

Non-invasive moisture content measurement system based on the ESP8266 microcontroller

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ABSTRACT

Moisture content in the process of drying is often unknown when carrying out the drying process, especially the fluidized dryer. A lot of experimental designs are needed when observing the drying phenomenon more deeply. It is because to stop and repeat the drying process from the beginning again when the sample is taken to test its moisture content needed more experiments. Therefore, this paper presents the development of a non-intrusive moisture measurement system prepared for fluidization type dryers. The method used in to conduct this research consists of (i) structural design analysis and (ii) functional (mechanical and electrical systems) and (iii) simple testing of the water content measurement system of constructed material. Test parameters observed include errors in measuring and fluctuating sensor signals against vibration applied to the weighing system. The results showed that non-intrusive moisture content measurement system for fluidized dryers based on the ESP8266 microcontroller had been successfully developed and worked normally. The measurement system has been calibrated with a coefficient of determination (R^2) close to one. Measurement error resulting from the effect of vibration on this system shows a very satisfactory value of 6.89%.

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1. INTRODUCTION

Drying is one of the oldest methods and requires a lot of money and time-consuming for the preservation of food or biologically active products [1-5] such as grains for decreasing the water content. Decreasing the water content of a dried product is very important to know from a dryer. It is to show the extent to which the product has reduced its water content. The performance of a dryer can be demonstrated by the drying rate and drying time parameters that start from measuring the moisture content of the dried product [6-9]. The suitability of the reduction in water content with the product's ability to release water becomes the focus of the investigation in addition to the energy requirements in the drying process. It is because agricultural products that are processed with dryers are easily damaged if not handled properly [10-12] and requires a lot of energy [13-19].

Various types of dryers and methods for measuring the moisture content of dried products continue to be developed. At present, the fluidization desiccant tends to be more widely studied and applied for drying, especially for agricultural materials. It according to several research results has advantages including being

efficient in delivering heat, giving uniform thermal to the product, significant drying rate, shorter drying time and relatively fast mass transfer rate [6, 20-24].

Methods for measuring the moisture content of a product during the drying process are still being developed. The conventional method, which is still being used in estimating the moisture content when drying is by taking samples of the dried product. It was conducted by Li *et al.* [8], which uses an electric drying oven (DHG-9040A; Hangzhou Lantain Instrument Co. Ltd., China) for grain. The grain used in this study was 500g with moisture content 25% wet basis. 15g of rice was taken as a sample for eleven observations. Other studies such as those conducted by Chuwattanakul and Eiamsa-ard [23] in measuring the moisture content of a product from a swirling fluidized bed dryer (SFBD) dryer for pepper seeds. The SFBD works at 70°C with the mass of pepper fed at 200g with a moisture content of 73% (w.b.). Pepper seed samples are taken every 10 minutes for one hour to determine the water content. It shows that the drying load on the tool will vary at each time interval caused by taking the material as a sample for the moisture content test.

On the one hand, the method that determines the time to measure water content in the middle of the drying process will require many experiments because it has to do the drying process repeatedly. It is intended that the number of samples to be dried has the same mass load in each drying process, as did Yogendrasidhar and Setty [22]. On the other hand, several studies do not focus on the effect of reducing the mass of dried products because they are taken for samples [8, 23]. Another method is to use a relatively expensive water content sensor, as conducted by Firouzi *et al.* [7].

However, some research using the weighing balance to find out the mass of the dried product by measuring the entire mass of the product along with the dryer as done by Chokphoemphun and Chokphoemphun [6]. Another method is to develop sensor devices such as those carried out by Zhang *et al.* [20] and Zhang *et al.* [21] for determining non-intrusive water content in a fluidizing type dryer. This device uses an electrostatic sensor array that is placed on the wall in the drying chamber. However, the influence of the speed factor of the fluidization of the material and the magnitude of the root-mean-square of the sensor signal fluctuations is a challenge in this method. It is why the error of the devices found in this study ranged from 8%-15%.

