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Development and Testing of a Mass, Temperature, and Relative Humidity (MTRH) Data logger for Drying Experiment

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ABSTRACT : *Temperature monitoring is crucial across various industrial and experimental applications, and processes. In an attempt to solve the problems of data collection during drying experiments, a mass, temperature and relative humidity data logger (MTRH data logger) was developed using Arduino micro controller that was integrated with two DYMH-103 Load cell and four DHT-11 digital temperature and relative humidity sensor for the measurement of mass, temperature and relative humidity during agricultural products drying experiments. The data logger was being powered by a 12 volts DC source and capable of recording its readings every 5 minutes in an embedded 16 GB SD card. The readings can also be observed from the 16 by 2 LCD display in the logger. The developed data logger was used simultaneously for same sample and environment assessment with other standard laboratory measuring instruments for calibration. The data logger was tested and calibrated in relative to other standard measuring instruments. A laboratory weighing balance SCALETECH SAB220 whose accuracy was 0.0001 gram was used to calibrate the mass measurement values. The temperature reading of the instrument was also compared and calibrated in relative to the readings of Applent AT4208 Multi Channel temperature meter of accuracy of 0.2%+1°C and the relative humidity readings compared and calibrated in relative to readings obtained using UNI T industrial hygrometer Model UT331 whose operating humidity ranges from 0%RH to 100%RH. The mathematical correlation between the readings of the developed instrument and the standard instrument was graphically obtained for all the different measuring components. The coefficient of determination for each correlation was also obtained to range between 0.9682 and 0.9994. The developed data logger offers a cost-effective solution with specific features that suites the requirements of a greenhouse drying experiment.*

KEYWORDS: *MTRH data logger, Temperature, Relative humidity, Mass Measurement, Greenhouse dryer.*

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I. INTRODUCTION

The knowledge of temperature, relative humidity, change in mass and other parameters inside and even outside a dryer during drying experiments is very necessary for both the analysis of the dryer and the drying kinetics of the materials being dried. The reliability and accuracy of instruments used in measuring such physical parameters are very important. A lot of standard measuring instruments are available in the market ranging from simple ones like analogue mercury in glass thermometer to more complex ones like the IOT embedded digital multiple data loggers. For a typical universally acceptable experimental result to be produced, a standard reliable measuring instrument should be used in the course of the experiment. During drying experiments, researchers who requires to monitor the mass of a drying sample will have to weigh the sample at intervals using a weighing balance. For the case of drying using solar dryers, the dryer would be opened and the sample removed for weighing. This intermittent opening and closing of the dryer will allow the inflow of air from the ambient into the dryer thereby introducing a thermal load which could not be captured or quantified during the thermal analysis and performance evaluation of the dryer. This obviously introduces an error which affects the analytical performance of the dryer. As a way to solve the problems associated with incessant opening and closing of the dryer during drying, a mass, temperature and relative humidity data logger (MTRH-data logger) was developed. It is capable of taking the temperature and relative humidity of four different locations as well as the measurement of two different sample masses simultaneously for a period of days or even weeks without actually opening the dryer. The time interval for the measurement and recording could vary from seconds to hours or even days depending on the setting by the user. MTRH data logger is a micro controller (Arduino mega) integrated with 4 units of DHT 11 temperature and relative humidity sensor, 2 units of DYMH 103 load sensors and a 16 by 2 LCD display which displays the temperature or the mass of the samples depending on the mode. It was programmed to display two modes (temperature mode and the mass mode). The two modes can be alternated using the mode button. This (MTRH) data logger was designed in a way to enable its use for continuous weighing of two samples and as well taking the temperature and relative humidity of four different locations within the dryer simultaneously. It is designed to record the temperature, mass and relative humidity every five minutes in the removable memory card or manually taken from the LCD display. The use of DHT11 is to avoid the challenges of traditional analog humidity sensors which requires signal circuit design, adjustment and calibration, for which, the precision cannot be guaranteed, so does the linearity, repetition, interchanging and consistency [1].

