Performance Evaluation of an Automatic Monitoring Device Developed for Grain Storage

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Abstract- Grains are rich sources of carbohydrates, proteins, fibres and oil. These components form daily constituents man in human diets and animal feed. Nigeria is one of the largest producers of grain crops in Africa, though, more than 60% of this is lost due to postharvest processing, whereas inadequate storage structures and inappropriate storage techniques cause about 45% damage to the produce. In Nigeria, huge losses occur in grains during storage based on traditional and intermediate methods being use, and the few modern structures used by the public sector are poorly managed. In order to reduce these losses, this study developed an automatic grain storage device which would monitor internal temperature and relative humidity of stored grains. The components of the storage monitoring device (SMD) including; temperature and humidity sensors, buck converters, Node MCU, Arduino IDE, H-bridge and fan were soldered and connected to perform the expected function. Readings from the SMD revealed that during storage, average temperature and relative humidity measured 34.4 °C and 63% respectively. A total weight loss of 4.1 kg (3.2%) at average moisture content of 13% was experienced. 2.3 kg and 1.8 kg of the entire weight loss were due to drop in moisture content and insect infestation respectively. The device was found to be effective because the slightest variations in parameters measured were indicative of the sensitivity and efficiency of the device.

Keywords- Grain, storage, temperature, moisture content, automatic device

1 INTRODUCTION

Production of grain crops has been on the increase over the years due to technological advancements such as improved seed variety, machine intelligence and irrigation facilities. In spite of the aforementioned government efforts, varying degree of losses caused by heat production and high moisture generated during grain respiration are on the increase (Ashok and Shakunthala, 2018; Olorunfemi et al., 2016). Nigeria produces approximately 2.85% of world legumes, Adesina (2019), and about 60 - 70% of the produce are stored by traditional method based on the immediate need of the farmers (Kartikeyan et al., 2009). While the remaining 30% is transferred to structures for safe keep, others are sold as the need arises (Adejumo and Raji, 2007; Ililiyasu et al., 2013).

During grain storage, high postharvest losses are incurred due to inadequate processing facilities and environmental factors type of storage structure, temperature, pH, moisture, relative humidity and others (Ililiyasu et al., 2013). Postharvest grain losses are of great concern to farmers because this often discouraged large scale investment in grain production (Olorunfemi et al., 2016). Reports show that annually, about 2.4 billion tonnes of foods, estimated at 2868 billion are lost due to inappropriate and inefficient harvesting and storage facilities (Adejumo and Raji, 2007). In order to reduce the huge postharvest losses, modern storage that uses scientific and technological innovations are required. For proper monitoring of moisture content and temperature within the storage structure (Bayode et al., 2018). As a result of these short comings, an automatic grain storage monitoring device (SMD) capable of regulating the temperature regime and relative humidity within the storage facilities was developed in the present study. In addition, the SMD would ensure appropriate gaseous exchange and also enhance digital monitoring at any location.

Bayode et al. (2018) developed a computer-aided management system which minimizes post-harvest grain losses at the storage level in Nigeria. The software designed has an interface which uses Dreamweaver 8 coded with Pre-processor Hypertext Programme (PHP) code and Database retrieved using MySQL was developed to handle all activities of grain storage validated as a case study silo complex. Average daily temperature and moisture content of the stored produce collected and computed for monitoring showed that the software saved 66% time when compared with manual operation.

In a related study, Olorunfemi et al. (2016), also performed similar operation using computer aided grain aeration management. Materials used included, temperature sensors, silo bins, probes, and fans. Temperature sensors were installed inside the silo bins at different sections. Mean daily temperatures were taken in the morning and evening and aeration systems were programmed to work at 5 hours intervals. During the study, maximum grain temperature (45°C) recorded was cooled down to 25°C by the aeration system. A comparative study was done between computer aided silo monitored and the manual silo, results revealed that postharvest grain loss during silo storage was reduced to < 1% from 5% allowable level. The power requirement increases as air flow rate and grain depth increased and aeration can be better monitored economically with the use of a computer system.

2 MATERIALS AND METHODS

The conceptual design of the grain monitoring device was sketched and the circuit diagram developed using Fritzing 2016 software, Version 0.9.3 as shown in Figure 1. A schematic diagram of integrated circuits, buck converter, breadboard, grain moisture content probe and module, Node MCU, DHT22, and Fan were soldered together and arranged on a circuit board as presented in Figure 2. The jack plug received 12V from the power source, and was stepped down to 5V using the buck
converter; the required voltage for effective performance of Node MCU.

