



## DESIGN, CONSTRUCTION AND TESTING OF A WEIGHING EQUIPMENT FOR POWDERED FOOD PRODUCTS

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### ARTICLE INFORMATION

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### ABSTRACT

*In local markets in third world countries, no standards are followed in terms of selling and buying powdered food products. This leads to variation in the amount of products sold or received by retailers or customers respectively. Ensuring a standard for such products are vital in maximizing profit for business owners and optimizing quantity of products received by customers. To solve this problem, a weighing equipment was designed, constructed, and tested. All materials used in the construction were locally sourced and assembled. After completion of the weighing equipment, it was tested with a powder product for about 300 s (at 60 s interval) and the corresponding mass (kg) was compared to a readily available digital scale. The results from the analysis showed that the developed weighing equipment have an approximate accuracy of about 95%. This meant that the average mass (kg) difference from the analysis was 5.06%. In addition, there was an average savings of about 0.150 kg of the powder product. Therefore, the developed weighing equipment will be vital to small scale businesses in third world countries.*

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### 1.0 Introduction

Measurement techniques have been of immense importance ever since the start of the human civilization when measurement was first needed to regulate the transfer of goods in trade by barter to ensure that exchange was fair. The 19<sup>th</sup> century revolution led to the development of new measuring techniques in the industrial world (Morris, 2001). The increased demand in digital weighing equipment in business enterprises in recent years is because of the quest to simplify measurement (Satish and Vanaraj, 2012). The demand for traditional weighing method has reduced significantly due to the availability of digital weighing equipment. This has also caused a revolution in the variety of design of digital weighing equipment. Several digital weighing scale designs have been presented in quite a number of publications; these designs exhibit different unique features. For instance, Pinto (2012a) conducted three different projects with different scales. The researcher started with the FagorBB-90 scale, a cheap simple scale with Liquid Crystal Display (LCD) screen. The goal of the project was to store the data on a Secure Digital (SD) card and further add more advanced features to the scale. The researcher did so by removing the original LCD screen and then added a new LCD screen and a microcontroller (LPC 2103) to enable easy control of the microcontroller fetched data from the SD card and do multiple calculations before outputting it on the LCD screen. The new features were time and date, increase or decrease in weight and multi user support. Pinto (2012b) further improved the scale to give it Bluetooth connectivity. The scale communicated with android mobile phone via a Bluetooth link. The researcher used the android application smart weight chart to show the data

as a graph. The researcher's second work was similar to the first work but with a different scale. Lastly, the researcher worked on the Beurer BG 16 scale that is used to measure weight, water percentage, fat percentage, and percentage of muscle. The same modifications as with the other scales were made. Though, the scale was very sophisticated, it was however expensive and not affordable by most people.

Modern instruments take into consideration the force of the earth's gravity in trying to ensure the accuracy of measured weights due to variation in earth's gravitational pull. The simplest form of a weighing equipment is the balance; it is used to balance two loads from opposite ends of a horizontal bar (Mushiri and Mbohwa, 2015). The delicate precision balances used today in scientific laboratories are based on the above principle. For heavier loads, scales based on steelyard were used (Abueejela and Belkasem, 2018). The mechanical scale was invented by Thaddeus Fairbanks in 1830. It uses a system of two or more connected levers to support the platform. When a load is placed on the platform, the levers divide the load so that a small weight can be used to balance a load thousands of times heavier (Shigwan *et al.*, 2016).

Modern precision balances, known as macro balances in scientific laboratories, are sensitive enough to measure loads up to 7.05 ounces (200 grams) to the nearest 3.5 million of an ounce (0.1 milligram). There are even more sensitive balances, called microbalances, that can weigh a maximum load of 0.00353 ounce (0.1 gram) to the nearest 3.53 hundred-millions of an ounce (1 millionth of a gram). Most precision balances are kept in glassed-in cabinets so that they are unaffected by external temperature changes and drafts (Raza and Turiac, 2016).

In third World countries such as Nigeria, many small scale food production business owners and small/medium scale Grocery Store owners in local communities do the process of weighing and filling of products manually. Such business owners who particularly produce items like Cassava flakes (locally and popularly known in Nigeria as Garri), flour, and other powdered products, etc. has to do the weighing and filling of the packaging processes manually. This leads to loss in profit because of the time and effort required in the manual handling.

