DEVELOPMENT OF COMPUTER-AIDED MANAGEMENT SYSTEM FOR MONITORING GRAINS STORED IN METAL SILOS

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Abstract
Traditional methods of managing grain have not guaranteed against grain losses, instead losses ranges from 20-50 %. In this vein, this study engages a computer based system for monitoring stored grains in metal silos. For the study, functions were formulated to measure weight, deterioration index, temperature, laboratory parameters, and moisture for grain samples. Standards were formulated for quality of grain to be accepted into the silo bins and stock index per silo. Coding instructions were set with a high level programming language using Dreamweaver platform and structural query language as database management system. The standard storage parameters for the different grains applied were; moisture content (≤ 12 %), insect damage (≤ 1 %), mould damage (≤ 1 %), hectolitre weight (68-75 kg/hl), colouration (normal), foreign matter (≤ 1 %) and year of harvest (≤ 1 year). Test samples of the stored grain were monitored and analysed at one of the National metal silo complexes using the developed package. The results obtained showed that total grain loss would be less than 1 %. There would be timely decision that saves cost, deter moulding and its antecedent losses. It is expected that the software developed will assist in good data management for grain storage to facilitate little or no grain losses during storage.

Keywords: aeration, losses, management, temperature, moisture

Introduction
The vision in the transformation strategy of the present government in Nigeria is to achieve hunger-free nation through agricultural sector that drives income growth, accelerates achievement of food and nutritional sector, generates employment and transforms Nigeria into a leading player in global food markets to wealth for millions of farmers (Agricultural Transformation Agenda (ATA), 2012). Nigeria has huge agricultural potential. It has 84 million hectares (ha) of arable land of which only 40 per cent is cultivated, it has 279 billion cubic meters of water and a population of over 167 million people being the most populous country in Africa (Akinwumi, 2013). Though the rate of world population growth is slowing down among the continents of the world, Africa leads with a 10-year growth rate between 2000 and 2010 of 26.1 per cent. Also, among the ten most populous nations in the world, Nigeria leads with a 10-year population growth of 26.8 per cent (Mbata, 2013).

According to the International Food Policy Research Institute, the value of agriculture in Nigeria at constant 2010 dollars was 99 billion dollars and this is projected to grow to 256 billion dollars by 2030 (Akinwumi, 2013). The Nigeria’s farm production efforts still have to be matched with adequate attention on storage, marketing and distribution. In this context, any effort at increasing agricultural production must be matched with equal if not greater efforts at producing adequate and efficient storage facilities and good management, in order to ensure availability
of food materials at relatively stable prices throughout the year, both for domestic consumption and for export (Maier et al, 2002; Igbeka, 2013; Olorunfemi et al, 2018). Moisture is one of the primary factors that affect the rate of grain spoilage in storage (Suleiman, 2013). Grain spoilage increases with moisture due to increase in grain respiration. The effect of moisture is exponential as the temperature of the stored grain environment increases. In the same vein, conditions for the optimum growth of storage moulds must be controlled by ensuring that the grain moisture content (interstitial water activity-a_w) is low at low relative humidity (< 65 %), temperature (< 10 °C), and that, the kernel should be intact with less damage and dusts (Ileleji et al, 2007; Olorunfemi et al, 2016). This work therefore aimed at introducing computer facilities through the use of computer data storage and monitoring system to determine early when spoilage sets in and need for preventive measures, as an effective way to avoid economic losses during grain storage.

Materials and Method

Personal visits were made to some of the locations of the National Strategic Grain Reserves Silo Complexes of the Federal Ministry of Agriculture and Rural Development of Nigeria, to obtain first-hand information about the prospects, problems and other essential challenges that were present.

Development of Parameter flow chart

Appendix 1 shows the flow chart of all the parameters that were considered to be important for good grain stock monitoring procedures. This is what dictates the processes of the software developed. There is no specific percentage for storage loss but the declared loss should be within acceptable levels based on established local conditions. Factors which largely contribute to storage loss are grain shrinkage and insect infestation. Shrinkage refers to loss in volume and in weight of grain placed in the bin and the loss is basically due to grain moisture reduction and respiration leading to dry matter losses.