A. LITERATURE REVIEW

A lot of temperature metering and control systems have been implemented using micro controllers. [2] presented the design and implementation of a standalone data logger for measuring relative humidity and temperature. It was a system that uses a microcontroller and an SD card for data storage. It had through experiments, demonstrated its effectiveness in collecting and storing data for extended periods. [1] also produced a temperature and humidity monitoring/sending system, which is based on digital technology and computer technology, using the DHT11 and DHT22 sensor. The system was able to overcome the challenges of poor linearity and low accuracy associated with use of traditional system of analog humidity sensor. It has a higher precision in measurement of temperature and humidity. [3] has designed and developed a low-cost data logger using an Arduino microcontroller for measuring relative humidity and temperature and found such to provide accurate and reliable measurements while being cost-effective. [4] had advanced in the use of microcontrollers for temperature and relative humidity data collection by creating the system architecture, for sensor interfacing, and web server implementation using the ESP8266 Wi-Fi module. The performance of the data logger was assessed through experimental tests and had shown its capability to capture and transmit data wirelessly with good accuracy. In year 2020, [5] developed an automatic temperature control system that could be used in modern gadgets and smart homes. They realized a system for controlling temperature automatically using Arduino Uno-based microcontroller system. From the available literature, the use of Arduino micro controller for temperature and relative humidity measurement is common and generally accepted. Numerous studies have explored different microcontroller platforms such as Arduino, Raspberry Pi, and ESP8266, to create cost-effective, reliable, and user-friendly data-logging solution. Arduino is a programmable micro controller whose code is written in a simple programming language similar to C and C++. The integration of load cells and temperature sensors into a micro controller for simultaneous data collection is not popular in literature. The (MTRH-data logger) is an Arduino microcontroller based data logger with the capacity to measure the weather parameters (temperature and relative humidity) as well as the mass of objects simultaneously at given intervals.

II. METHODOLOGY

The developed mass, temperature, and relative humidity (MTRH) data logger for drying experiment is made up of four sets of temperature and relative humidity sensors (DHT11 digital Temperature and relative humidity sensor) and two load cells (DYMH-103) rated 10-kilogram and 5-kilogram maximum load respectively.