Therefore, there is the need to solve this peculiar problem for the local communities in Nigeria, which has led to the design and construction of this weighing equipment. This equipment could also be used by the food and beverages industries to fill and weigh products such as powdered sugar, salt, coffee, milk, flour, spices, etc.

## **2. Materials and Method**

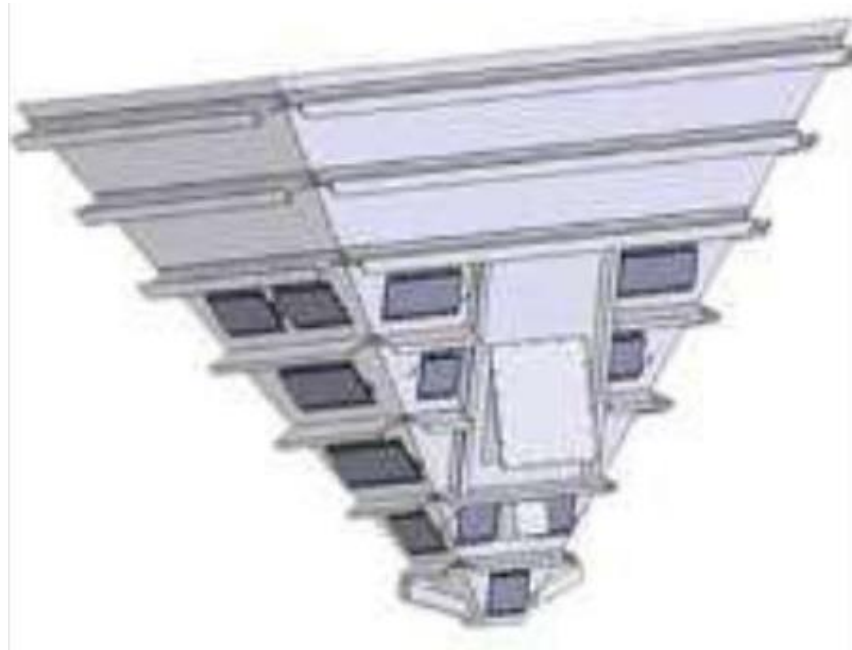
### **2.1. Materials**

The materials used for the construction of the equipment are: hopper, load cell sensor, Arduino Uno board (microcontroller), stepper motor, stepper motor driver, input key and LCD screen, power supply, and frame. Sections 2.1.1 – 2.1.5 presents the description of the components used in this study.

#### **2.1.1. Hopper**

The hopper is cone shaped with cavity, through which the product (power), pass into the stepper motor unit for filling process. The hopper wall is made of plastic with a thickness of 2.0 mm. The

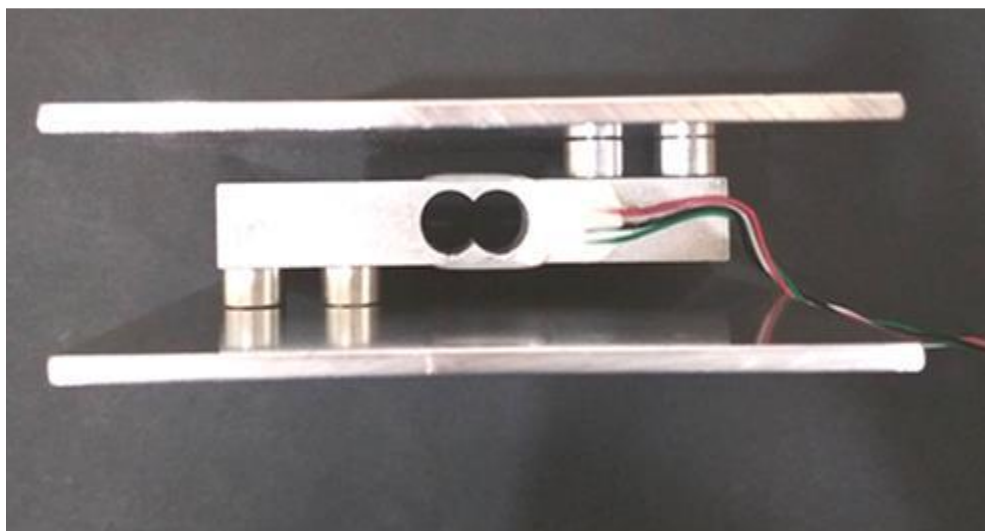
top of the hopper has a measurement of 260 mm by 260 mm, the cavity measurement is 60 mm by 60 mm, while the height of the hopper is 300 mm (from the top to the cavity). The hopper has the capacity to hold 5.309 kg of product (powder). There is a 20 mm Polyvinyl Chloride (PVC) inlet pipe that connects the hopper to the stepper motor unit. Figure 1 presents the designed hopper used in this work.