Determination of weight loss

The weight loss can be calculated by volumetric method using bulk density apparatus (M’Avung’ana, 2005). The idea is that a weight loss can be measured by comparing the weights of standard volume of damaged and undamaged grain. It involves separating the grains into damaged and undamaged fractions. After measuring the weight and volume occupied by each fraction, the litre weight of each was calculated. The percentage weight loss was then calculated using Equation 1,

\[
\% \text{ Wt loss} = \frac{(W_d-W_u) \times 100}{W_u \times L_u \times L_d} \times 100
\]  

Where, \(W_u\) = Weight (m\(^3\)) of undamaged grains \\
\(L_u\) = Volume (litre) of undamaged grains \\
\(L_d\) = Vol. (litre) of damaged grains

Determination of grain deterioration

Grain deterioration has been defined as the measure of carbon dioxide-CO\(_2\) evolved by the grain (Igbeka, 1983). The process of grain deterioration is primarily driven by aerobic respiration of fungi as they consume carbohydrates in the kernel releasing off CO\(_2\), water-H\(_2\)O and heat. The complete consumption of a typical carbohydrate- \(C_6H_{12}O_6\) in aerobic condition is represented by Equation 2 (Ileleji, 2012);

\[
C_6H_{12}O_6 + 6O_2 = 6CO_2 + H_2O + \text{Heat (2820 KJ per 180 gm of } C_6H_{12}O_6) \]

Mathematically, the \(CO_2\) production is defined as Equation 3 [13];
Log \((CO_2) = AM - B\) \hspace{1cm} (3)

Where \(CO_2\) is per 100g dry matter
M is % moisture content, wet basis
A and B are grain constants (Table 1)

**Table 1. Constants A and B for Equation. 5 as adapted (Igbeka, 1994).**

<table>
<thead>
<tr>
<th>Grain Type</th>
<th>Moisture Range % Wb</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>10.0 - 13.2</td>
<td>0.17</td>
<td>2.00</td>
</tr>
<tr>
<td>Sorghum</td>
<td>10.0 - 13.2</td>
<td>0.12</td>
<td>1.65</td>
</tr>
<tr>
<td>Rough Rice</td>
<td>10.0 - 13.2</td>
<td>0.21</td>
<td>3.04</td>
</tr>
<tr>
<td>Brown Rice</td>
<td>10.0 - 13.7</td>
<td>0.17</td>
<td>2.67</td>
</tr>
<tr>
<td>Polished Rice</td>
<td>10.0 - 14.1</td>
<td>0.16</td>
<td>2.83</td>
</tr>
<tr>
<td>Wheat, Soft</td>
<td>10.0 - 14.0</td>
<td>0.09</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td>14.1 - 17.0</td>
<td>0.36</td>
<td>5.14</td>
</tr>
</tbody>
</table>

Combining equations 4 and 5 will give the dry matter loss, water generated and heat. The result also showed that 1 kg of CO\(_2\) gives 10680 KJ of heat, 0.909 kg of water and 0.682 kg of dry matter loss.

**Determination of moisture equilibrium**

Equilibrium Moisture Content (EMC) is the moisture content of a product at which it is in equilibrium with its environmental factors, particularly relative humidity and ambient temperature (Equation 1). According to Igbeka (1994) and Olorunfemi et al. (2016),

\[1 - RH = EXP(-KTm^n)\] \hspace{1cm} (4)

Where, RH is Relative Humidity
T is Temperature
K, m, n are constants

**Introduction of Insect/Pest Monitoring Devices**

Insects, rodents and mites cause direct weight losses by their use of the commodity as a food source. Further loss may be caused by their effects on the quality of the commodity which leads to reduction of value of the product. Insect damage in a stored grain ecosystem depends on initial insect pest infestation, grain nutritional value, grain moisture, moulds, presence of predatory insect, and the stored grain environment. The physiological formation of most common insects varies from one to another. Red flour beetles require damaged seeds for them to strive. Bean weevils will feed on most on peas, cowpeas, lentils and other legumes, lesser grain borers could feed on a variety of foods, mainly cereals, beans, and chick-peas. As reported, the optimum temperature for the proliferation of an average insect is between 25-30 \(^\circ\)C while the optimum breeding relative humidity range is between 60 to 80 per cent (this is equivalent to the grain moisture content of 13-15 %).

Population of insect detection is necessary to be able to assess the presence or absence of insect, but more importantly monitoring provides a measurement of the population that may be useful for an Integrated Pest Management System (Use
of all available knowledge or methods to keep pest populations below economically damaging levels in a manner that is profitable and causes no harm to human health and the environment. Usually two or more live insects injurious to grain results in the special grade of infestation and can lower the value of the grain. Insect Damaged Kernels (IDK). For example, 32 or more IDK per 100 g results in “sample grade”. “Sample grade” means unfit for human consumption which significantly lowers the value of the grain (Opit, 2013; Bosomtwe et al, 2019).