To know the phenomenon during drying (not only the final quality of the product), but it is also important to develop a non-intrusive method of measuring water content for other fluidizing dryers, which are more effective. Loadcell sensors equipped with microcontrollers have the advantage of being relatively inexpensive, more straightforward construction, easy to find electrical components, sensitivity, and response that can be adjusted. Therefore, this paper presents the development of a system for measuring water content in laboratory-scale fluidized dryers. The relationship between water content and characteristics of the loadcell sensor signal is investigated and modeled. Estimation of material content estimation data is recorded and directly transferred via the internet to the personal computer.

2. MATERIAL AND RESEARCH METHOD

In this study, a system designed to estimate water content in a dried product, especially for a fluidizing type dryer on a laboratory scale. This methodology is separated into four stages: (i) design (ii) construction, (iii) functional testing and calibration, and (iv) testing of the system without being integrated with a dryer. Parts of a laboratory-scale non-intrusive water level measurement system are presented in Figure 1. The weighing basket is designed at the bottom in a conical shape with an angle of 55°, a flat diameter of 50 mm, and a height of 300 mm. The form of the basket adjusts to the swirling fluidized bed dryer. The height of the tool frame is 1000 mm with a length and width of legs of 500 mm, 500 mm, respectively. A mass measuring sensor with 5000g capacity is placed at the top of the tool frame. A control box as an electrical device container is placed on one side of the tool frame.

The schematic diagram of the electrical devices contained in the control box is presented in Figure 2. A microcontroller is prepared to be able to acquire and transmit sample mass measurement data. An indicator display on the control box is also embedded so that the operator can monitor the progress of the drying process. A feature for setting initial mass and water content is also prepared in this water content measurement system. The working procedure for measuring non-intrusive water content is presented in Figure 3. The sample used in this test was soybean obtained from a local farm shop.

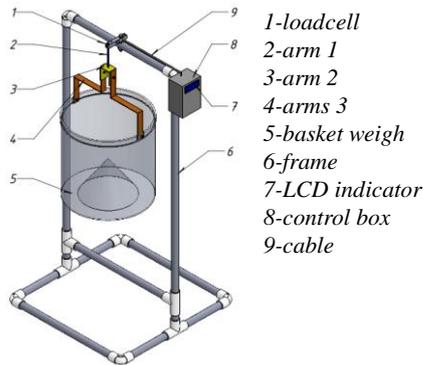


Figure 1. Schematic design of a system for measuring non-intrusive water content

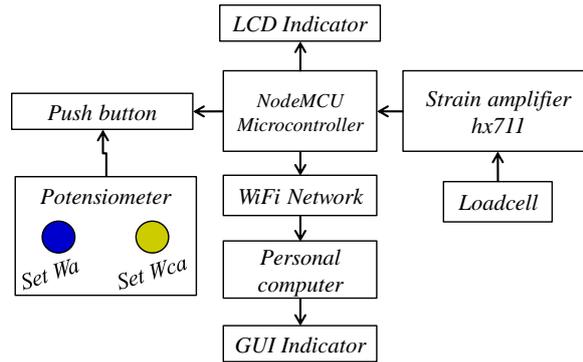


Figure 2. Schematic diagram of an electronic device measuring non-intrusive water content

