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Integrated Bulk Grain Management (IBGM) in Metallic Silos in the Tropics

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Abstract*—Bulk storage of grains in metallic silos is one of the biggest milestones in technological development in the area of crop processing and storage. This is due to the storage capacities it can afford, and its ability to reduce enormous post-harvest/storage losses recorded over the years in this area, especially in the developing countries. As the most popular way of storing grains in commercial quantity worldwide, a wide range of grains, cereals, pulses and paddy crops could be stored in metallic silos. Grains stored in metallic silos could be consumed directly by man, sold to make financial gains, used as seed if the sources and species are known, and could be processed into a wide range of confectioneries/food for human and animal consumption. In bulk grain storage in metallic silos, there is always a continuous interaction between the grains which are dormant but alife, and the environment (stored grain ecosystem) which is expected to facilitate the degeneration of quality and mass of the stored grains, especially over a period. These losses are naturally associated with, moisture migration and condensation, insect/ pest activities, handling losses, mould and seepage losses. However, a good knowledge of the stored grain eco-system in a non sealed storage, and proper manipulation of grain storage variables/ parameters, will no doubt lead to a good and successful storage with minimal storage losses. Since the quality of grains stored, cannot get better in storage, but can only be maintained, it buttresses the importance of storing high quality grains by all standards. The aim and objective of this work is to review the different management practices that make up the Integrated Bulk Grains Management of grains (IBGM) in metallic silos especially in the tropics. The various management practices that made (IBGM) such as, Grain reception, Gain management, Grain releases exercise, and workers health and safety will be extensively reviewed, with a view to providing useful information that will help to reduce the huge storage losses recorded in the storage of grains/paddy crops in metallic silos in the tropics, to below 5%, which is the FAO recommended maximum limit for grain storage losses in metallic silos in developing countries.

Keywords*—Bulk grain handling; Grain management; metallic silo; stored grain ecosystem.

I. INTRODUCTION

Grains are small hard dry seeds varying in sizes depending the type and specie, with or without attached hull and fruit layers harvested from grain crops for human and animal use [1]. Three major types of grains include cereals, legumes and oil seeds. Grains can be whole grains, broken or refined grains. While a whole grain contains entirely the kernel namely bran, germ, and endosperm, broken or incomplete grains may fall short, but refined grain are milled grains. The behaviour of different kinds of grains in harvesting, drying, handling, processing and storage either in small quantity or in bulk, differs from one grain to the other due to individual unique intrinsic, biological, physical, mechanical, thermodynamics and aerodynamics properties they possesses [2]. Metallic silos refer to all vessels used for the storage of large quantity of granular bulk liquids/solids materials. They are normally made of metallic materials mostly from corrugated galvanized steel sheets with varying degree of zinc coating, rolled to a curve and bolted together to form a vertical cylindrical shape . The cylindrical shape bin is then anchored to a floor level ring which is fixed to a circular mass of reinforced concrete floor. A conical shaped roof of steel sheets is fastened on top of the cylinder as roof [3]. The most popular type of metallic silos in use worldwide presently is the cylindrical type with sloping roof, made from the new high performance corrugated steel sheets (z-600), with magnesium and zinc protective coatings.

Plate 1: A Silo facility. Source, [4].

The magnesium based chemical composition of this coating, makes it ten times more resistant to adverse condition than the traditional galvanized steel, because the composition of its coating has been optimized to provide resistance to adverse conditions [4]. It is also easily adapted to high volume prefabrication manufacture because

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it is relatively light in weight, impervious to vapour and requires no sealing. Metallic silos can be designed in a wide range of shapes and sizes depending on its purpose, the intended material to store and for how long. Apart from having manholes for inspection, loading and unloading facilities are important factors to be considered in metallic silo design. Its bottom shape as a factor for distinction can be flat, with or without raised platform, tapered and conical. While the later can discharge by gravity, flat bottom silos needed another form of material handling equipment for discharge, probably an auger or a conveyor [2]. Other important ancillaries that must be inculcated in design of high capacity silos to enhance efficiency includes special temperature/relative humidity monitoring and control system/devices, for efficient monitoring and control of stored grains ecosystem [5]. Others are provisions of manholes/windows, for inspection of grains and an internal ladder for accessing the grains to carry out a task. In bulk storage in metallic silos variables such as temperature, relative humidity, initial grain condition, and the integrity of the metallic structure are important, thus the success of any bulk storage of grains in metallic silos depends on how well the recommended standards for each were strictly adhered to [6]. Major problems associated with bulk storage in metallic silos includes, moisture condensation and migration, insect/pest infestation, water ingress and seepage, mould and mycotoxin. Various new innovations to better efficiency in design that tends to address some of this issue include the double wall ring silos for insulation [7]. Others are the evolution of roof extractors to remove hot air from head space, increasing corrugated pitch of galvanized steel to lower sticking of grains to silo walls, inculcation of dust filtration system/equipment in designs and increasing the capacity of aeration fans [4]

