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Design of the Microcontroller Based Fish Dryer

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***Abstract*—In this paper the design and implementation of microcontroller-based fish dryer is presented. Particularly, the design and construction of a heating and drying chamber are presented along with the design and implementation of an arduino microcontroller-based feedback control system that is used to monitor the drying conditions within the chamber such as, the inflow of air (air speed), the relative humidity and temperature. In the design process Computer Aided Design (CAD) tools were employed to give the basic layout of the different sections of the system. Mathematical calculations were also carried out to determine appropriate system parameters values. During the implementation galvanized iron was used in the construction of the various chambers of the system. The software for the system was written in C++ and the program was stored in the ROM of the arduino microcontroller. Four samples of catfish were used to evaluate the drying process in the system. The results show that within the drying time of 210 minutes (3.5hours), the moisture content of all the fishes was reduced to a safe value below 15%. Particularly, among the four fishes used for the test, fish 2 with initial weight of 0.9 kg had the smallest moisture content of 12.22 % after drying to a final weight of 0.79 kg. On the other hand, fish 1 with initial weight of 1.1 kg had the highest moisture content of 14.55 % after drying to a final weight of 0.94 kg. The microcontroller-based fish dryer presented in this paper will be appropriate for small and medium scale fish farmers**

Keywords— Fish Dryer, Drying Chamber, Moisture Content, Arduino Microcontroller, Feedback Control System, Catfish.

I. INTRODUCTION

The global production of farmed fish such as finfish, crustaceans, molluscs and other aquatic animals was 70.2 million tonnes in 2013, up by 5.6 percent from 66.5 million tonnes in 2012 [1]. Between 2004 and 2013, the African continent alone recorded over 200 percent increase in fish production from 558,888 tonnes in 2004 to 1,615,608 tonnes in 2013 [1]. Normally, the amount of fish consumed is far less than the quantity produced. Also, the fish farms and fish capturing areas where the fishes are harvested are located far from the marketing areas thereby increasing the possibility of fish decomposition and the uncertainties of their sale when they finally make it to the market. This poses a great problem to the fishing industry; hence the need for fish preservation is a necessity.

Remarkably, fish preservation remains a major challenge in third world countries, such as Nigeria owning to poor technological growth in this region [1, 2]. In view of an inadequate technological base and the lack of well trained personnel in handling food preservation in developing countries, more than 50% of their harvested food is often lost to spoilage, [3, 4]. To access these modern technological preservation methods, third world countries have no choice but to purchase the required equipment from advanced countries usually at a high financial cost. In most cases, the equipment are electronically based and require some level of training for operators before they can be utilized, which also comes at an additional financial cost. Therefore, there is need to develop an indigenous automated drying system to address these basic challenges. Consequently, in this paper the design and implementation of the microcontroller based smokeless fish dryer (MBSFD) for small and medium scale enterprises (SMEs) is presented.

Notably, the design and implementation presented in this paper covered the following areas: the construction of a heating chamber and the design and implementation of a feedback system to monitor the drying conditions within the chamber such as, the inflow of air (air speed), the relative humidity and temperature; and a telemetry monitoring system for remote access and monitoring of the drying process. This is designed to assistance the end users in monitoring the drying process without being physically present at the site where the dry system is located.

II. REVIEW OF RELATED LITERATURE

Over the years, from ancient times to present, diverse food preservation techniques such as drying, salting, smoking, heating, freezing, or canning have been developed and used to prevent or inhibit food spoilage [5, 6,7]. Drying as the most commonly used early method in food preservation can be described as the process of extracting water present in foods by applying latent heat of vapourization [8,9, 10, 11]. Primitive societies used this method to preserve meat, fish and other kinds of food by placing them under the heat of the sun.

Today, drying of food is still being used as a major technique for preservation; however, the drying process is carried out in a more improved and sophisticated manner, by using diverse machinery and equipment, rather than the conventional sun drying practice. The principal reasons for food drying is to reduce the growth and activities of microorganisms, which are the major causes of food spoilage and decay [12, 13, 14, 15]. These microorganisms that promote the undesired changes in the chemical composition of food require sufficient water to grow and multiply, therefore in the absence of water most of these organisms die off [16].

Drying as a major method for food preservation can be carried out in different forms. TNAU stated that the different forms of drying can be grouped into two (2) major categories, that is, natural drying (also known as sun drying) and artificial drying [17,18, 19]. These different categories of drying are used for different purposes and applications.

The advantage of natural (sun) drying drying method is that it is inexpensive and relatively easy to manage. However, disadvantages can be seen in the inadequate control and exposure of the fishes to contaminants during the drying process while using this method of drying [20].

Artificial drying method of drying offers better control than the natural drying process, by employing the use of equipment powered by combustion, electrical and mechanical energy as the case maybe [20, 21]. This equipment is used in increasing the temperature of air around the fish in a controlled environment, therefore resulting in uniform drying and high quality products. In addition to the advantages of this method, the process is quick and can be automatically operated.

However, the process of artificial drying is not without some disadvantages. Some disadvantages of this method can be seen in the high initial investment cost involved in the purchase and installation of the equipment. Also, this equipment due to their large size are only suitable and effective for use when employed in large fish farms. However, despite these disadvantages, the artificial means of drying is more advantageous when compared to the natural means of drying which can be more difficult. some artificial methods of drying includes ; vacuum drying, freeze drying, solar drying, microwave drying, mechanical/convective driers [22].