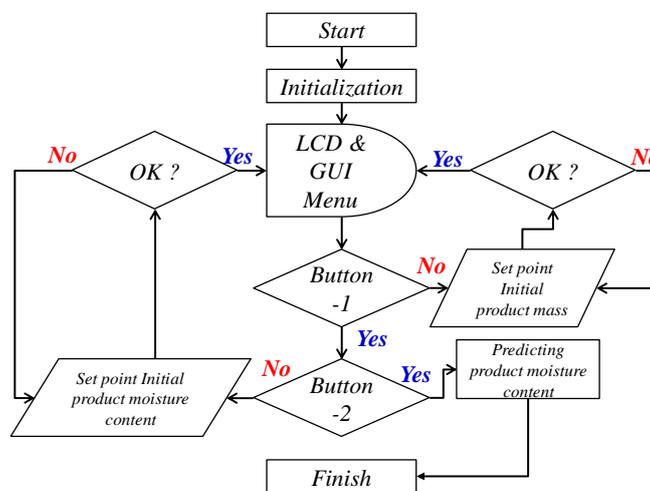


Figure 3. Workflow chart of non-intrusive water content measurement system

2.1. Data collection and preparation

The moisture content measurement system is tested by giving a load in the form of soybean samples with mass variations from 100g to 2000 g. Soybean mass was weighed using a digital scale (0.00 g), and the initial water content of soybean was put at 10%. The sample mass recorded by the sensor and waits until ±5 minutes. The moisture content of the sample material against time is calculated using (1-3). The equation becomes one of the algorithms embedded in the microcontroller.

$$M_s = \frac{M_{wa}(1-W_{ca})}{W_{ca}} \tag{1}$$

$$M_{wa} = W_{ca} \cdot W_a \tag{2}$$

$$W_{c(i)} = \frac{(W_{(i)} - M_s)}{W_{(i)}} \tag{3}$$

where, M_s -mass solids (g), M_{wa} -initial mass of water (g), W_{ca} -initial water content (% w.b.), W_a - initial mass samples (g), $W_{c(i)}$ -water content of material to i (% w.b.), $W_{(i)}$ -mass of material to- i (g).

The effect of the shaking factor on the stability of the sensor reading is investigated by varying the amplitude of the weighing baskets of 20 mm, 40 mm, 60 mm, 80 mm, and 1000 mm, respectively as shown in Figure 4. During the shock, the mass of the sample will always be measured until the basket is stationary and added 60 seconds.

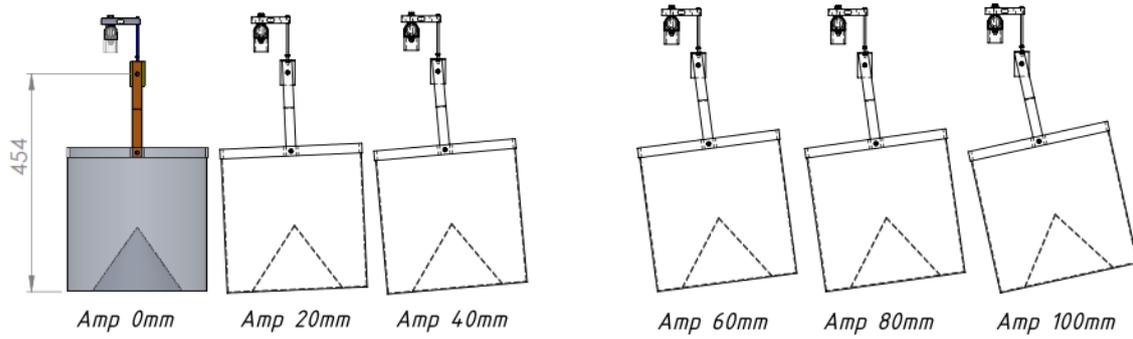


Figure 4. The amplitude applied to the device

2.2. Estimation of product water content

Estimation of changes in product water content is done by developing (1) until (3) into a programming algorithm. Measurement data from sensors that refer to the weight of the material in the weigh basket become an independent factor in this system. The dependent factor is the input data in the form of mass and initial water content of the material to be entered into the weigh basket by the operator. The amount of mass and initial moisture content of the product are monitored on the monitor screen that is prepared in the control box.

3. RESULTS AND ANALYSIS

3.1. Design of non-intrusive moisture content measurement system

3.1.1. Mechanical components

The mechanical hardware components of the non-intrusive water level measuring system are presented in Figure 5. The tool frame is made of a 12.7 mm diameter pipe. Weigh basket with aluminum material has a thickness and the number of holes of 1 mm, 10 mesh, respectively. The swinging arm is made of a 3 mm diameter wire. The weigh basket becomes a container for the sample to be placed when drying fluidization is carried out.