Integrated grain management in metallic silos is the act of using different grain management techniques to minimize storage losses, in bulk storage of grains. As a unit process, steps involved includes, observing sanitation, strict adherence to grain reception standards, grain management, and grain release standards which depends on the intended use. Integrated grain management in metallic silos actually stars during the reception of the grains in bulk. Since the reception of high quality grains gives a huge advantage going into storage, and insect infestation may start from the field into the storage structure, quality standard for received grains must be strictly adhered to. The harvest of grains in the grain producing areas is seasonal, normally once in a year especially in the developing countries. However, harvesting method used for a particular crop plays an important role on its storability. If the method of harvest and threshing is the type that depicts high percentage broken grain, the batch will have more tendencies to insect attack more than whole grains [8]. However, good planning ensures that grains reception is done within the shortest possible time before grains get infested and deterioration sets in. Prior to the arrival of the grains in trucks it is important to carry out comprehensive sanitation of the silo facility, servicing of all material handling equipment, lubrication of all mechanical moving parts, re-certification of all weighing equipment to be used, and the test run of all electric motors, equipment, and the entire system. Empty bins should be cleaned properly; the silos cells aeration duct/ lids, covering the pathways should be opened inside the silo. Necessary documentations regarding the exercise are also vital. The right personnel for various roles and tasks such as inspection, analysis and grading, weighing and clerical, maintenance, plant operation and security must be identified and adequately briefed and reminded of their assigned specific roles and task ahead.

II. GRAIN RECEPTION

(A) (A) Sanitation.

Comprehensive sanitation of the grain facility is a very vital aspect of integrated grain management. This involves cutting of bushes/grasses that can habour pests, cleaning of the various sections of the tunnels/pits, and the preparation of the silo cells. Others are clearing the lines, of all the material handling equipment like conveyors, elevators, discharge augers lines and chutes with grain dust from intake pit and collecting them at emergency exits of various materials handling equipment. During cleaning, any dirt, dust, or left over grains is burnt and after all the tunnels are left open for natural ventilation. The preparation of the silo cells for reception is unique. This includes the physical cleaning of the internal silo body and floor for old sticking grains and scraping of the stubborn ones. All the aeration ducts needs to be opened cleaned and the lids inspected for holes that could cause leakages of grains into the aeration duct. If detected, must be adequately blocked. Liquid insecticides may be used to spray into all the corners of the silo and concrete cracks and the silo is fumigated. The prepared silo is locked until it will be put to use, when the surface aeration lids will be closed [9]. Areas and surroundings of the silo facility must be cleared cleaned, and sprayed with insecticide or burnt. The entire compound, the pits, tunnels, work house, and the commodity warehouse must be sprayed with insecticide.

(B) Lubrication/Servicing of Equipment

The laboratory equipment for grain analysis must be calibrated, checked to ensure that it is functioning properly. Good equipment will ensure that only good grains of acceptable standard are received for storage. Uncalibarted equipment can compromise standard. All silo equipment including the reception pits, grains handling equipment, cleaners, dust collector and blowers, storage bins, temperature monitoring system, chemical dust dispenser, bagging plant, should be checked, cleaned and repaired if need be, to ensure a trouble free operation. Equipment spare parts, fuel, oil and lubricants must be sourced or, easy ways of replenishment established. All grain handling equipment such as conveyor, elevators, cleaners, sweep augers, intake pits, cyclone, and the aeration fans should be checked for wear. All their bearings and revolution parts should be checked and lubricated. It should be thorough, any weak part or links indentified should be changed before commencement of the exercise. All electric motors should be checked and test run from the control panel, to be sure it is in order. The cleaner and the aspirating unit