The factors that affect fish drying include; temperature, relative humidity , air speed ,surface area and volume of fish, the nature of the fish, the thickness of the fish, temperature of the fish and the water content [23, 24, 25, 26].

III. METHODOLOGY

The methodology employed in this work entails both analytical and empirical. In the design process Computer Aided Design (CAD) tools were employed to give the basic layout of the system showing the different sections and layout of the system. Mathematical calculations were carried out to determine the sizing of the system components and determination of appropriate system parameters values. Lastly, during the implementation galvanized iron was used in the construction of the various chambers of the system.

A. System Design: System Control Unit

The design of the Microcontroller Based Fish Dryer (MBSFD) is divided into four sections as follows (Figure 1): the System control unit, the Power supply unit, the Drying chamber, and the Heating layer housing the electric heating element and the inlet fan for circulation of the hot air section. The materials for the Implementation include galvanized metal sheets, and aluminum sheets.

The dryer is designed to dry nine pieces of catfish of average weight 1.0 kg each, totaling 9 kg per batch. The dryer has dimensions of 75 x 49 x 53 cm, (height, width, horizontal depth)

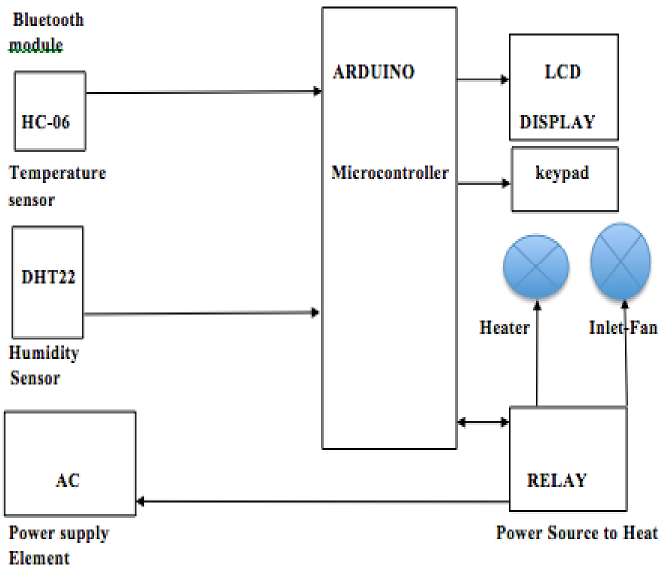

Figure 1: Block Diagram Of The System Components

The system control unit is designed using ATMEGA328P-PU Arduino microcontroller. Other components of the entire system are interfaced to the microcontroller and the Arduino microcontroller carries out the control function by using C++ software program stored in the ROM of the microcontroller. Particularly, the linear temperature and humidity sensor chip (DHT22) interfaced to the ATMEGA328P-PU Arduino microcontroller collects temperature and humidity readings from the heating chamber of the dryer. This information is processed by the micro program and passed on to the Liquid Crystal Display (LCD). The LCD display is interfaced to PINS 2-8 of the microcontroller, and displays the current readings of the sensor in the chamber. Also, the relays used for automated switching of the heater is interfaced at PIN 9 and 10 of the ATMEGA328P-PU Arduino microcontroller with a basic function of controlling the heater in the drier by either cutting off the power supply or initiating a contact. Lastly, the fans are interfaced to the microcontroller via a relay. The control unit is enclosed by an insulated material so as to avoid adverse effect of heat from the heating chamber.

B. System Design: Interfacing of the Bluetooth Module

The HC-06 Bluetooth module comprises of four pins as follows: VCC (+5V) to power the module; TX/TXD (3.3V) for transmitting data to the microcontroller; RX/RXD for receiving data from the microcontroller; and GND to ground for power. The connections areas follow:

- Ground (GND) pin is connected to ground on the microcontroller;
- VCC (3.6-6V) is connected to 5V on the microcontroller;
- TX/TXD is connected to digital Pin 1 (RX) on the microcontroller; and
- RX/RXD is connected to digital pin 2 (TX).

However, since the digital pins of the microcontroller are 5V, it implies the RX/RXD (3.3V) pin and the Bluetooth module stands a great risk of damage. Hence, in connecting the RX/RXD pin to the microcontroller a voltage divider is designed as follows;

$$Vo = Vi * \frac{R2}{R1+R2} \quad (1)$$

Where:

Vo is the output voltage (3.3V required by HC-06); Vi is the input voltage (5V) from microcontroller and R1 and R2 are the resistors across the circuit (R2 = 2*R1). Hence,

from equation (1): $\mathrm{Vo} = 5 * \frac{10}{5+10} = \frac{50}{15} = 3.33\mathrm{V}$

Lastly, the LED used as indicator is connected to the pin D7 (Figure 2) of the ATMEGA328P-PU Arduino microcontroller , using a 300 ohm resistor at the anode to protect the LED from excess current.