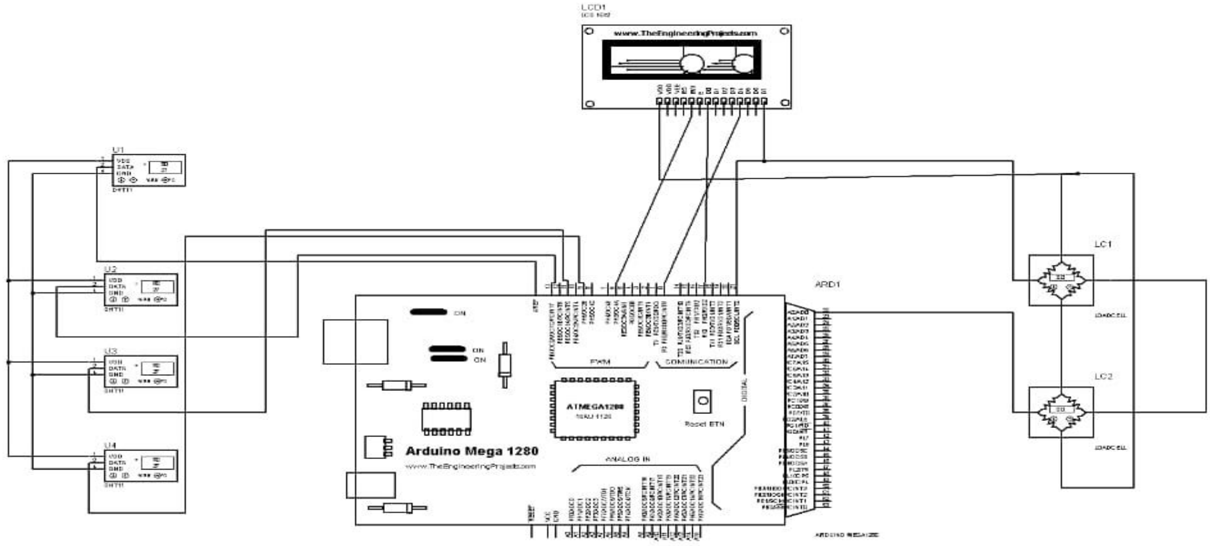

Fig. 1 circuit diagram of the (MTRH) data logger.

The data logger was tested and calibrated using other standard measuring instruments. A laboratory weighing balance SCALETECH: SAB220 whose accuracy was 0.0001 gram was used to calibrate the mass measurement values. The temperature reading of the instrument was also calibrated with that of Applent AT4208 Multi Channel temperature meter of accuracy of 0.2%+1°C and the relative humidity readings calibrated with that obtained using UNI T industrial hygrometer Model: UT331 whose operating humidity ranges from 0%RH to 100%RH. The results obtained were as shown in the table below.

A. RELATIVE HUMIDITY READINGS CALIBRATION

The developed instrument (MTRH data logger) was simultaneously used with UNI T industrial hygrometer Model: UT331 in measuring the relative humidity of same locations inside a greenhouse. The readings were plotted where RH^C is the UNI T industrial hygrometer reading while RH^1, RH^2, $RH^3$and RH^4 are the readings from channels 1-4 of the MTRH data logger. The various values of the hygrometer readings and the corresponding readings of the MTRH data logger were plotted to obtain the mathematical relationship and the coefficient of determination for the four channels with respect to the UNI T industrial hygrometer Model UT331. The value of the hygrometer reading was labelled RHC while that of the MTRH data logger was labelled RH1, RH2, RH3 and RH4.