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should be checked and cleaned. All transmission agents like belts, chains, gears and sprocket should be checked and bad ones replaced. If electric motors are using speed reducers box or gear that contains oil, the gear oil should be gauged and if it is below the level, gear oil should be topped to the required level. The conveyor top fish plate should be opened and the entire chain joint observed and lubricated for easy movement. The elevator cups and belts are also inspected and checked for wear, bad cups or loosed belts and nuts. Any bad component should be changed or re – tightened. The sweep/discharged auger must be checked and their electric motors should be fixed and test run. The weighbridge must be lubricated if it is analog, the test point/knife edge must be in good condition, and all other parts that needed lubrication should be done. A test weight should be used in house to test for its accuracy. If it is digital type, the load cells wires and connection should be checked to avoid damage to wires that can lead to erroneous output. The load cells should be inspected and cleaned. The visual display unit and other accessories should be checked. After all, the weighbridge should be re- certified by the Department of Weigh and Measure, Federal Ministry of Commerce or the appropriate authorities and a certificate issued to the silo management. The entire electrical wiring system emanating from the generator house via the control panel to the equipment should be traced to look for rat eating up wires, bridged and damaged wires before operations. The generators should be serviced as at when due. The transformer should be checked for optimum performance. The silo cell should be re-opened for last treatment. Powdered insecticide should be used on the floor and all cracks/ corners. After all, final fumigation of the silos is carried out and the inspection window are locked and sealed finally for grain reception.

(C) Arrival of Trucks.

Before the arrival of the first truck, there should be a registration system in place for record purposes and queuing of trucks on arrival. In many silo facilities, the security department is strictly in charge of keeping such records, though other complimenting records are kept at the weighbridge and Laboratory. If a truck arrives at the silo facility with grains, preliminary checks will be carried out, to confirm the authenticity of the Award Letter for supply of grains, by the silo management. After the confirmation, the trained laboratory personnel goes into the truck to inspect and take samples of the grains for analysis.

(D) Grain Sampling/Grading

Grain sampling is the act of collection of a quantity of grains, which is assumed a representative sample of the whole grain, for the purpose of carrying out analysis. Samples are taken with grain probes, sampler or sampling spear. Primary samples are drawn from bags as many bags as possible and are properly mixed. The samples are collected with sample bags properly labeled with identification particulars such as, dates, agents/farmer/suppliers/names/products and truck numbers.

The size of the primary sample drawn depends on the size of the consignment as shown below.

Size of Consignment	Number of Bags Sampled
Less than 10 bags	Drawn from every bag
10 – 100 bags	drawn from at least 10 bags
Over 100 bags	Square root of total numbers of bags

The purpose of assessing the quality of the grain is to properly identify the grains and its homogeneity with respect to its intrinsic accurate characteristics, to check if it meets the standard. These results can be used to present a quality analysis report that could be used to grade the grain, determine price and evaluate the suitability for storage, use, or for other planning purposes. [14].

(E) Quality Standard Of Recieved Grains.

The quality assessment of grains and standard differs among organization, countries, establishment, markets and customers, all depending on the intended use. For instance, animal feed producer grain acceptable standard will defers from grains for storage. However, any kind of grain assessment are mostly based on physical/biological properties, since the quality attributes and biochemical characteristics may take several days to determine especially where destructive method of analysis are used. If non-destructive methods (ultra sound, radiographic, magnetic particle) are used, it may just take hours [1]. Such properties are size, shape, colour, hectoliters weight, density, moisture content, insect damage, broken grain and foreign matters. In many grain analysis laboratories, the samples taken are divided into portions, properly mixed and one of the samples will be used for the analysis. Apart from bulk density, moisture content and hectolitre weight, other parameters or factors are expressed as a percentage of the whole. Find below the acceptable standard for maize storage as recommended by FAO.

Table:1. Acceptable Standard for maize storage in the tropics

S/N	Parameters	Values
1	Moisture content	≥ 13%
2	Hectolitre	≥ 68-75kg/H
3	Insect damage grains	≥ 1%
4	Broken grains	≥ 1%
5	Foreign matter	≥ 1%
6	Mould infested grains	≥ 1%
7	Colour	Homogenous

Source, (14)

After the analysis, if the grain meets this standard, the trucks with the consignment proceeds to the weighbridge for weighing, otherwise the consignment will be rejected.