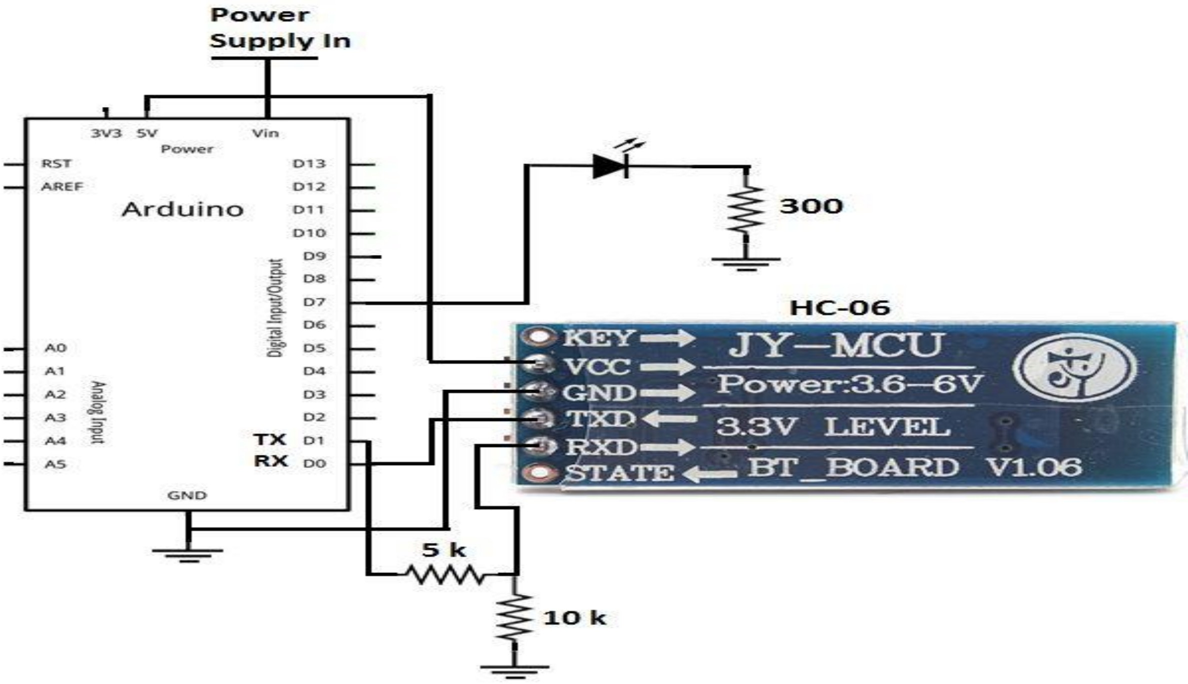

Figure 2: Interface of the Bluetooth module to the microcontroller

C. System Design: Interfacing Of The Sensor (Dht22) and Keypad

The DHT22 sensor has four pins, VCC, GND, data pin and a not connected pin, which has no usage. A pull-up resistor of 5K to 10K Ohms is required to keep the data line high in order to enable the communication between the sensor and the microcontroller. In the design presented in this paper, a resistor of 10k ohms is chosen and used to connect the data line to the microcontroller. Though the data line can be connected without the pull-up resistor it is advised to do so in order for the line to always be energized to get signals. The interface of the humidity and temperature sensor module to the microcontroller is shown in figure 3.

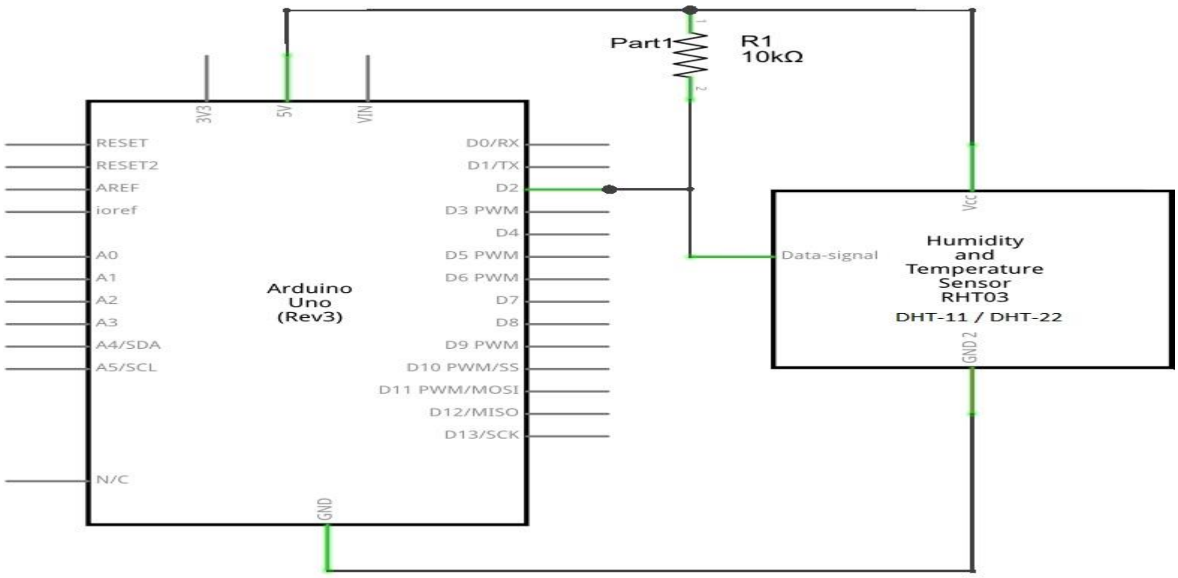

Figure 3: Interface of the DHT22 Sensor to the Microcontroller

The 4X4 keypad used has eight (8) pin-out, these pins are interfaced directly to the microcontroller on digital pins 3 to 10, as shown in figure 4.

