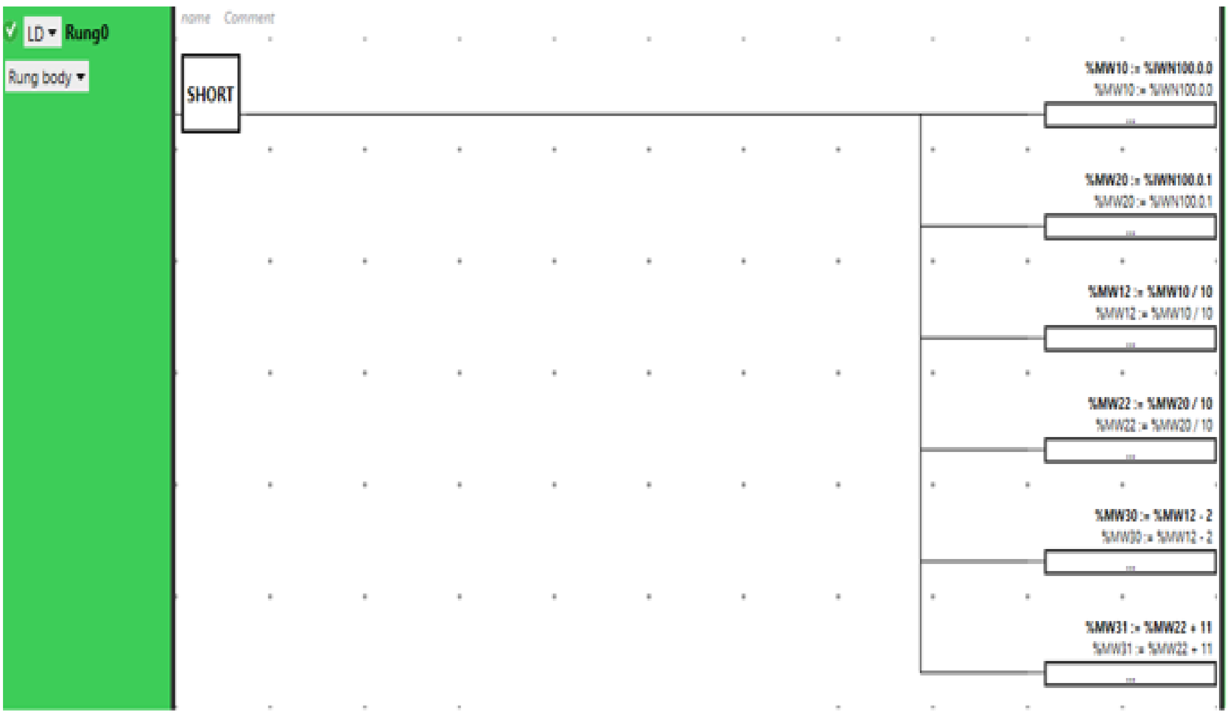

Fig. 9. Ladder diagram

3 Results and Discussion

The tobacco dryer machine with a refrigeration system transforms harvested tobacco leaves into ready-to-package products using PLC and SCADA. It comprises of two outside split ACs put in series as the refrigeration system, with the cut tobacco leaves stacked on shelves in the drying chamber. After all the leaves have been prepared, the system is activated. When the engine is running, the refrigeration system will operate, sucking moisture from the tobacco leaves and converting it to water vapor. The vaporized water is subsequently released into the drainage canal. As the cooling system or refrigeration system advances, the tobacco leaves' moisture content will decrease, and they will dry without altering their aroma or color. This system will continue to operate until the drying time is complete and the temperature and humidity reach the predetermined upper and lower limits, respectively. The monitored systems for the SCADA system monitoring process are temperature and humidity. The controlled system is the on-and-off tobacco leaf drying system. Fig. 11 describes a tobacco drier with refrigeration system

This tobacco drier may be manually or mechanically operated. To operate this device, tobacco leaves to be dried must be initially loaded to the dryer's shelves . The initial step in using this tool is to pick the desired mode of operation, either manual or automatic. During manual operation, the steps of the drying process are initiated by pressing the on/off push button on the control device, and temperature and humidity are controlled by the STC-3028 input on the device. Each phase of the work process will proceed automatically if it is automated.