The Node MCU positioned on the breadboard and all other components by receiving and sending signals within the hardware and software when connected to the internet. Arduino IDE was used to program (sketch) the microcontroller. Signals received from moisture content probe is sent to the grain moisture content module and then pass through the Node MCU for processing. The Digital Humidity and Temperature sensors (DHT22) outputs received in respect of the two environmental factors being monitored inside storage structure would send signals to the H-bridge which will automatically on the fan and state the direction of rotation.

4 PERFORMANCE EVALUATION

The efficiency of the storage monitoring device developed for the present study was evaluated using cowpea as test produce. A hermetic storage structure was adopted using an airtight bucket container and the device was connected to the container. Samples of cowpea (Sampea 8) was purchased at Giwa market in Zaria, Kaduna state during the month of February, 2020. The grains were sorted on the laboratory slab, filled into the bucket and the initial moisture content measured using Foss Infratec™ 1241. The set up was covered tightly to assume airtight before fixing the device. The filled storage structure was then weighed using a weighing scale and the initial weight was 128.2 kg before it was then stored at room temperature for 6 weeks. At one-week interval, weights, storage temperature and relative humidity were measured and recorded. The final moisture content and postharvest losses or damages to grains were also logged.

5 RESULTS AND DISCUSSION

5.1 RESULTS

The device was tested using cowpea stored at domestic level and ambient environment. Results obtained are presented in Table 1.

| Week | Weight (kg) | Temp. (°C) | RH (%) | Initial MC (%) | Final MC (%) | Postharvest Losses | Damaged Weight (kg) |
|------|-------------|------------|--------|----------------|--------------|--------------------|---------------------|
| 1    | 128.2       | 33.7       | 60     | 14             | -            | -                  | -                   |
| 2    | 128.2       | 34.2       | 62     | -              | -            | -                  | -                   |
| 3    | 127.1       | 34.6       | 63     | -              | -            | -                  | -                   |
| 4    | 126.4       | 34.8       | 64     | -              | -            | -                  | -                   |
| 5    | 125.6       | 35.1       | 65     | -              | -            | -                  | -                   |
| 6    | 124.1       | 35.1       | 65     | 12             | 1.8          | -                  | -                   |

As observed from the Table 1, the moisture content of the stored grain reduced from 14% to 12% and there was percentage weight loss of 3.2% during storage. Obvious losses in the grain weight occurred between weeks 3, 4, 5 and 6. A total weight loss of 4.1 kg (3.2%) was experienced within the 6 weeks of storage. Aside weight loss due to moisture content, postharvest losses was also measured using the quantity of grains infected by insects during storage. Out of the 4.1 kg weight loss recorded during storage, 1.8 kg was due to insect infestation after sorting. An increase in temperature and relative humidity was experienced during the 6 weeks storage duration. The mean temperature increase was 1.4°C and relative humidity varies between 60 – 65%.
5.2 DISCUSSIONS
Weight loss during storage could be attributed to loss in moisture content and insect infestation. This result is in agreement with the studies of Likhayo et al. (2018) who noticed that factors such as temperature, moisture content, uncontrolled oxygen within the storage structure could cause weight loss during grain storage. Contrary to Iliyasu et al. (2013), the results on weight loss caused by insect infestation was found to be negated by the earlier studies of the authors who stated that if hermetic conditions are applicable, insect infestation should be insignificant.

Mean daily temperature increase was arrogated to grain respiration during storage resulting in heat built up inside the storage structure. The quantity of heat generated due to respiration is largely dependent on the storage moisture content. High moisture content at storage inception result in high respiration rate and high temperature. Continuous increase in storage temperature results in formation of water droplets within the walls of the storage structure, hence, increasing the relative humidity and encouraging mould growth. Studies of Sawant et al. (2012) was found to be in consonance with this observation. Control of excessive temperature during storage, especially prolonged storage was addressed with the fan attached to the storage monitoring device that expels the heated air inside the structure. Change in relative humidity during storage was confirmed in the studies of Volenik et al. (2007) and Coradi et al. (2014) that relative humidity within a storage environment could either increase or decrease depending on the weather condition during which the produce is stored.

6 CONCLUSION
The storage monitoring device developed effectively performed its intended functions. The temperature and relative humidity measured during storage ranges between 33.7 – 35.1 °C and 60 – 65% respectively. The stored grain was observed to have a percentage weight loss of 3.2% during storage at average moisture content of 13%. The performance evaluation shows that it can be utilized on larger storage structures like silos and performed its intended functions. The device is simple, easy to install, require less technical know-how and relatively economical when compared to storage losses experienced in grain management in Nigeria.

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