**Figure 1:** Hopper

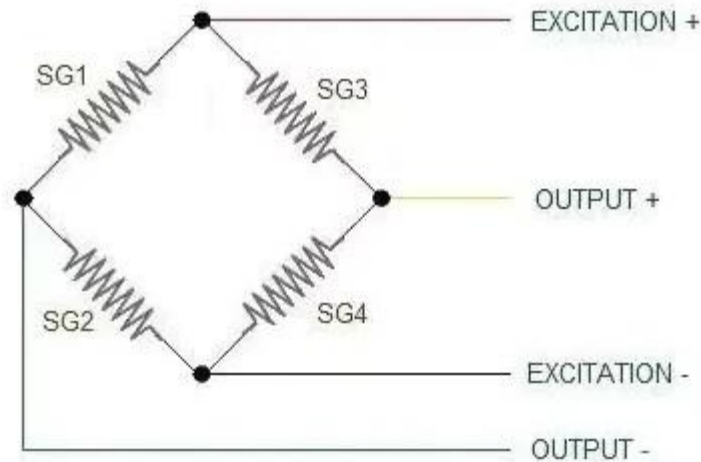
### 2.1.2. Load Cell and Sensor

A load cell is an electronic sensor used for measuring weight and force. When a force is applied to it, an electrical signal at the milli-voltage level transmits on its output wires. In addition, the load cell is a transducer that converts force into measurable electrical output. Figure 2, shows the load cell and sensor used for this work.



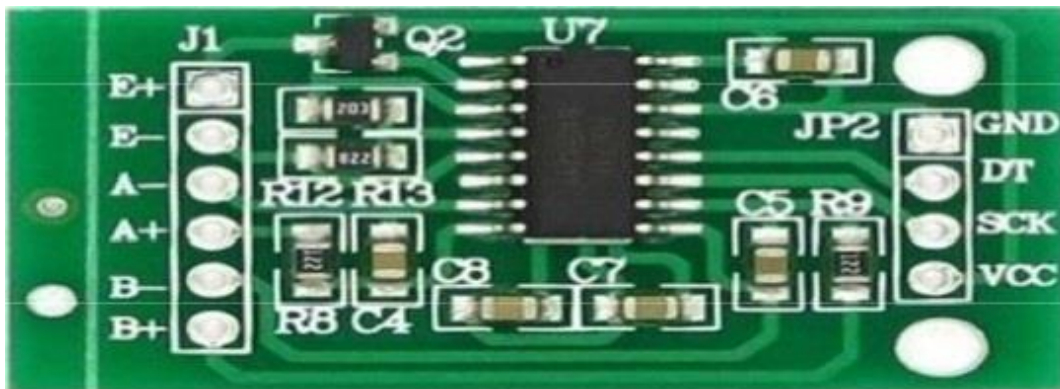
**Figure 2:** Load cell and sensor

A woody board with the dimension of 100 mm length and 50 mm width was mounted on one side of the sensor, where load or force was applied, while the main side of the load cell was mounted on the base of the entire system. When a force was applied on the load cell (this comprises a metal core and a set of electrical resistances) there was a transformation (this was corroborated by the work done by Jazmati (2022)). However, the load cell returned to its original state when the force was removed. The accuracy and quality of the load cell was dependent on the reversibility of the material (Jazmati, 2022). Figure 3 presents the electrical wiring of the load cell. The load cell comprises of four wires, which are: red for excitation (+), black for excitation (-), white for output (-), green for output (+).