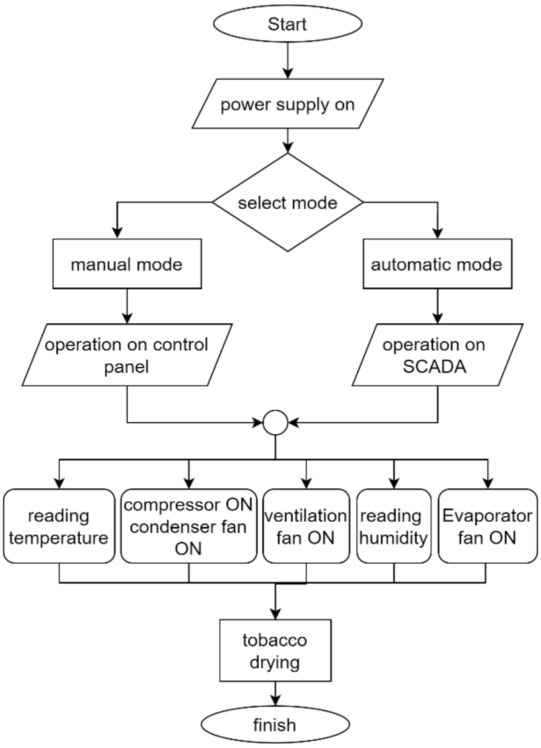

Fig. 11. Working Description of the tobacco dryer with refrigeration system

When the tobacco drying process is completed, all components will stop (off) automatically. The system is controlled by PLC and monitored by SCADA, including temperature and humidity control which is regulated through the modbus thermohygrostat setting XY-MD02. The results of the manufacture of a tobacco dryer with a refrigeration system as shown in Fig. 12.

The test was carried out six times with five different humidity tests and one time difference in capacity, namely 1 kg and 5 kg. In addition to collecting data related to changes that occur in tobacco leaves, monitoring of changes in temperature and humidity that occur in the system is also carried out.

Fig. 12 tobacco dryer with a refrigeration system

The test is carried out by setting the temperature: 40°C - 50°C and the humidity range varies, 25%-32%, 35%-40%, 40%-45%, 50%-55%.

3.1 Test Result 1

This test was conducted to determine the length of drying time, and changes in weight and moisture content experienced by tobacco leaves with an initial weight of 1 kg, and an initial moisture content of 30%. Temperature settings are maintained in the range of 40°C - 50°C and humidity in the range of 25%-32%. Table 1 and Fig. 13 show that to achieve a moisture content of 13% takes 2-hour drying time, from an initial weight of 1 kg to 315 grams.

Table 1. Test Data 1

No	Tobacco weight before drying (grams)	Tobacco weight after drying (grams)	Drying time (minutes)	Tobacco moisture content before drying	Tobacco moisture content after drying
1	1000	1000	0	30%	30%
2	1000	797	30	30%	25%
3	797	627	60	25%	20%
4	627	436	90	20%	16%
5	436	315	120	16%	13%

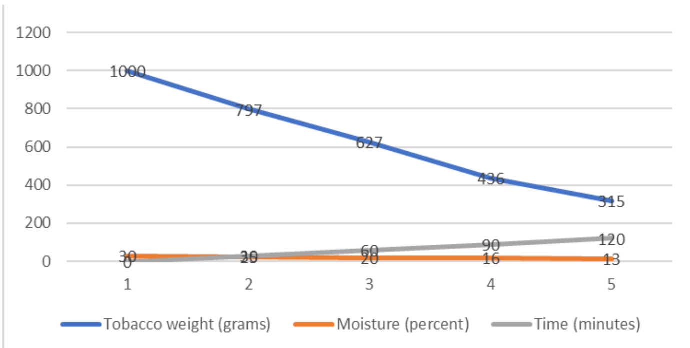

Fig. 13 Graph of Moisture Content and Test Weight 1 Kg with 25%-32% of Tobacco from Test Data 1

3.2 Test Result 2

This test was conducted to determine the length of drying time, and changes in weight and moisture content experienced by tobacco leaves with an initial weight of 1 kg, and an initial moisture content of 30%. Temperature settings are maintained in the range of 40°C - 50°C and humidity in the range of 35%-40%. Table 2 and Fig. 14 shows that it takes 2 hour and 10 minutes to reach a moisture content of 12.5%, from an initial weight of 1 kg to 270 grams.