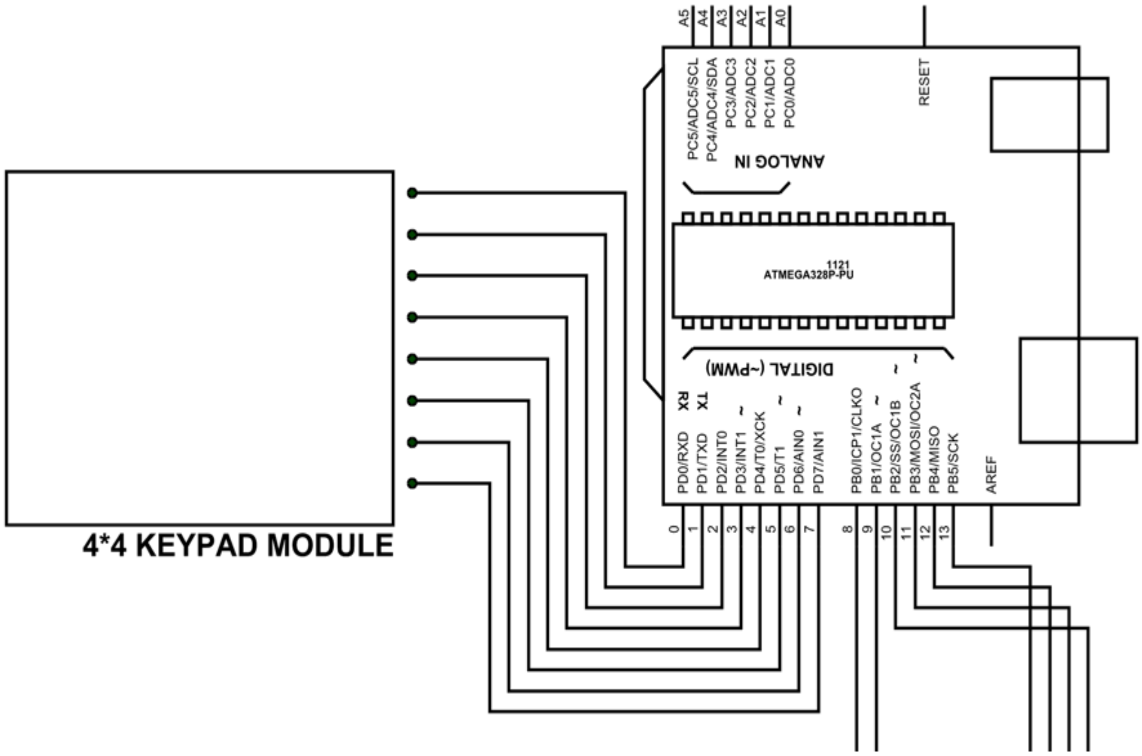

Figure 4: Interface of the keypad to the microcontroller

D. System Design: Interfacing of the LCD (20x4 Display)

The LCD display was interfaced to the microcontroller using an I^2C connector. The connector acts as a demultiplexer, it has 20 pins of which 16pins (input pins) are used to interface with the LCD, and the remaining 4 pins (output pins) are utilized to interface with the analog pins on the microcontroller. The output pins layout of the I2C connectors are as follows: the SDA (data line), SCL (clock line), the VCC and GND pins.

- GND is connected GND on the microcontroller;
- VCC is connected to VCC (5V) on the microcontroller;

- SDA is connected on analog input pin 4 of the microcontroller; and
- SCL is on analog input pin 5 of the microcontroller.

E. System Design: Design of the System Power Supply

The Power supply unit is designed with the aid of a transformer of suitable voltage and power rating, diodes, capacitors and a voltage regulator to give the desired outputs. The schematic representation of the regulated power supply unit is shown in figure 5.

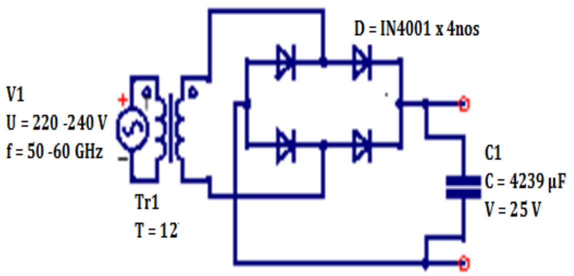

Figure 5: Design of a regulated Power Supply Unit (PSU) for the control unit

The control system needs a regulated output of +5V and +9V DC. The maximum current rating for the entire design is 0.5 A (that is 500 mA). of 220/12V is used. Therefore, the power supply unit consist of a step down transformer of 220/12 V, 500mA , along with IN4001 silicon diodes D1 to D4 bridge (used as rectifier), and capacitor Cf (as capacitive filter,). The choice of capacitor value is determined as follows:

$$c_f = \frac{1}{(2\sqrt{2})F_r K_r R_l} \qquad (2)$$

Where Fr is the ripple frequency ; Kr is the ripple constant; Rl is the minimum coil resistance and Fr is the 100HZ = (50 + 50) HZ , then

$$Kr = \frac{\text{RMS ripple voltage}}{\text{DC output voltage}} \qquad (3)$$

a)

Where: Rms Ripple voltage = Rms ripple current , then 500mv = 500mA

: . Kr = (500 x 0.001)/(12) =0.0417 = 41.7x0.001

Rl = 20Ω (min) and from equation 2

Cf = 1/(2.81 x 100 x 0.0417 x 20) = 1/235.7 = 0.004239 ; that is Cf = 4239µF

However, a capacitor of the rating 4239µF does not exist in the market, so 3300 µF was selected. Also, to determine the voltage rating of a capacitor is given as 2 x DC output voltage which gives . 2 x 12V = 24V; However 25V is used.