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(F) Weighing of Bulk Grain /Intake

There are two kinds of intake pits namely: the wet and dry intake pits. While the later is used when dry grains are received, wet intake pit can be used to receive fresh and wet grain, whereby the grains will be passed through a drier and weighed with in-line weigh before other grain reception processes. For dry intake of grains, trucks carrying consignment of accepted grains proceeds to the weighbridge for weighing. It is important that the correct quantity in weight of grain delivered is well established since it is the basis of payment. After the first weight is determined (gross weight), the truck proceeds to the dry the intake pit for discharge of the grains. A typical intake pit may take any shape, covered with a mesh with a grain transporting equipment lying beneath transporting the grains away for onward processes. However, it will be pertinent to note that at the intake pit, 100% inspection of grain is carried out, since all the bags are opened and grains are allowed to pour down freely into the reception pit. From the intake pit the grains are transported to the cleaner for cleaning, abounds the designated silo cell with the use of different grain handling equipment. When the truck is emptied, all the foreign matters accumulated, both from the intake pit, cleaner cyclone, rejected bags, empty bags, and any unwanted materials are loaded back to the truck for the second weighing. After the determination of the second weigh called (Tare) the weighing clerk computes the difference between the gross weight and the (Tare) and it becomes the weight of the grain delivered to the silo complex. The clerk also prints out a weighbridge ticket indicating the weight. A representative of the silo facility and the supplier equally sign on the ticket to authenticate it, as the agreed weight of grains delivered. Weight of grains delivered, date, the grain type, vehicle number, and driver's particulars will be boldly indicated.

(G) Grain Cleaning/ Transport Of Grains To Designated Silos

. It will be vital to note that the energizing sequence of equipment is such that the last equipment /machines needs to be energized first, and in that sequence till the first equipment. This is to avoid over feeding of the preceding equipment and to prevent clogging. As the grains are offloaded into the reception pit, it is conveyed to an elevator that will lift it and discharge into the cleaner which by design can only handle grains discharged into them by gravity. Ideally and for optimum performance, the cleaner should be incorporated with an aspirator and cyclone for sucking away of lighter particle/dust, based on different aerodynamics properties of every object in flight. A magnetic separator and destoner needed also to be installed, just before the grain enters the cleaner. Magnetic separator and destoner, pick all metals and stones in flight with the grains, and make it easier for clean grains to emerge from the cleaner. During cleaning, insect attacked, mechanically broken grains and dust are also collected in separate bag via a chute, while a pure clean grain proceeds. As the grain proceeds, a suitable approved rate of insecticide of fumigants or chemical dust powder are added to the grain stream at the recommended rate, using chemical dust dispenses, and chemical tablet dispenser respectively. The cleaned grains are finally moved into designated bins and the records are kept in the bin cards.

III. GRAIN MANAGEMENT

(A) Leveling of Grains.

Due to the vertical/ point loading system of grains in metallic silos, grain discharged into metallic silos forms a conical shape after discharge. However each grain cone differs from the other due to different angle of repose, coefficient of static friction and aerodynamics properties Due to this conical nature, the grain level indicators are always designed to be fixed below the original cylindrical height taking into consideration of the conical shape of the grain. However level indicator alarm is more preferred, than ordinary indicator with light signal which shows in the control panel. This is because it will physically raise the alarm, to give the operator a signal whenever the silo is full during loading. Leveling of grains is a good grain management practice. This is because it creates bigger head space that will afford the grain worker enough space, in carrying out of other activities on the grain mass inside the silo as shown below. Fig:.1 below shows the shape of levelled and non levelled grains inside metallic silos. Levelling of grains after of reception or discharge is imperative considering the surface area of grain involved. Since most of insect activity, deterioration happens at the top of the grain in the head spare, reduction of the surface area helps to minimize the grain volume exposed to the attack of insects and damage. Levelling of grains also increases aeration efficiency and facilitate easy sampling and grain fumigation.

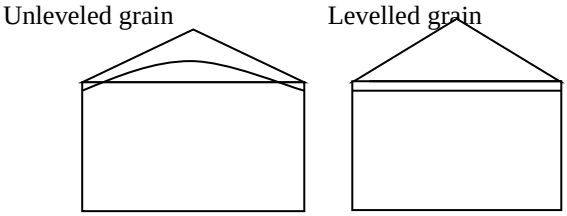

Figure 1: Diagram of levelled and unleveled grains in metallic silos.

(B) Temperature/Humidity Monitoring and control.

Grain is living matter which respires, producing heat and moisture. However when the grain is clean, dry, sound and at less or equal to 12.5% moisture content, all the metabolic processes such as respiration are extremely low. Thus, in that condition the grain becomes dormant and stores well. On the contrary, any deterioration in the grain quality and or development of (hot spots) due to moisture condensation, rain leakages or insect activity, will result in increased metabolic activity which produces heat that will manifest inform of a temperature rise [10].