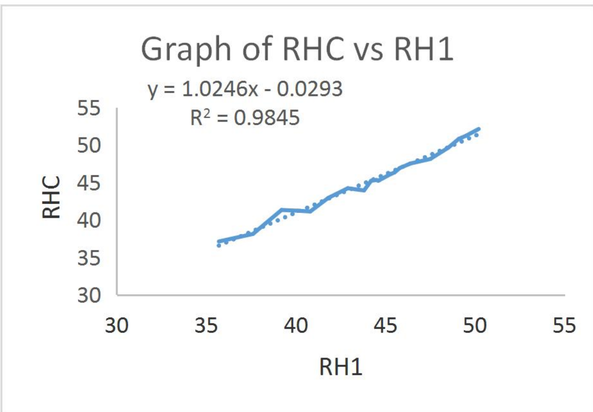

Fig. 2: Graph of RHC vs RH1

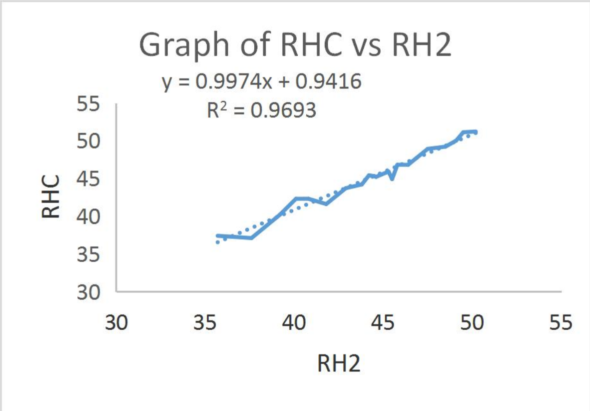

Fig. 3. Graph of RHC vs RH2

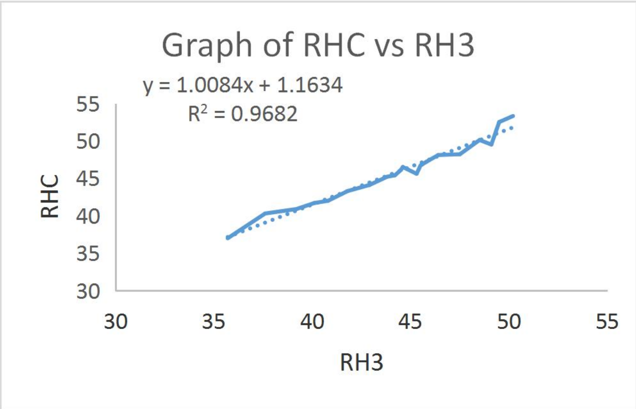

Fig. 4: Graph of RHC vs RH3

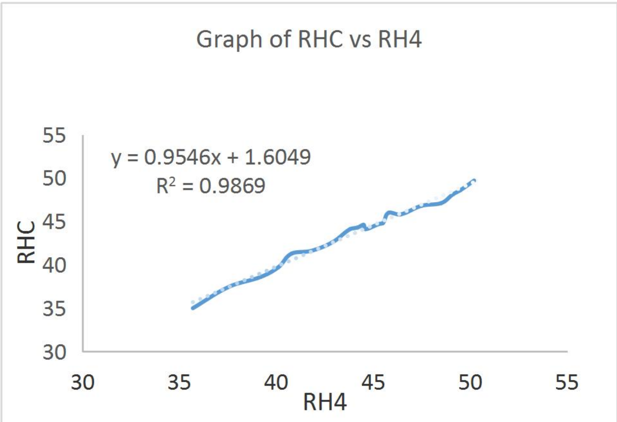

Fig. 5: Graph of RHC vs RH4

B. TEMPERATURE CALIBRATION AND DATA ANALYSIS

Temperature readings were taken using the MTRH data logger simultaneously with the Applent AT4208 Multi Channel temperature meter at same location. The various readings of the temperature meter and the corresponding MTRH data logger reading was plotted for the four temperature sensors of the data logger (T1, T2, T3 and T4) versus the corresponding reading of the Applent AT4208 temperature meter as shown below.