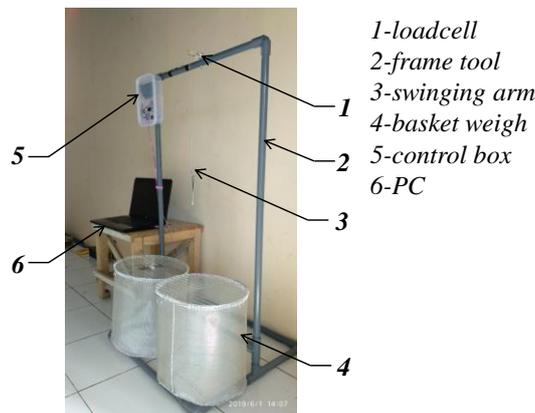


Figure 5. Mechanical components of the system

3.1.2. Electrical components

This component uses the ESP8266 data processor in the form of a Nodemcu microcontroller as shown Figure 6. This type of microcontroller was chosen because it has been supported for serial communication online so that the data measured by the sensor can be immediately transferred to the internet network. A loadcell sensor with a capacity of 5000g is used to measure the mass of the product in a weigh basket. An on/off button is used to cut and forward the signal, and a 1000 ohm rotating potentiometer is used as the input feature for mass data and the initial moisture content of the dried product. All data is displayed on a 20x4 LCD screen. Measurement data is sent to the cloud via an internet access point network.

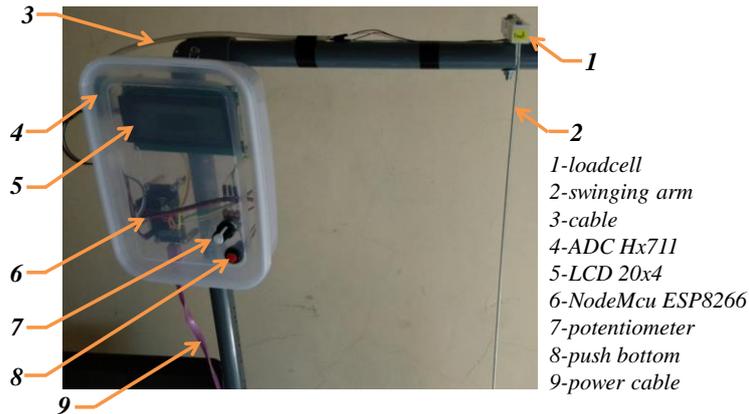


Figure 6. Electronic components of the system

3.1.3. Algorithm of the program

The algorithm for the microcontroller for the water content measurement system was developed using the Arduino open-source software. Information system for recording data on Web-logging using the open-source software Notepad ++. Graphical user interface (GUI) for displaying measurement data recording is presented in Figure 7. One example of a data recording page is shown in Figure 8.



Figure 7. Graphical user interface system for measuring non-intrusive water content

Data ke-	Tanggal	Waktu	Percobaan	Initial Massa Bahan (g)	Initial Wc (% bb)	Massa bahan di Dryer (gr)	Prediksi Wc (% bb)
2996	2019-05-29	23:08:46		170	0.00	0.26	0.00
2995	2019-05-29	23:08:44		172	0.00	0.02	0.00
2994	2019-05-29	23:08:43		170	0.00	0.06	0.00
2993	2019-05-29	23:08:42		172	0.00	0.18	0.00
2992	2019-05-29	23:08:41		172	0.00	0.00	0.00
2991	2019-05-29	23:08:40		170	0.00	0.02	0.00
2990	2019-05-29	23:08:38		172	0.00	0.13	0.00
2989	2019-05-29	23:08:37		170	0.00	0.02	0.00
2988	2019-05-29	23:08:36		172	0.00	0.31	0.00
2987	2019-05-29	23:08:35		170	0.00	0.21	0.00

Figure 8. Example data recording page

3.2. Management of load cell signal output

3.2.1. Calibration system for moisture measurement

The calibration system measuring water content aims to show the reliability of the sensors used. Loadcell sensor signal output in the form of analogue data represented by changes in voltage on the loadcell beam when subjected to a load whose unit is mV as shown in Figure 9. The sensor signal output received by the microcontroller will be forwarded to the personal computer via the internet network. The program algorithm embedded in the microcontroller requires the sensor to send data every second.