**Figure 3:** Load cell wiring (Jazmati, 2022).

The output signal produced by the load cell was in the range of millivolts, therefore, there was a need for an amplifier to convert the signal into a level that can be transformed into digital signal and then process it. For this purpose, HX711 amplifier sensor was employed. The HX711 amplifier sensor includes HX711 chip with analog-to-digital conversion capability in 24-bit accuracy. The HX711 module amplified the low-voltage output of the load cell and sends it to the Arduino (the Arduino eventually calculated the weight from this data/information). A pictorial view of the HX711 amplifier used is shown in Figure 4.



**Figure 4:** Pictorial view of HX711 amplifier

### 2.1.3. Microcontroller (Arduino Nano)

The Arduino-Nano board used in this work contain the Atmega 328 p microcontroller. The Arduino Nano is a microcontroller board designed by Arduino, which operates on 5 V and consists of 28 pins. It has a wide range of applications and is a major microcontroller board because of its small size and flexibility. A pin configuration of Arduino Nano chip board used in this work is presented in Figure 5. The memories (capacity) embedded in the Arduino Nano chip board include: a flash memory of 32 kb, Static Random Access Memory (SRAM) of the Microcontroller board is 8 kb, Electrically Erasable Programmable Read-Only Memory (EEPROM) is 1 kb, and it has a preinstalled bootloader on it, which takes a flash memory of 2 kb. The circuit diagram of the Arduino Nano device used in this work is presented in Figure 6.