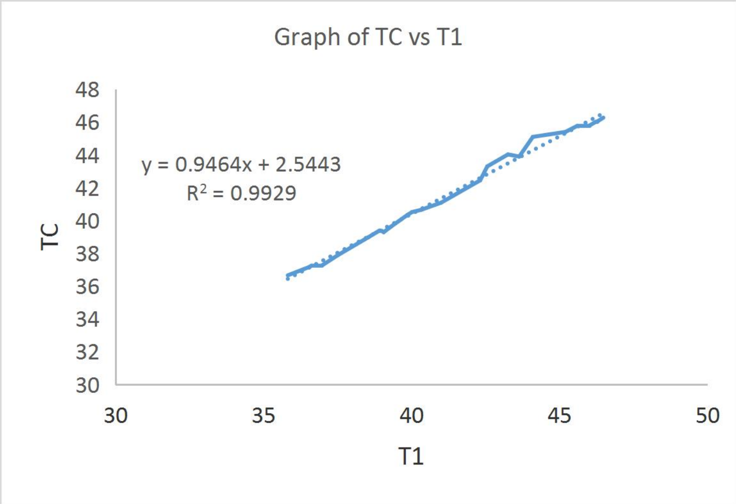

Fig. 6: Graph of TC vs T1

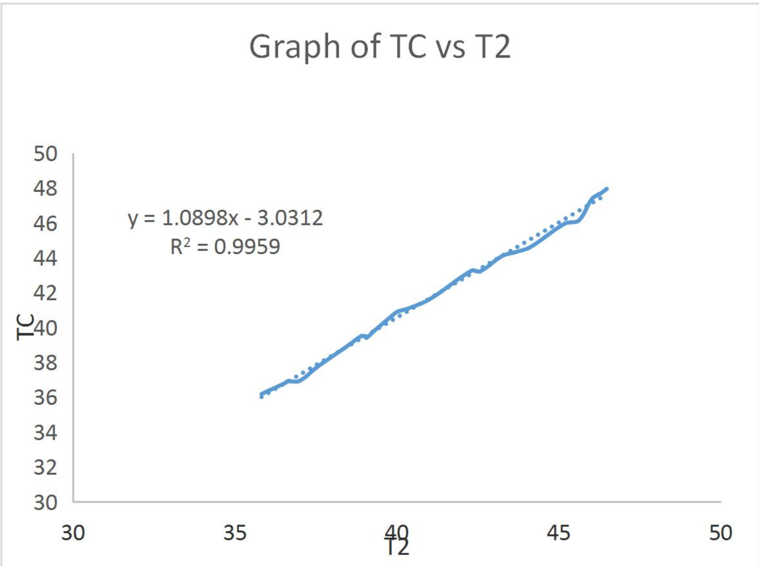

Fig. 7: Graph of TC vs T2

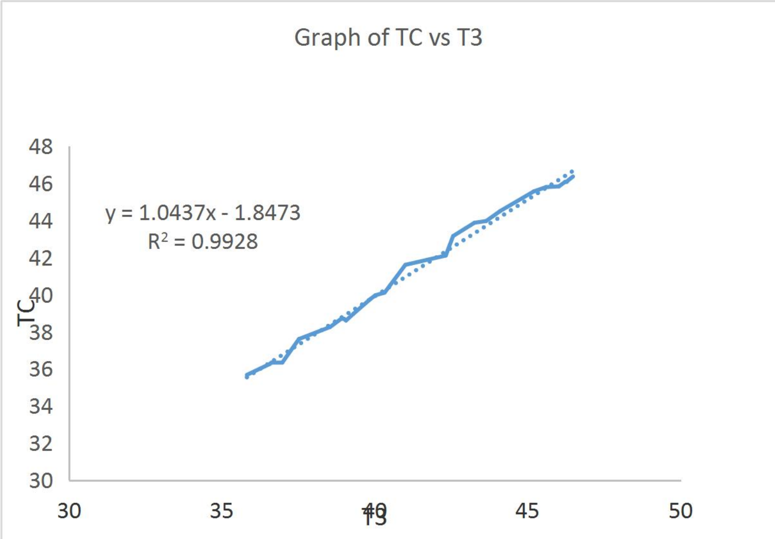

Fig. 8: Graph of TC vs T3

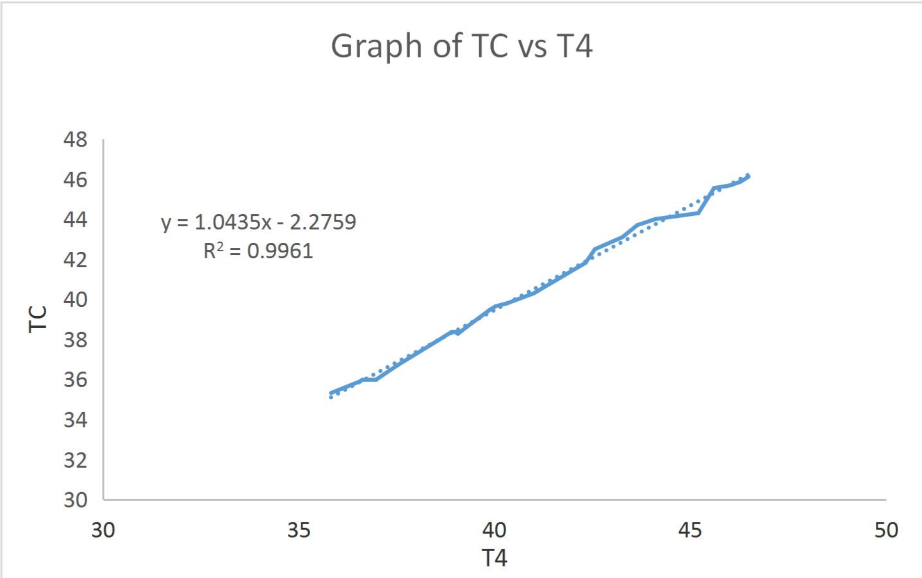

Fig. 9: Graph of TC vs T4

C. MASS READINGS CALIBRATION AND DATA ANALYSIS

Various samples of poultry manure were weighed using the standard laboratory weighing balance SCALETECH SAB220 and also weighed using the MTRH data logger and the results computed as follows where;

MC is the mass reading of the SAB 220 weighing balance

M1 is the mass reading of load cell 1 of the MTRH data logger

M2 is the mass reading of load cell 2 of the MTRH data logger

The graph both M1 and M2 were plotted against the corresponding value of MC to obtain the mathematical relationship and also the coefficient of determination.