The relationship of the mass of the standard sample (g) with the loadcell sensor signal output (mV) is presented in (6). The equation gives a coefficient of determination (R^2) close to one. This shows the close relationship between the two parameters. Therefore, this sensor is still acceptable to explain and estimate the weight of the material in the weighing basket. It is in line with the results of the study of Carmona *et al.* [25], who obtained the results of the calibration of the load cell sensor with a maximum load measurement range of 500 kg. This calibration also uses root mean square error (RMSE) to determine errors from the sensor estimation.

$$y = 1.001x + 0.8288 \quad R^2 = 1 \tag{4}$$

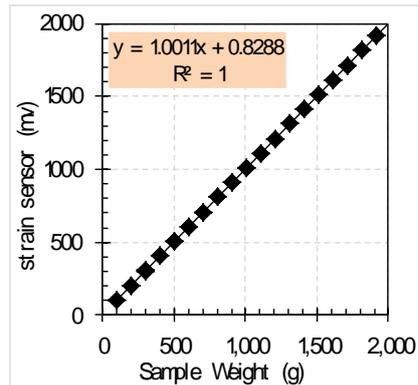


Figure 9. The results of the calibration of the load cell sensor

3.2.2. Measurement fluctuations against amplitude

The results of applying amplitude to see the effect of shocks on this water content measurement system are presented in Figure 10. The magnitude applied from the smallest to the largest produces fluctuations in the mass measurement results of the sample, and the measurement time is stable, which varies in each mass of material being tested. The most significant fluctuation of measurement results is found in samples with a mass of 1000 g and an amplitude of 80 mm, which is 12.39%. The longest stable measurement time due to the application of magnitude in this water content measurement system is found in the 2000 g sample, which is 3600 seconds, and the shortest is in the sample with a mass of 100 g, which is 26 seconds.

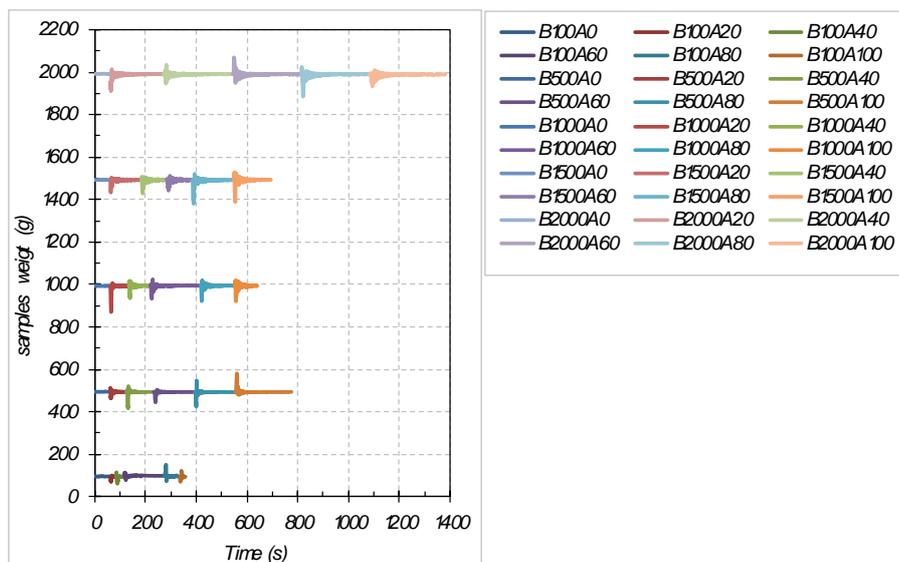


Figure 10. The effect of applying amplitude on the system of measuring water content

Errors due to fluctuations in the product mass measurement results at each amplitude are presented in Figure 11. The results show that the most significant errors were found in the sample mass of 100 g and the amplitude of 40 mm. Overall, the test with a sample mass of 100g produced the most significant measurement error compared to the mass of the other samples. It is allegedly due to the light condition of the sample mass, which causes the weigh basket and sample to move more freely with a shorter period than when given a heavier load. This is in line with the results of research Susilo *et al.* [26], who reported that the mass of a harmonic motion mechanism would affect the period of vibration other than the damping constant of the device itself. The most significant standard deviation of the measurement results is the mass treatment of 1000 g samples with an amplitude of 20 mm as shown in Figure 12. The smallest standard deviation was found in each treatment, the lowest amplitude of all types of sample masses. The overall standard deviation that occurs from this measurement is less than 3.0%.