The temperature monitoring system in a metallic silos is a remote monitoring system that dictates temperature at various levels/heights. It is basically a thermocouple that sends signal to the control panel via sensor wires dropping from the roof to the floor of the silo bins. However the recent developments in technology of temperature

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monitoring system is the emergence of wireless temperature monitoring system, which sends information wherever its read out equipment is, no farther than three kilometers square from the position of the silos. The Plant operator must read the temperature monitoring system daily and records forwarded to the management for interpretation and suitable control action. Ambient temperature and relative humidity are important information that is needed often. They are normally read and recorded using mobile or fixed thermometer and hygrometer meter, as an important element to be considered before any control action is taken about the temperature variation. If found that any silo shows increase in temperature then aeration is subscribed. However should the temperature increase happens abruptly with big differential value, then emergency procedures must be initiated. These include intensive aeration and or grain turning.

(C) Aeration of Grains.

This is the act of creating forced ventilation with cool air at low airflow rates, through the grain mass to maintain uniform temperature throughout the bulk, and in the process bring about reduction and equilibrating of the grain temperature. Before aeration is commenced, the properties of air in respect to temperature and relative humidity must be conducive so that wetting of grain or introduction of hot air does not occurs. The top silo vents and manhole covers should be opened to discharge the air out of the bins during aeration. Effective aeration can have the following effect on stored grain.

- To lower the temperature of the grain in order to slow down the bio-chemical degradation process of mould, insect and fungi (cooling ventilation).
- To keep the grain at a constant temperature by systematically evaluating the heat produce by the grain mass itself (maintenance ventilation).
- To dry the grain slowly (drying ventilation)

The most appropriate time for aeration is when the ambient temperature is lower that the temperature of the grain bulk, at average relative humidity. In a situation whereby aeration is desired when the relative humidity is high, dehumidifiers could be incorporated to the aeration system do dehumidify the incoming air sent into the silos. The efficiency of aeration depends on a lot of factors including the grain type, bulk density, void volume, grain size, presence of docks and fines, type and capacity of aeration fans, the aeration floor design layout and foreign matter present in the grain bulk. The round bin aeration flow layouts are three major types namely: the square Y, the pad, and the double T. The three perform optimally but the pad has proven to be the best effective, with a limitation by being the mostly difficult in terms of design, costs and construction. The types of fans used for aeration includes, axial and centrifugal types. While centrifugal is most expensive, it has relatively quiet operation with more airflow per Horse power (Hsp) delivery than axial fans, thus many silos management prefer centrifugal to axial. Fan controls could be manual or automatic with the help of control sensors. The axial flow fan is less expensive but noisy in operation, with more airflow in delivery at horse power less than 4 Horse power

(D) Grain Turning.

Grain turning or re – circulation is the movement of grain from one silo bin to another preferably empty. This exercise takes the same preparation as grain reception. This may be an emergency measure necessitated by rapid increase in temperature of grains, indicated by the temperature monitoring system or programmed as precautionary operational procedure during which grain in moved from one silo cell to another, may be once every six months. The essence is to discover causes of temperature rise, as well as to monitor the grains visually when they are being moved, to ascertain the quality of the grain and to properly expose the grains to open air as the highest form of aeration. Others are to exchange grains position in the bulk. During the turning, the grains are inspected; samples are taken to determine physical attributes and quality. The grains are cleaned and fumigated as it moves to the receiving bin. There should be proper records on when the exercise took place and the result of the grain analysis. Grain turning must be undertaken carefully to minimize cost, resulting from damage due to breakage and other indirect cost. However, the cost effectiveness of grain turning exercise is still under scrutiny especially where the cost of the grain turning is still being compared to the losses if it`s not done. The age of the grain and the moisture content of the grain is also an important issue, since the quantity of broken rains will increase after grain turning due to old age of the grain and decrease in the moisture content.

(E) Bin Inspection.