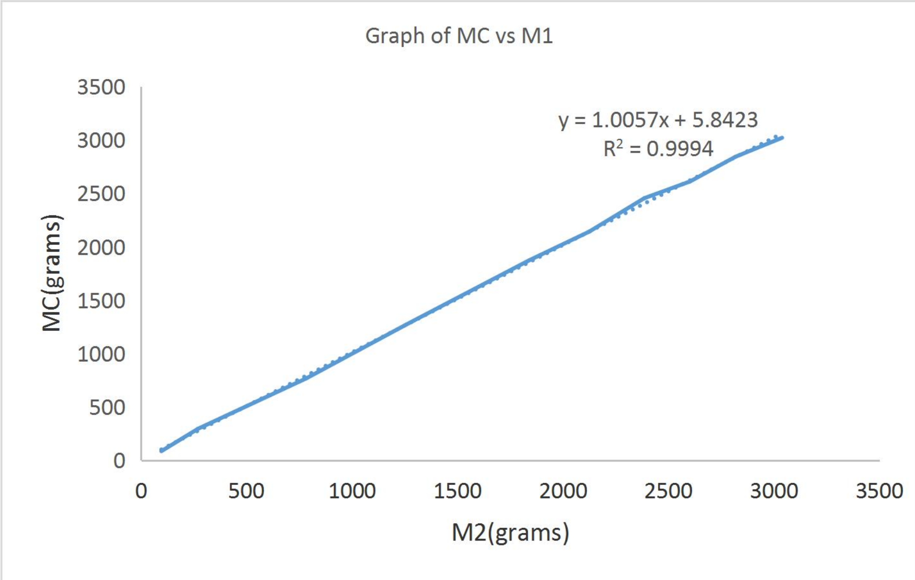

Fig. 10:Graph of MC vs M1

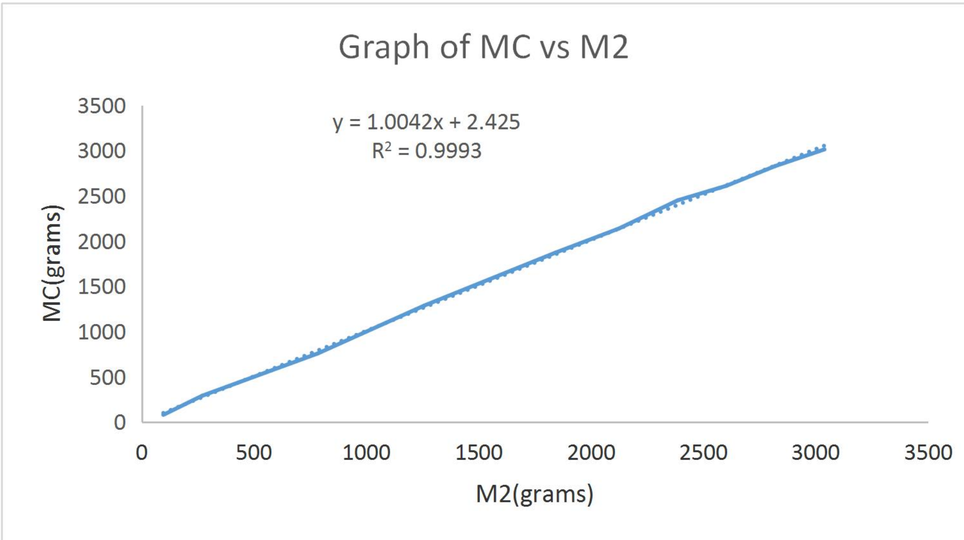

Fig.11: Graph of MC vs M1

III. RESULTS AND DISCUSSION

For all the three parameters being measured (mass, relative humidity and temperature) a graph of the data logger readings were plotted with the corresponding values from a standard instrument. A mathematical equation was developed to relate the data logger readings to other standard measuring instrument. This equation gives the relationship between the values of the MTRH data logger and the standard instruments. The coefficient of determination (R^2) which is the square of the correlation coefficient was also obtained. The coefficient of determination show the proportion of the variance in the Standard instruments that can be accounted for by the MTRH data logger readings. R^2 values range from 0 to 1: The various mathematical correlations and the corresponding coefficient of determination is tabulated below

S/N	Parameters	Trend line equation	Coefficient of determination (R^2)
1	Relative humidity DYMH 103-01	Y = 1.0246x – 0.0293	R^2 = 0.9845
2	Relative humidity DYMH 103-02	Y = 0.9974x + 0.9416	R^2 = 0.9693
3	Relative humidity DYMH 103-03	Y = 1.0084x + 1.1634	R^2 = 0.9682
4	Relative humidity DYMH 103-04	Y = 0.9546x + 1.60499	R^2 = 0.9869
5	Temperature DYMH 103-01	Y = 1.0437x – 1.8473	R^2 = 0.9929
6	Temperature DYMH 103-02	Y = 1.0898x – 3.0312	R^2 = 0.9959
7	Temperature DYMH 103-03	Y = 1.0437x – 1.8473	R^2 = 0.9928
8	Temperature DYMH 103-04	Y = 1.0435x - 2.2759	R^2 = 0.9961
9	Mass DHT 11-01	Y = 1.0057x + 5.8423	R^2 = 0.9994
10	Mass DHT 11-02	Y = 1.0042x + 2.425	R^2 = 0.9993

Where x represents the readings from the MTRH data logger and Y is the corresponding value using the standard instrument

IV. CONCLUSION AND RECOMMENDATION

A mass, temperature and relative humidity data logger (MTRH data logger) has been developed and tested. A mathematical relationship between the developed instrument and other standard laboratory measuring instrument has been established. These established correlation is for the purposes of calibration and reprogramming. The value of the obtained correlation coefficient has shown its high standard of accuracy. The designed project was tested a number of times and certified to achieve the aim of the project and will serve as a stepping stone in the development of an Arduino integrated MASS, TEMPERATURE, RELATIVE HUMIDITY DATA LOGGERS.

The sponsorship for mass production of this work is highly recommended because this development represents a significant advancement in a simultaneous temperature, relative humidity and mass monitoring technology. Its customization features, accuracy, and portability make it a valuable tool for various industrial and field drying applications. By offering an affordable and versatile solution, this device empowers users to easily collect temperature, mass and relative humidity data during drying experiments and other related industrial applications. As technology continues to evolve, innovations like these pave the way for enhanced efficiency, reliability, in data collections. It is evident from this project work that Temperature, Humidity and mass Sensor Project can be cheaply made from locally available components and be used to collect the temperature, mass and humidity data. All the components required are so small and compact that they can be packaged into a small portable box.

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