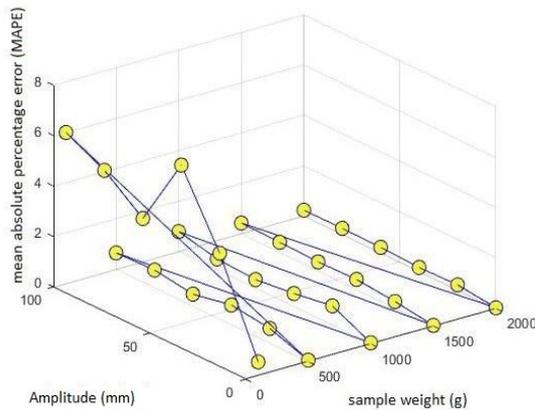


Figure 11. Relationship to treatment of measurement errors

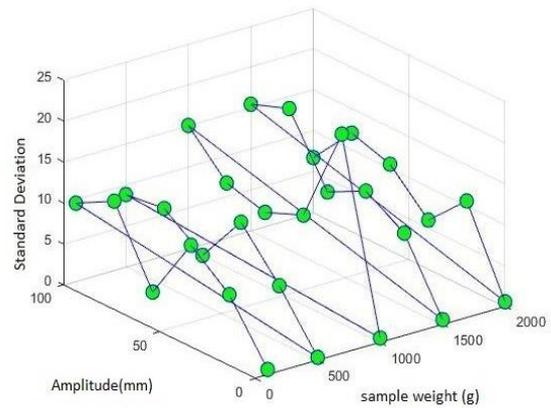


Figure 12. Relationship of treatment to standard deviation of measurement

The longest stable time from measurements measured in the mass treatment of 2000 g samples and the amplitude of 100 mm is 360 seconds as shown in Figure 13. The shortest stable measurement time was found in the mass treatment of 100 g samples, and the amplitude of 100 mm was 26 seconds. These results indicate that the stable time of measurement tends to be longer under conditions of heavier sample masses compared to lighter ones. Therefore, the results of this study suggest that for some samples equal to or smaller than 2000 g, at least a steady measurement of 151 seconds is required.

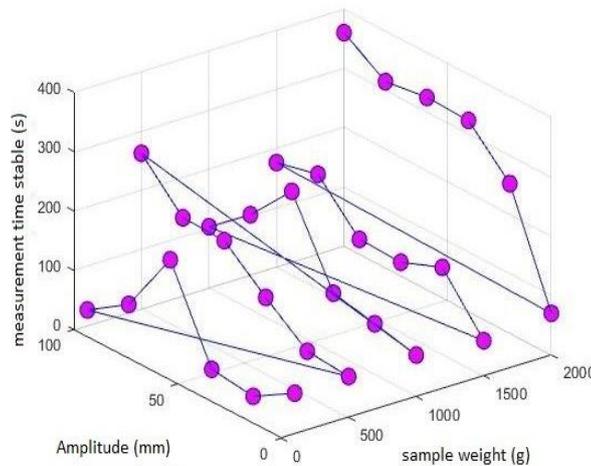


Figure 13. Relationship of treatment to the measurement time stable

4. CONCLUSION

A non-intrusive water level measuring system prepared for fluidizing type dryers has been developed and tested. This system utilizes a load cell sensor and data recording integrated with the internet network. Calibration of the system also shows a very satisfying thing with a coefficient of determination close to one. The error for each measurement is also within the acceptable limit of 6.89%. This paper recommends the use of a measure waiting time of ± 2.5 minutes for the mass of material dried 2000 g with a fluidizing type dryer. The next activity of this research is to test the performance of a measurement system integrated with a fluidizing dryer to determine the overall performance of this system.

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