Table 2. Test Data 2

No	Tobacco weight before drying (grams)	Tobacco weight after drying (grams)	Drying time (minutes)	Tobacco moisture content before drying	Tobacco moisture content after drying
1	1000	1000	0	30%	30%
2	1000	818	30	30%	25,5%
3	818	667	60	25,5%	21%
4	667	462	90	21%	16,5%
5	462	355	120	16,5%	14%
6	355	270	130	14%	12,5%

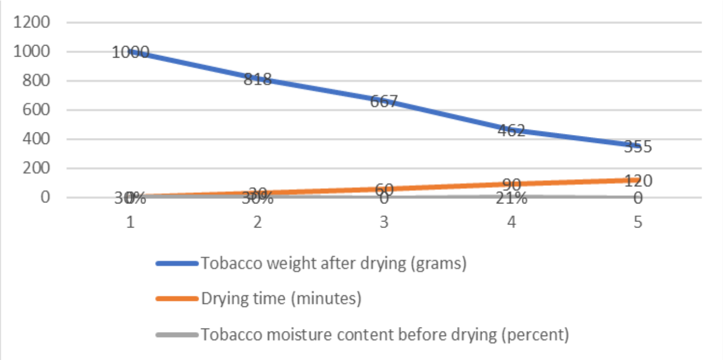

Fig. 14 Graph of Changes Moisture Content and Test Weight 1 Kg with 35%-40% humidity of Tobacco from Test Data 2

3.3 Test Result 3

This test was conducted to determine the length of drying time, and changes in weight and moisture content experienced by tobacco leaves with an initial weight of 1 kg, and an initial moisture content of 30%. Temperature settings are maintained in the range of 40°C - 50°C and humidity in the range of 40%-45% (Table 3 dan Fig. 15).

Table 3. Test Data 3

No	Tobacco weight before drying (grams)	Tobacco weight after drying (grams)	Drying time (minutes)	Tobacco moisture content before drying	Tobacco moisture content after drying
1	1000	1000	0	30%	30%
2	1000	836	30	30%	26%
3	836	698	60	26%	22%
4	698	538	90	22%	18%
5	538	404	120	18%	15%
6	404	258	140	15	12%

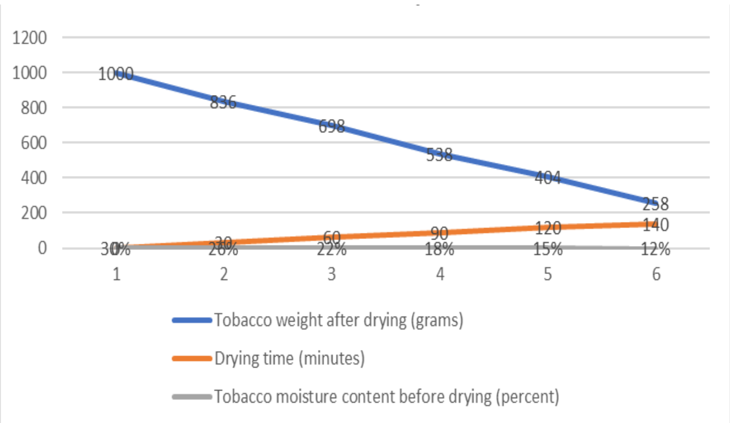

Fig. 15 Graph of Changes in Moisture Content and Weight 1 Kg with 40%-45% humidity of Tobacco from Test Data 3

3.4 Test Result 4

This experiment was conducted to determine the drying time and weight and moisture content changes tobacco leaves with an initial weight of 1 kg and an initial moisture content of 30% experienced. Temperature settings are maintained between 40°C and 50°C, and humidity settings are maintained between 45% and 50%. Table 4 and Fig. 16 demonstrate that in order to achieve a moisture content of 13%, it takes 2 hours and 30 minutes of drying time and a reduction in weight from 1 kilogram to 318 grams.

Table 4. Test Data 4

No	Tobacco weight before drying (grams)	Tobacco weight after drying (grams)	Drying time (minutes)	Tobacco moisture content before drying	Tobacco moisture content after drying
1	1000	1000	0	30%	30%
2	1000	850	30	30%	26,5%
3	850	720	60	26,5%	22,5%
4	720	597	90	22,5%	19%
5	597	439	120	19%	16%
6	439	318	150	16%	13%

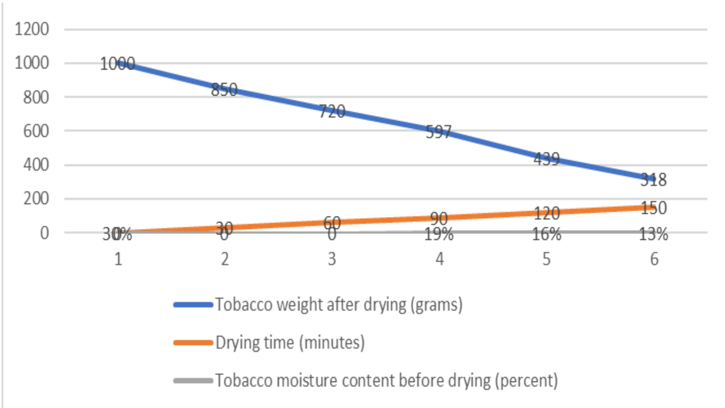

Fig. 16 Graph of Changes Moisture in Content and Test Weight 1 Kg with 45%-50% humidity of Tobacco from Test Data 4