F. System Design: Fan and Heating Element

The centrifugal fan operates on alternating current, it has a power rating of 175watts with its speed at 900rpm and delivers an air volume of about 610 m3/h at a pressure of 640pa. On the other hand, the heating element has a total power rating of 1000 watts. Both have voltage requirements levels of 240 Vac . Therefore, they are directly powered from the dryer mains supply. However, due to the need for control in switching the heater and fan “ON” and “OFF”, two (2) relays are interfaced; this ensures the control of the two components. The specification of the relay used is 10A/250VAC.

The relay has 3 pins as shown in Figure 6. The signal pins are interfaced to Pin 11 and 12 of the ATMEGA328P-PU Arduino microcontroller for the heater and fan respectively. The NC (Normally Closed) point of each relay is connected to the load, while the C (Common) point is connected to the neutral of AC power source while the live goes directly to the load thereby completing the circuit.

Figure 6: 5V Relay Pin-Out

G. System Design: The Drying Chamber And Trays

The drying chamber is located at mid-section of the dryer. It has double walls made up of a plain metal sheet measuring 40cm (height), 35cm (width), and 40cm(depth) with filled fiber fur (as insulator) between the walls to reduce heat loss across the wall. The design of the drying chamber and air circulation within the chamber is shown in figure 7.

The chamber has air inlet at the bottom left corner wall of the chamber. This provision allows air into the chamber. At the top of the chamber are 15 mm diameter hole. This hole allows for the flow of moist air out of the drying chamber into exhaust pipe from which the air is expelled out of the dryer. The volume (capacity) of the drying chamber is determined as follows:

Volume of the Chamber (Vc): is calculated as;

$$Vc = H \times W \times D \qquad (4)$$

where: H is height of chamber (H= 40 cm) ; W is the width of chamber (W= 35 cm) and

D is the depth of chamber (D= 35 cm), then
Vc = 40 x 35 x 35 = 49000 cm3

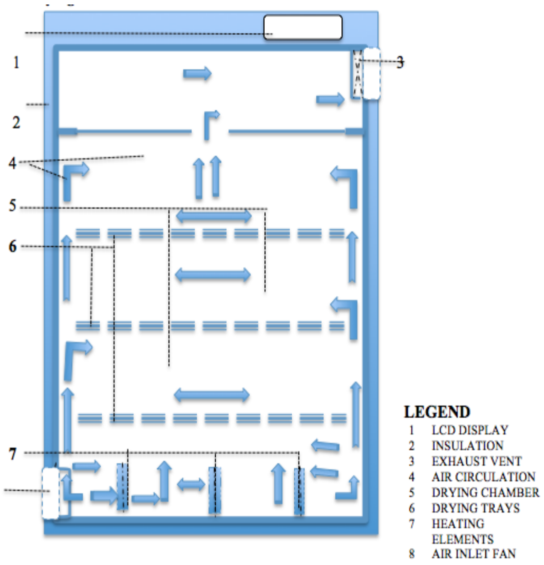

Figure.7: The Drying Chamber and Air Circulation

The trays (Figure 8) used in this design are made up of a mesh of steel ropes that serve as a platform to place the fishes to be dried, each tray with dimension 35 cm by 40 cm has a capacity to hold three (3) fishes. A total of 3 trays are accommodated at once in the drying chamber making it possible for nine (9) fishes to be dried simultaneously. The drying chamber has railings on which these drying trays slide in and out of the chamber. Figure 8 shows the fish drying trays

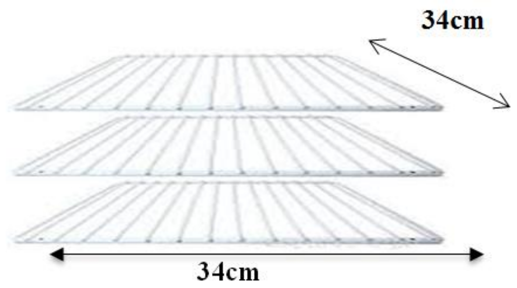

Figure 8: The Drying Tray

H. System Design: The Fan housing and Heating Layer Section

The fan housing (figure 9) and heating layer are located adjacent to each other to limit the time it takes for hot air to flow into the drying chamber. In order to effectively force ambient air into the drying chamber across the heating elements and at the same time expel moist air from the chamber, there exists two (2) fans (1 inlet and 1 outlet fan) measuring (15 x 15 x 5cm) inside a housing. The inlet fan is mounted in front of the air inlet opening located at the bottom part of the dryer while the outlet fan is located at the top part of the dryer (exhaust chamber) in front of the air outlet opening. The design of the fan housing section is shown in figure 9.