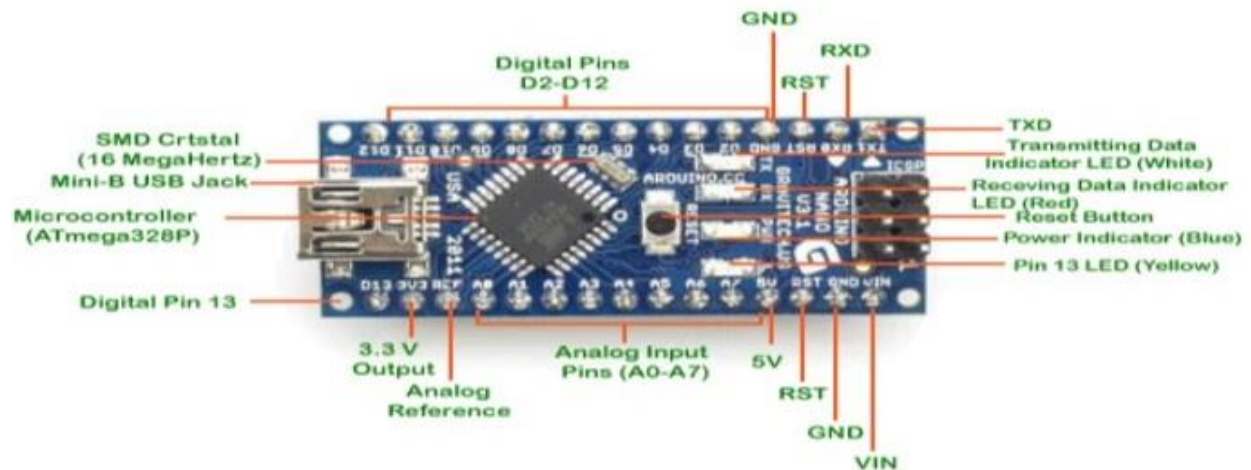


Figure 5: Pin Configuration of Arduino Nano

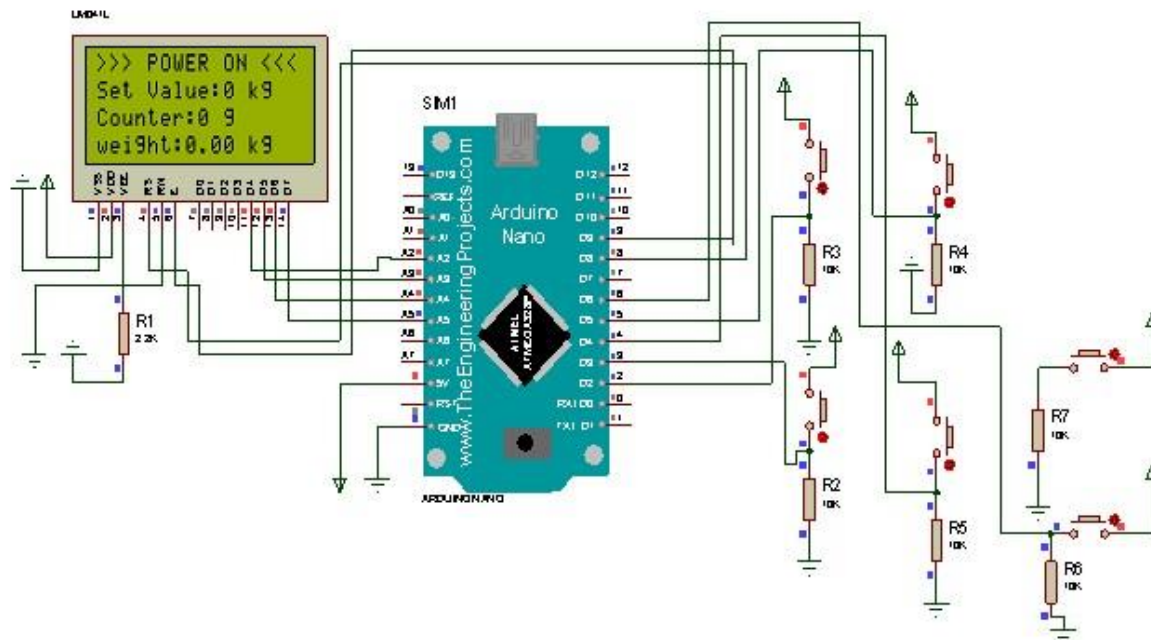


Figure 6: Circuit diagram of Arduino Nano device



#### 2.1.4. Liquid Crystal Display (LCD)

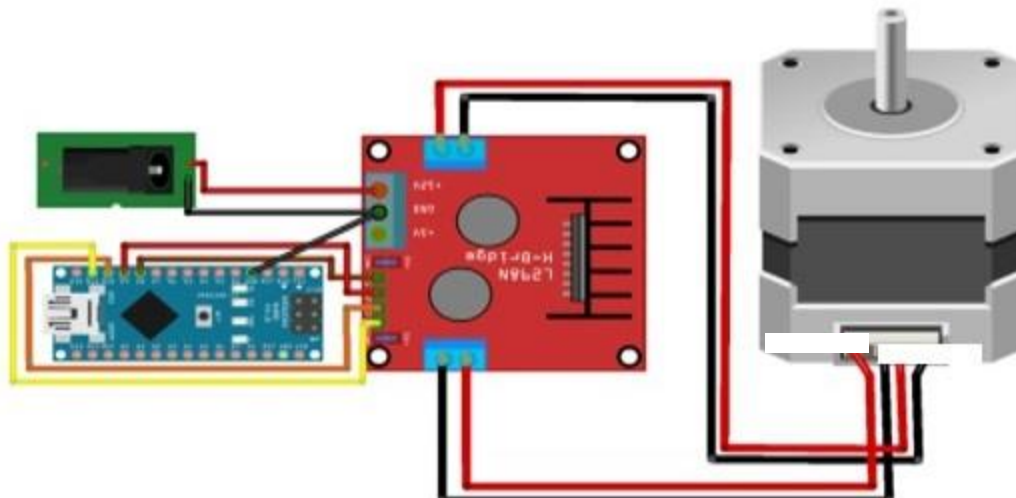
It is an electronic display module used in an extensive range of applications like mobile phones, calculators, computers, Television sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes (LED). The reason for using this module in this work was because it was inexpensive, easy to program, animations were possible, and there were no limitations on the display of custom characters. Table I presents the pin number description of the LCD circuit diagram of the Arduino Nano device shown in Figure 6.