Determinant of monthly laboratory parameters
The determination of the parameters utilised in the analysis of grain samples in the laboratory before decision was taken on whether the consignment should be accepted or rejected are implied in Equations (5) to (9) (Olorunfemi. et al, 2016);

\[
\text{Foreign matter} \% = \frac{\text{wt of foreign matter in the sample}}{\text{Total wt of sample}} \times 100
\]

\[
\text{Insect damage percentage} \% = \frac{\text{wt of insect damaged grain in the sample}}{\text{Total wt of sample}} \times 100
\]

\[
\text{Mould damaged percentage} \% = \frac{\text{wt of mould damaged grain in the sample}}{\text{Total wt of sample}} \times 100
\]

\[
\text{Broken grain percentage} \% = \frac{\text{wt of broken grain in the sample}}{\text{Total wt of sample}} \times 100
\]

\[
\text{Hectolitre weight} \% = \frac{\text{weight of grains in the cylinder}}{\text{Volume of the cylinder}} \times 100
\]

Development of computer-aided software for monitoring of stored grain
Computer-aided monitoring (CAM) is the integration of computers into the management and production process to improve productivity. It is the technology concerned with the use of digital computers to perform certain functions in design and productivity (Adejuyigbe, 2010; Opit, 2013).

The computer software was designed for a comprehensive Grain Stock Management System (GSMS) to handle all transactions and activities at grain storage; this was validated at the national silo location. Daily temperature and moisture content of the stored grains were obtained and computed as indicators for daily and timely aeration, and grain movement (Krishramurthy, 2005; Olorunfemi, 2015). The software developed has three major sections: the front-end (Graphical/user interface) which the user interacts with, this section was developed using Dreamweaver 8, the middle-end (coding section) was developed using Pre-processor Hypertext (PHP) code, and the back-end (database) was developed using high Structured Query language program (MySQL). The algorithm utilized followed the following procedures:

1. Set storage = 0
2. Initial grainrequest
3. If grainrequest > 0, then
4. Storage = storage + grainrequest
5. Else
6. Set storage = full
7. Repeat 3
8. stop

The algorithm used has been summarised into the flow chart presented in Figure 2.

Results and Discussion
Grain storage and monitoring system was developed. The software was built to manage the day to day transactions at the storage silos location. It records supplies,
releases and losses based on shrinkages, stock monitoring, and other events capable of contributing to stock level. It indicates the balance stock after every monthly deduction in weight is made. Before the grains are received into the metal silo, storage parameters must be met; ≤ 1% broken grain, ≤ 1% of foreign matter content, ≤ 12% moisture content, ≤ 1% mould damage, 68-75 kg/Hl hecatolitre weight, no colouration, and age of less than one year. The results of laboratory analysis were entered. Example of a report generated for a consignment supplied and computed with software is shown in Figure 1.

Table 5 shows the result sheet of grain supplied, ‘accepted’ or ‘rejected’. Immediately the data generated from laboratory analysis are entered on the page, these data are processed and the software indicates if the consignment met standard acceptable parameters.

Table 5 Display of saved data in database of laboratory results

Grain management flow chart, Figure 2 indicated the process followed for stock monitoring program to be followed.

Figure 1 (a & b). Registered goods supplied with contract number 1556
The goods registration login page contains the following links: Add Goods, Change Password, and Logout. This is where all the users log in with their assigned user’s name and password.

![Silo Operations Management System](image)

Figure 4. Goods Registration Page

Figure 4 interface was where all the suppliers are registered. For example, after registration, the manager will confirm if the name of supplier corresponds with the list from coordinating center. Before getting to this page, the user must have been assigned password and unique username to avoid mix-up in the bio-data. Once the good meet the requirements, the confirmation beams with the caption “confirm”. Then the truck will be allowed to come into the silo complex or warehouse for offloading. But at the initial, once the good supply is registered, it will appear in the administrative page as “not confirm”. A contract number would be awarded automatically. This number cannot be erased or changed.

Table 6 shows the list of grain goods that were received with detailed of contract number, date of reception, Driver’s name and truck number. It also indicated the type of goods, the remark on its acceptability, and the officer who took delivery of the goods.

Figure 3. Goods Registration Login Page

![Flow chart](image)

Figure 2. Flow chart developed for computer-aided stock management of stored grain in metal silo

Monitoring begins at the entrance of supplied grains into the storage location. Goods registration login page interface (Figure 3) is the login page where the user enters his name and password. The administrative page contains the following links: Laboratory Analysis, Admin Area, and Logout.
Table 6. List of registered goods at arrival as generated by the software

<table>
<thead>
<tr>
<th>S.N</th>
<th>Vehicle</th>
<th>Driver</th>
<th>Reg. No.</th>
<th>Quantity</th>
<th>Officer</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Omega</td>
<td>Sunday</td>
<td>2013</td>
<td>21.44</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>2</td>
<td>abina</td>
<td>Sunday</td>
<td>2013</td>
<td>20.52</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>3</td>
<td>Sunday</td>
<td>Holiday</td>
<td>2013</td>
<td>17.13</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>4</td>
<td>Ilokoro</td>
<td>Holiday</td>
<td>2013</td>
<td>31.06</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>5</td>
<td>Abere</td>
<td>Holiday</td>
<td>2013</td>
<td>21.44</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>6</td>
<td>Omega</td>
<td>Holiday</td>
<td>2013</td>
<td>21.44</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>7</td>
<td>Uwara</td>
<td>Holiday</td>
<td>2013</td>
<td>20.02</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>8</td>
<td>Ikolo</td>
<td>Holiday</td>
<td>2013</td>
<td>24.03</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>9</td>
<td>Oyo</td>
<td>Holiday</td>
<td>2013</td>
<td>30</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>10</td>
<td>Oyo</td>
<td>Holiday</td>
<td>2013</td>
<td>30</td>
<td>Ayeni A</td>
<td>ACCEPTED</td>
</tr>
</tbody>
</table>