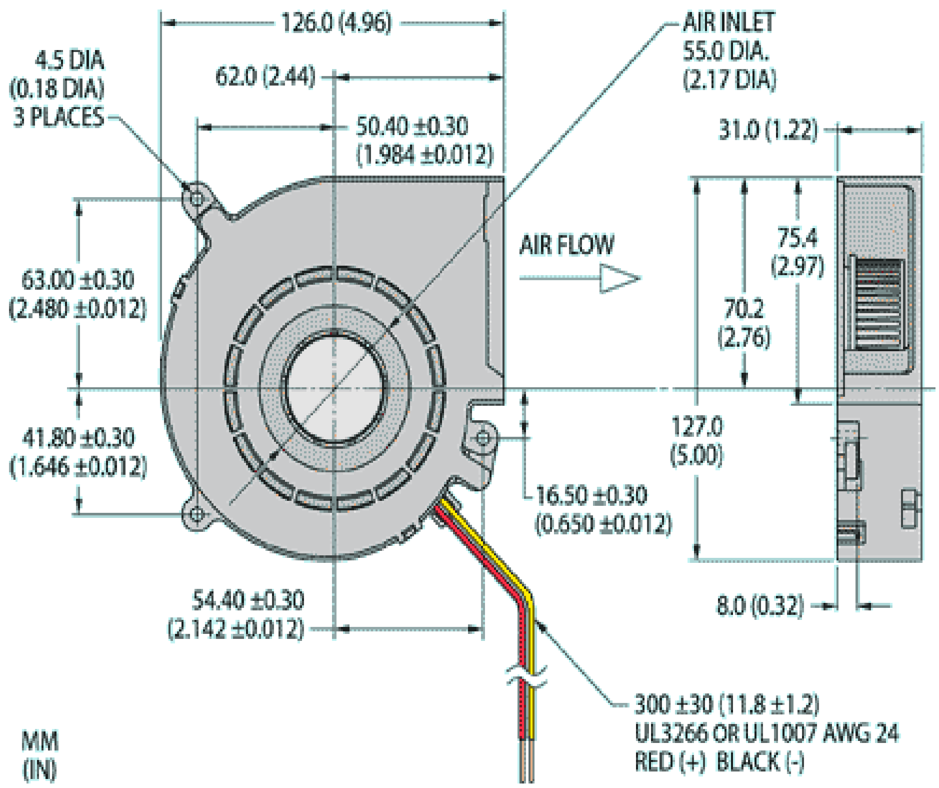

Figure 9: The fan housing design

The 1000 w heating element consists of two serially connected electric heating elements of 500 w/220v (AC) capacity each are used to heat the incoming air.

IV THE IMPLEMENTATION AND EVALUATION OF THE SYSTEM

During the implementation galvanized iron was used in the construction of the various chambers of the system. The picture of the constructed MBFD is shown in figure 10 whereas the picture of the constructed inside of the MBFD is shown in figure 11. The system software for this system was written in C++ programming. The program was stored in the ROM of the microcontroller.

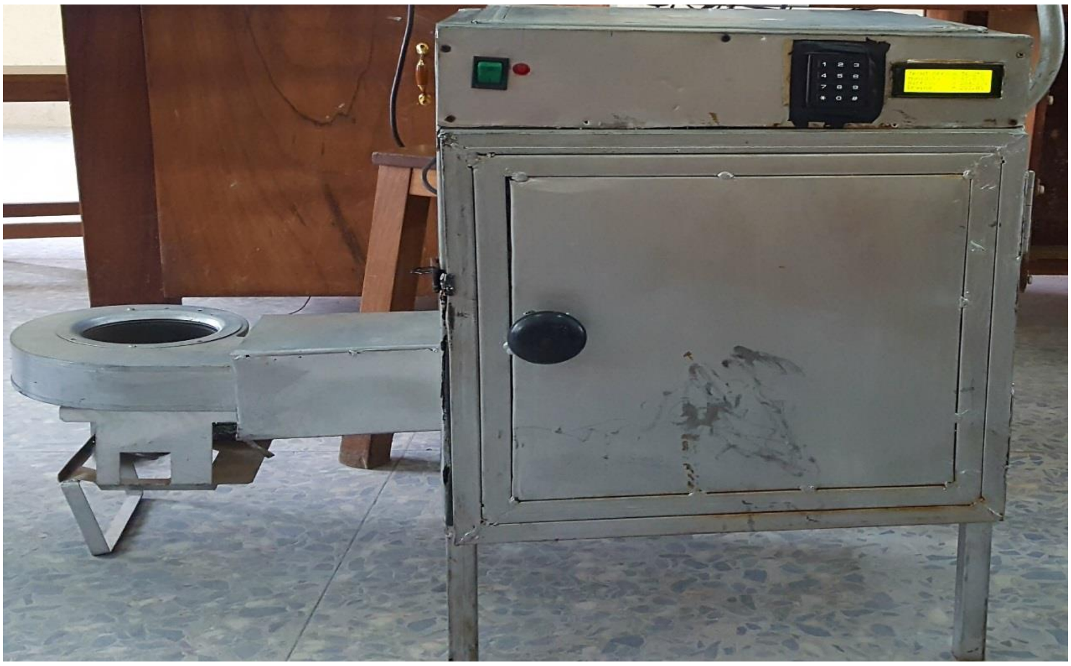

Figure 10: The picture of the constructed Microcontroller Based Fish Dryer (MBFD)