**Table I:** Pin connection description of the LCD circuit diagram

Pin No	Symbol	Description
1	V <sub>SS</sub>	Gnd
2	V <sub>DD</sub>	V <sub>CC</sub>
3	V <sub>0</sub>	Through 1 k resistor to Gnd
4	RS	Arduino digital pin 8
5	RW	Gnd
6	E	Arduino digital pin 9
11	D <sub>4</sub>	Arduino analog pin A <sub>2</sub>
12	D <sub>5</sub>	Arduino analog pin A <sub>3</sub>
13	D <sub>6</sub>	Arduino analog pin A <sub>4</sub>
14	D <sub>7</sub>	Arduino analog pin A <sub>5</sub>
15	A	Gnd
16	K	Through 1k resistor to V <sub>CC</sub>

#### 2.1.5. Stepper motor and driver

The stepper motor used in this work is NEMA17 and the Driver is L298N. This driver board is usually used to control DC motors, but it was an economical alternative to control stepper motors. It can control both the speed and the spinning direction of most stepper motors like a NEMA 17 (this was why it was employed in this work). The L298N Motor Driver Board was built around the L298 dual full-bridge driver, made by STMicroelectronics. With this motor driver you can control DC motors, stepper motors, relays, and solenoids. It came with two separate channels, called A and B, that can be used to drive two (2) DC motors, or one (1) stepper motor when combined. The L298N was mounted on a (red) breakout board, which made wiring a lot easier. The breakout board included a 78M05 5 V power regulator. Figure 7 shows the connection of NEMA 17 stepper motor and L298 driver with the Arduino Nano device.



**Figure 7:** Circuit connection of stepper motor and L298 driver with Arduino Nano device

## 2.2. Methods

The equipment is based on microcontroller and load cell. A program was developed to interface the Analogue to Digital Converter (ADC) with the microcontroller to implement the analogue to digital conversion. In addition, a signal conditioning circuitry was designed and built for the load cell output. The weighing equipment consists of a hopper which is used to store the material (powder) for dispensing. The input was carried out with buttons and the corresponding values displayed on the LCD screen. The filling process was controlled by the use of stepper motors. The stepper motor was used because of stable speed control (with fluctuating load) and constant torque (over a range of speed). The contents dispensed from the hopper filled the holding container (This was corroborated by the work published by Abdallah and Elmessery, 2018).

The weighing and filling equipment was powered by a single phase, 220 V – 230 V A.C power supply. It was operated either with a single phase generator or from a mains supply. The frame was rectangular in shape and was made from a 3.0 mm thick steel. It has a dimension of 914.4 mm (3 ft) height and 304.8 mm (1 ft) wide. The frame is the main body of the equipment which supports other parts. It has a base sitter where the load cell and stepper were mounted. Under this sitter, LEDs were installed to give light to the base sitter. While at the top of the frame, the hopper, LCD, buttons and indicator LEDs were mounted.

The design, construction and testing of a weighing equipment for powdered food products in a country such as Nigeria cost Forty-eight Thousand Naira (N48,000.00). This is about One Hundred and Fifteen US dollars (\$103.98) as at March 2023 (from oanda.com website).

## 2.3. Principle of Operation of the Developed Equipment

When the switch was turned on, the system displayed some basic function on the liquid crystal display (LCD). The equipment continued to boot until the fan, proximity sensor, the base light and the load cell were ready for use. After this process, the stepper motor was turned on and off and then operations such as set value, counter and the current Weight was carried out. It is important to note that before the value was set, the product (powder) was already loaded in the Hopper. The set value was in kilogram (kg), but the counter was in gram (g) and the overall

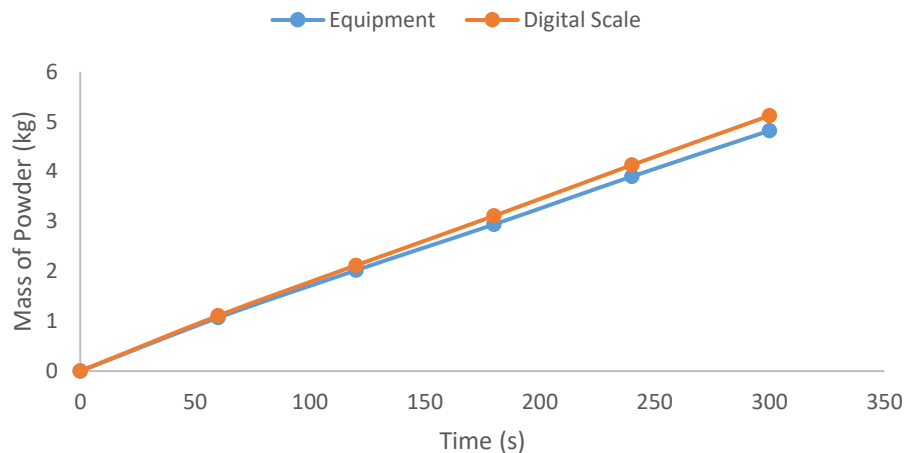
weight was in kilogram (kg). When the set value was put at 1.00 kg (1000g) and the start key was pressed/activated, the equipment checked if there was a container positioned to receive the product. When a container was not available, the equipment did not execute the required operation until a container was made available. Furthermore, when a container was positioned and the start button was pressed, the filling process was engaged by turning on the stepper motor. At this time, the counter value began to increase, indicating that the equipment was working. The filling process stopped when the set value of 1.00 kg was reached, and the counter value was at 1000 g. Therefore, the overall weight of the product measured was 1.00 kg. This process was repeated for other weight ranges and resulting product compared with a digital scale.