3.5 Test Result 5

This test was conducted to determine the length of drying time, and changes in weight and moisture content experienced by tobacco leaves with an initial weight of 1 kg, and an initial moisture content of 30%. Temperature settings are maintained in the range of 40°C - 50°C and humidity in the range of 50%-55%. Table 5 and Fig. 17 show that it takes 2 hours and 40 minutes to reach a moisture content of 12.5%, and a reduction in weight from 1 kg to 278 grams.

Table 5. Test Data 5

No	Tobacco weight before drying (grams)	Tobacco weight after drying (grams)	Drying time (minutes)	Tobacco moisture content before drying	Tobacco moisture content after drying
1	1000	1000	0	30%	30%
2	1000	868zzz	30	30%	27%
3	868	742	60	27%	23%
4	742	606	90	23%	19,5%
5	606	462	120	19,5%	16,5%
6	462	356	150	16,5%	14%
7	356	278	160	14%	12,5%

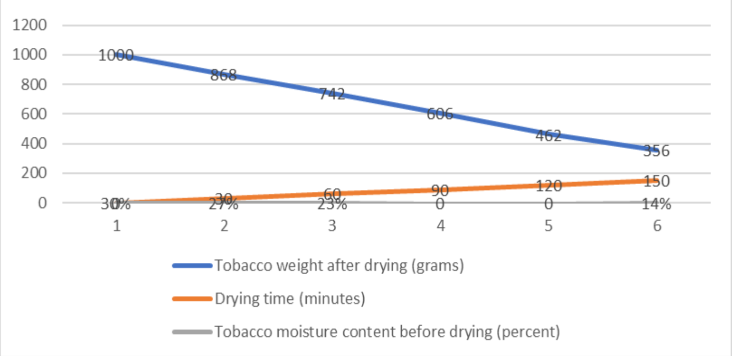

Fig. 17 Graph of Changes in Moisture Content and Test Weight 1 Kg with 50%-55% humidity of Tobacco from Test Data 5

3.6 Test Result 6

This test was conducted to determine the length of drying time, and changes in weight and moisture content experienced by tobacco leaves with an initial weight of 5 kg, and an initial moisture content of 30%. Temperature settings are maintained in the range of 40°C - 50°C and humidity in the range of 25%-32% (Table 6 and Fig. 18).

Table 6. Test Data 6

No	Tobacco weight before drying (grams)	Tobacco weight after drying (grams)	Drying time (minutes)	Tobacco moisture content before drying	Tobacco moisture content after drying
1	5000	5000	0	30%	30%
2	5000	3886	50	30%	25%
3	5000	3218	97	25%	22%
4	5000	2661	108	22%	19,5%
5	5000	2216	144	19,5%	17,5%
6	5000	1770	177	17,5%	15,5%
7	5000	1436	196	15,5%	14%
8	5000	1214	215	14%	13%
9	5000	880	255	13%	11,5%

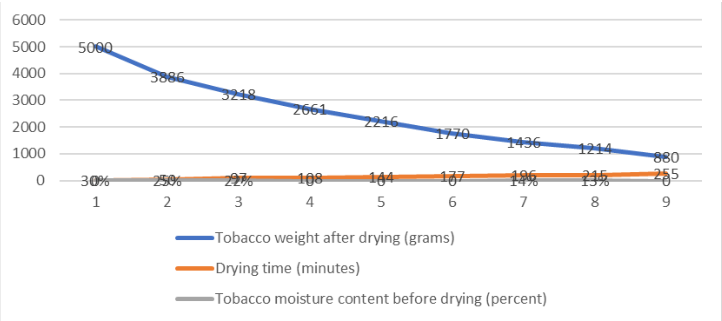

Fig. 18 Graph of Changes in Moisture Content and Test Weight 5 Kgs with 25%-32% humidity of Tobacco from Test Data 6

The test data in table 4.8, shows that to achieve a moisture content of 12.5% it takes a drying time of 4 hours 15 minutes, and a reduction in weight from 5 kg to 880 grams.