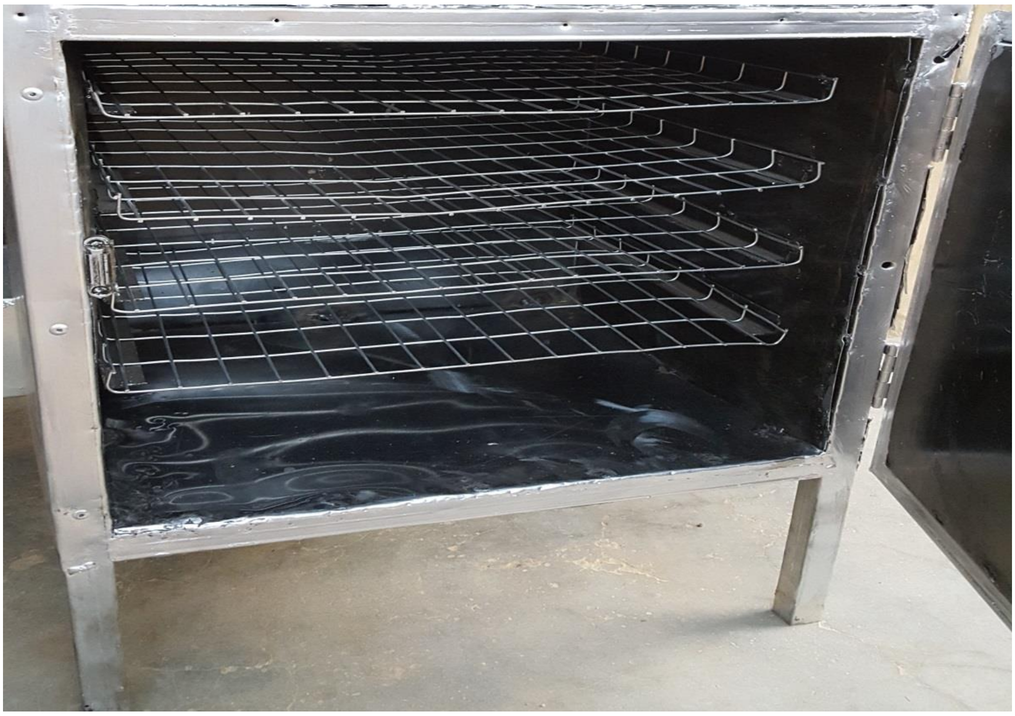

Figure 11: The picture of the constructed inside of the Microcontroller Based Fish Dryer (MBFD)

Four samples of catfish were used to evaluate the drying process in the system. The dryer was turned on; fishes were first weighted before they were placed into the drying chamber. During the drying process the weight of each fish sample was measured every 15 minutes for the first two hours and every 30 minutes afterwards.

During the test, an external temperature sensor was used to measure the ambient temperature of the air being sucked into the chamber before heating up. The DHT22 sensor inside the chamber were used to measure the temperature and relative humidity of the drying chamber where the fish samples were kept. The fish samples were taken out and weighed on a scale at the time intervals (15 minutes for the first two hours and every 30 minutes afterwards). This was continued until the final weight and hence the final moisture content was determined. According to Adamu et al., [28], the final moisture content that is safe for preserving fish is between 10 to 15%. The time taken for the drying was the total time of drying including the time used for the intermittent weight taken in the determination of the moisture content. Drying curves were obtained in the form of moisture content versus time. The moisture content (Mc) given in percentage (%) was calculated using equation 5;

$$Mc\ (\%) = \frac{Ww - Wd}{Ww}\ X100 \qquad (5)$$

where Mc is the moisture content, Ww is the weight of wet fish and Wd is the weight of dry fish.

The result of the temperature and relative humidity measurements is shown in Table 1, and a graph of temperature and relative humidity is plotted against time as shown in the figure 12.

Table 1. Result of the temperature and relative humidity measurements

Time (min)	Ambient Temperature(^{o}C)	Temperature (^{o}C)	Humidity(%)
0	29	40	60
30	31	53	57
60	30	60	58
90	32	80	70
120	30	80	68
150	30	80	65
180	31	80	65
210	30	80	60

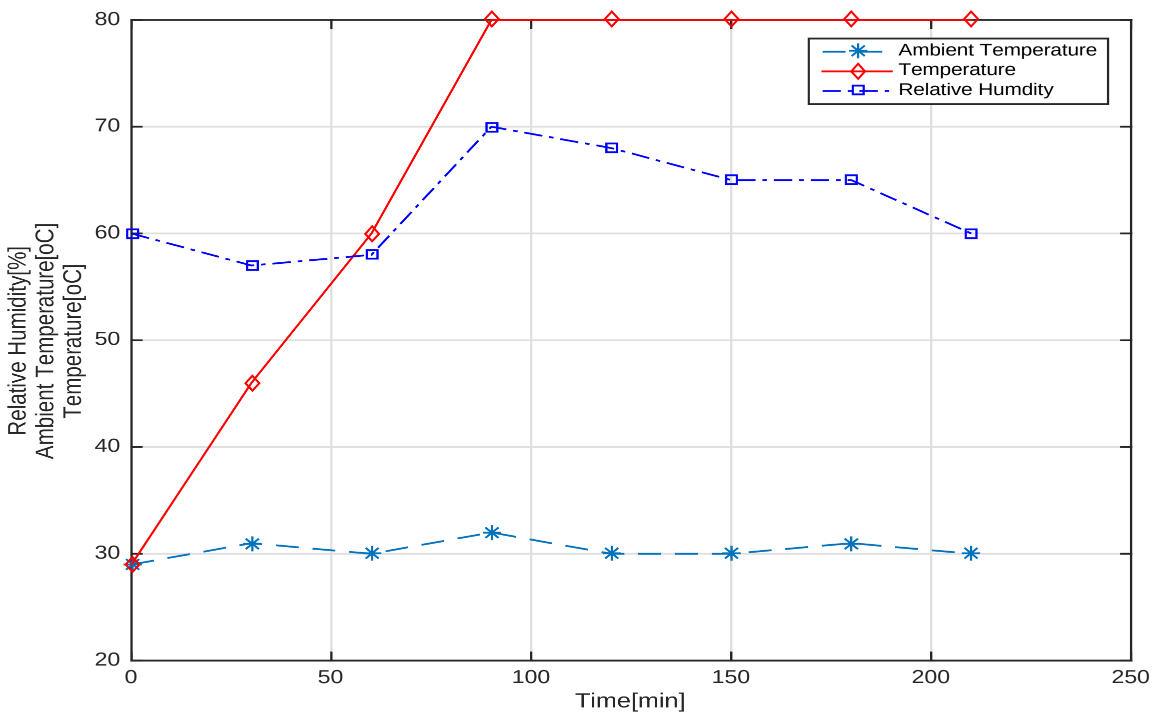

Figure 12: Graphical Representation for temperature and relative humidity measurements inside the drying chamber