### 3. Results and Discussion

The results from the developed equipment are presented in Section 3.1.

#### 3.1. Effect of Powder filling on the weighing system

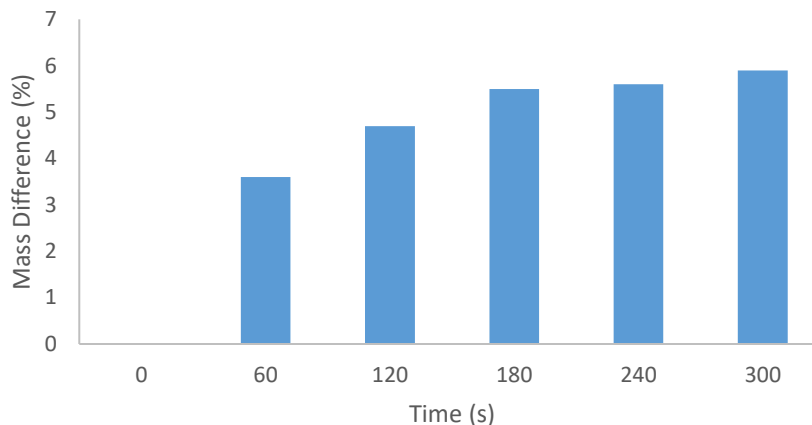
The mass (kg) of a powder was weighed by the developed equipment and recorded at different time intervals. While the corresponding powder product weighed from the developed equipment was weighed by a digital scale and recorded accordingly. Figure 8, presents the plot of the powder mass (kg) at different time (s) intervals for both the developed weighing equipment and digital scale.



**Figure 8:** A graph of mass of powder (kg) against time (s)

It is observed that at 300 s, a mass of 4.82 kg of the powder was measured by the developed weighing equipment. When the corresponding powder product was weighed by a digital scale, the reading given was 5.12 kg. This gives a percentage difference of 5.9%, meaning that the accuracy of the weighing systems is about 94.1 %. The implication of this result is that, for every 4.82 kg of powder weighed by the developed equipment there is a savings of about 0.30 kg. Further analysis shows that there is a linear relationship between the mass of the powder weighed and the time it takes to weigh the powder. The average percentage difference from the data analysed is given as 5.06% (or 94.94% average accuracy). This is an average savings of about 0.150 kg of powder by the developed weighing equipment. The percentage of the mass difference between the digital scale and the developed weighing equipment is presented in Figure 9.





**Figure 9:** A graph of mass difference in percentage at various time intervals

It is observed that as the time increases the percentage difference increases. Meaning that, the longer the developed weighing equipment is put in use, the increase in powder savings. In addition, the percentage difference is quite minimal and the developed weighing equipment can be said to have approximately 95% accuracy on the average. This device will be valuable to small scale businesses in third world countries.

#### 4. Conclusion

Low cost weighing equipment which can be used for filling and weighing was developed. The operation of this equipment is simple and the chance of error in weight calculation is significantly reduced to about 5.06%. Therefore, the effort required for the manual weighing and filling is highly minimized. Weight calculation is done using the load cell. The task the operator has to perform is to give the input value and collect the container/bag after the process is concluded. The developed equipment has an average accuracy of approximately 95%. The developed weighing equipment will be beneficial to small scale businesses in third world countries.

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