Figure 5 is the monthly management interface. This is the page where all data obtained for each silo samples are entered. The results obtained would be compared with the previous month in order to determine if the grain in stock is deteriorating or otherwise.

Figure 6. Monthly report page

The temperature readings of a given silo were taking every day or regularly (Figure 7). The silo number was selected by the user and the date of the year would be entered to ensure proper monitoring. If it is found that any silo shows increase in temperature of 0.5 °C or abnormal spot increment, aeration should be done. The interface for temperature readings showed the values generated from data saved and indicated when to aerate as soon as the temperature exceeds the ideal temperature.

Previous works showed that monitoring of the records of temperature readings would make operators to achieve better pest control by adjusting bin temperature. Hence to prevent insect movement temperatures should be lower than 45 °F and to prevent insect multiplication temperature should be lower than 59 °F (Olorunfemi et al. 2018). The stock adjustment form page (Figure 8) allows regular updating of stock; this is “temperature readings”, it also features the basic interface menu of the software such as grain delivery, stock adjustment, and so on.

On the clicking of the run icon (Generate report) in Figure 5, the main program interface/ dialog box pops up by which operations are performed, it features the basic interface menu of the software as shown in Figure 6, with about five sub-menu buttons such as: “view registered goods”, “monthly stock update” “lab test”
necessitated as a result of insect infestation, shrinkage, moulding, theft, possibility of weight loss. The manager at the station or desk officer at the headquarters is allowed to adjust the total grain stock but approval must be given.

This provides linkage for different consignment of grains and the number of silo where they are stored (Figure 9).

Figure 7. Monthly temperature readings monitored with computer-aided management

Figure 8. Monthly stock adjustment page

The entire stock can be monitored through the stock monitoring page. It

Figure 9. Silo monitoring management page

Temperature cables could provide valuable information for isolated spots inside grain bins, especially where handheld grain sampling probe cannot collect samples and temperature probes could not penetrate the grain bulk. Daily record of temperature reading makes the users to be on their toes whenever the readings fluctuate sharply from the expected range. Thorough manual inspections provide valuable information about the quality of stored grain near the surface but have severe limitations in deeper regions of the bin unless a vacuum probe is used. The officer assigned must daily read and record the temperatures on this prescribed page so that management could be kept abreast of the temperature-condition of the stored grain. If it is found that any silo showed a variation in temperature of 1 - 2 °C, aeration is suggested. When it is observed that there are temperature increases rapidly by more than 2 °C, the entire stock in the silo cell must be recycled. Sufficient exposure to different temperature and relative humidity would dry grain to the moisture as indicate. Experience has proved that stored grain moisture decreases with increase air temperature.
Aeration is the stored grain management technique of forcing cool air at low airflow rate through the mass in order to equalize the grain temperature and in the process effect cooling. Growth of insects, mites, moulds and other microbes are at their highest levels in the 68 °F – 95 °F range. Monitoring of the records of temperature readings would make operators to achieve better pest control by adjusting bin temperature. Hence to prevent insect movement temperatures should be lower than 45 °F and to prevent insect multiplication temperature should be lower than 59 °F.

The storage management page is where the administrator would load each silo with a specific grain. The officer must supply his name, then select the silo and enter the quantity of grain to be sent in tons. The date must be entered along with the contract number of the supplier to ensure proper monitoring and accuracy. The storage management page consists of the following page; silo number, type of grain, name of officer, and month of the year. The temperature reading of a given silo is taken every day. The Silo number will be selected by the user and the date of the year will be entered to ensure, proper monitoring. The plant operator must daily read and record the temperatures on this page for interpretation by the manager in charge. If it is found that any silo shows increase in the temperature of 0.5°C or abnormal spot increment, aeration should be done. Temperature reading daily will expose timely any deterioration spots and grain condition at various levels within the bin.

Conclusion

The results obtained from the software indicate a very wide margin of advantages over the error-prone manual recording of data. This work had indicated how avoidable losses that have characterised the grain storage industry could be overcome. The data already entered is safe and accurate. There is security and access control. Search allows for record querying based on user chosen parameter, records can be printed at the storage location, any of the other branches, and even at the Headquarters concurrently.

References