Table 1 and figure 12 it can be observed that the relative humidity reached its peak mid-way into the drying process, therefore indicating that water was being evaporated from the fishes. The relative humidity however started to drop towards the end of the drying process. Notably, towards the end of the drying process the relative humidity dropped towards the prevailing ambient relative humidity. This implies that a humid free environment will greatly impact on the time required to dry the fish and this agrees with the research findings by Adamu et. al. [28].

Additionally, the results for the moisture content test are shown in Table 2 and figure 13. The results in Table 2 and figure 13 show that within the drying time of 210 minutes (3.5hours) , the moisture content of the fish was reduced to a safe moisture content. This is similar to the result obtained by Adamu et al. [28]. However, generally, the time taken for drying as stated earlier depends on the weights, sizes of fish, type of fish, the initial moisture content, the fat content of the fish and the uniformity and intensity of heat supplied. In this case, fish 2 with initial weight of 0.9 kg had the smallest moisture content of 12.22 % after drying to a final weight of 0.79 kg. On the other hand, fish 1 with initial weight of 1.1 kg had the highest moisture content of 14.55 % after drying to a final weight of 0.94 kg.

Table 2: Result of moisture content test on wet basis

Fish Number	Initial Weight (kg)	Final Weight(kg)	Moisture Content (%)
1	1.1	0.94	14.55
2	0.9	0.79	12.22
3	1.4	1.2	14.29
4	0.91	0.79	13.19

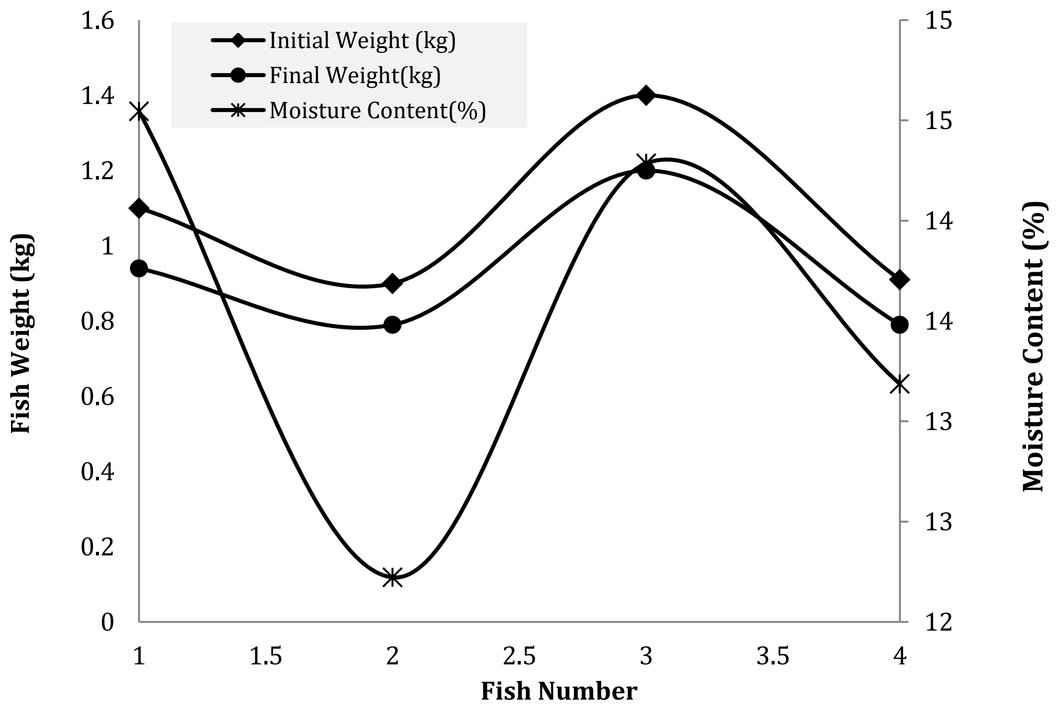

Table 2: Results of the moisture content test on wet basis

V. CONCLUSION

The design , implementation and valuation of microcontroller-based fish dryer is presented. The design and construction of the heating and drying chamber are presented along with the design and implementation of an arduino microcontroller-based feedback control system that is used to monitor the drying conditions within the chamber such as, the inflow of air (air speed), the relative humidity and temperature. The software for the system was written in C++ and the program was stored in the ROM of the arduino microcontroller.

The drying chamber is designed to accommodate a maximum of 9 kg of fish. Some samples of catfish were used to evaluate the drying process in the system. The results show that within the in less than four hours than the moisture content of all the sample fishes was reduced to a safe value below 15%. The results also showed that ambient humidity greatly impact on the time required to dry the fish and this agrees with existing research findings. The dryer presented is particularly meant for small and medium scale fish farmers.

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