3.7 Automated Work Tools Testing with SCADA

The following is the sequence of automatic work testing and manual work drying machine testing:

1. Before the tool is powered by a source of electrical energy, first connect the PLC input/output with the input/output on the tool according to the design.
2. A flowing 220 VAC electrical energy source is established by turning on the MCB.
3. Set the selector switch to the automatic position.
4. Connect the USB cable from the PLC to the laptop or PC.
5. Download the program from the computer to the PLC using the communication cable, then run the program by pressing the start controller command.
6. After pressing the start controller button, press the logout command.
7. After that, open the software application, select the File menu, then click "compile," then select the Tools menu, then click "computer setup wizard," click next until the command finishes, then click "run."
8. After running, it will be seen that the indicator light will light up, indicating the system is ready to work.

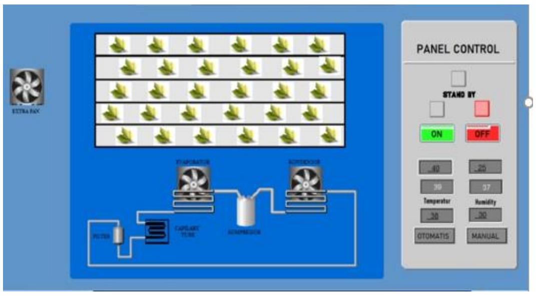

Fig. 19. Stand By Indicator On

9. Press the on button next, the compressor, evaporator fan, condenser fan, and ventilation fan will work together.

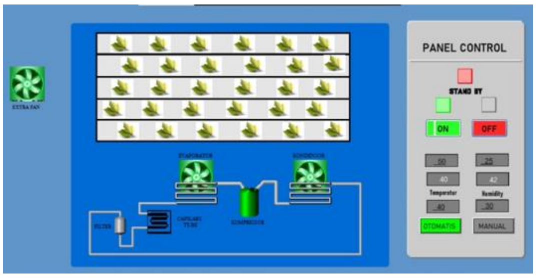

Fig. 20. Compressor, Evaporator Fan, Condenser Fan and Ventilation Fan ON

10. XY-MD02 thermohygrostat sensors monitor chamber temperature and humidity. The compressor, condenser, and fan shut off at 50 °C. The compressor, condenser, and fan restart when the temperature drops to 40 °C

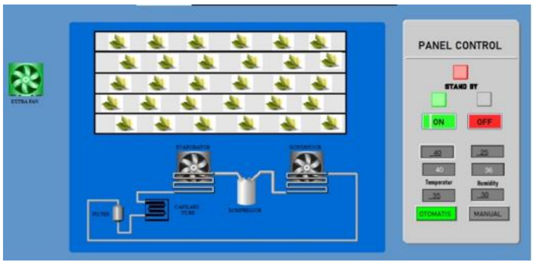

Fig. 21. Compressor, Evaporator Fan and Condenser Fan Off

11. Ventilation stops at 25% humidity. Ventilation restarts at 32% humidity..

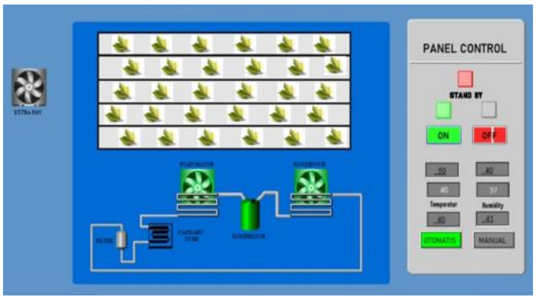

Fig. 22. Ventilation Fan Stop Working

12. All work systems will repeat continuously until the setting time.

4 Conclusion

1. The test results of controlling the tobacco drying machine run well.
2. The results of the SCADA software test function for monitoring the working process of the tobacco dryer machine run well.
3. The best results were achieved with a drying duration of 2 hours and 20 minutes by weight under conditions of 1000 grams of tobacco, a moisture content of 30% prior to drying, a temperature range of 40°C to 50°C, and a relative humidity range of 25% to 32%. After drying, the weight of the tobacco is 258 grams, and its moisture content is 13%.
4. According to the results of the tobacco drying test, a drying period of 4 hours and 15 minutes by weight generated the best results with a starting weight of tobacco of 5000 grams, a water content of 30% prior to drying, a temperature range of 40°C to 50°C, and a humidity range of 40% to 45%. After drying, the weight of the tobacco is 880 grams, and its moisture content is 11.5%.

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