Once grains has been loaded in the silo cells, regular inspections at intervals at least once in a week must be conducted to physically look at the grain condition, to check for signs of insect infestation, ingress of rain and grain deterioration [12]. The inspection should be carried out from the roof man hole if bin is full, or from side inspection windows if not full. Samples should be taken for detail laboratory analysis. Areas like the aeration duct should be inspected regularly for signs of infestation such as, presence of life insect and insects webbing. Signs of crawling and flying insects on the top of the grain piles may be an indication of damage already done within the pile. During inspection, sign of leakage of rain water and the integrity of the structure should also be checked and if there are signs of insect infestation the adequate integrated pest management method (IPM) should be used to address the problem [13].

(F) Integrated Pest Management (IPM).

This aspect of grain management is the most important due to information regarding insect population and morbidity rate, insects developing resistance to chemical treatment, and the effect of chemical residue from chemical used to control insects. Integrated Pest Management includes the use of all available knowledge/method to keep pest population below economically damaging level in a

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manner that is profitable and causes no harm to human and the environment [3]. Sanitation, treatment of empty bins using residual insecticide before loading is starting point of good integrated pest management. Others are storing of clean grains with grain protectant, periodic sampling and analysis of stored grains, efficient aeration and fumigation. Effective aeration ensures low insect population and there will be less need to repeatedly fumigate. Frequent use of the same insecticide may results in rapid development of resistance. (IPM) is more effective if insect traps are used to trap and identify the kinds of insect during infestation, or any other means of identifying the insect type before treatment. This will not only equip the silo management, with information of whom the enemy is, and the best way to fight it, but will also give an insight about the insect morbidity and how fast they can finish your grain. There are different types of insect traps, such as sticky flight trap with pheromone to lure insect into the traps, multiple funnel traps, bucket trap, pitfall trap. Each of these traps are kept or hung inside a silo bin, warehouse or in the desired environment and checked at the interval of three hours or more [13]. The trap has the capability of attracting insects and trapping them until they are harvested by the trained personnel. Keeping record of where and how often a trap catches insects is part of a well conducted (IPM).Management. Most popular kind of insects that attacks grain in storage in Nigeria includes: lesser grain borer, mot, maize weevil, rusty grain beetle, red floor beetle, indeamealmot, grain weevil, larger grain borer, confuse floor beetle. Saw tooth grain beetle, angoumois grain moth, rice weevil and warehouse moth. However, there are different factors that affect the mortality of insects and insect's population which includes: available of food, habitat, temperature of grain, relative humidity and the moisture content of the grain.

Application of grain protectant and fumigants during grain reception or grain turning is very necessary. This is because of grain carrying larvae of insect that will go on to hatch as soon as it gets into the bin. However, the recommended dosage of fumigants and grain protectants must be used at all times and safety regulations adhere to. Trained personnel should always carry out fumigation and other kinds of pesticides application to grains. After loading and leveling of grain in the silo powdered insecticides such as storicide, deltamethrin, Accettelic or diatomaceous earth, or coopex dust could be used to top dress the grain to secure the grain against invading flying insects. Grain turning as an aspect of (IPM) is also vital as moving grains from one point to the other will even kill insects.

In bulk storage of grain, in metallic silo, the problem of rodent is limited to damaging of electric wires, and that of redundant equipment and machines. To reduce the problem of rodents, ensure good hygiene and a clean environment; sweep all the surrounding around the grain reception area, the warehouse tunnels and burn all the dirt. All the drains should be kept clean and surrounding grasses/bushes cleared. Chemical control can be used to reduce the number of the rodents, using different types of rodenticide or rat poison. Biological control such as introduction of different types of rat traps or the introduction of a male and female cat in the environment could be more effective.

(G) Fumigation.

The act of using posphine or other fumigants for the control of insect population in stored grains. It is basically the use of posphine liberated by tablets or pellets that spreads evenly and rapidly to the most inaccessible corners and the grain bulk. Posphine does not taint, discolour or disflavour the grains treated, it does not affect neither seed viability nor leaves any residue [13]. It must be applied in an air tight or near an air tight environment to restrict the gas effect from disappearing quickly. Sealing should always be done, so as to avoid the gas from leaking, probably before it reaches a high concentration enough to kill the insects. Requirement for safe and effective fumigation includes reading and understanding the posphine label. Enclosures to be treated should be well sealed, and application of the right recommended dosage of posphine should be done by trained personnel. Others are monitoring posphine level during fumigation and ensuring safety by wearing protective gears and protecting others by putting sign like (Dangerous chemical please stay away). Fumigation inside a metallic silo can be made more effective by using polythene to cover the entire grain surface after treatment. Long probes can be used to bury the posphine tablets deep inside the bulk at distances.

(*H) Mould and Mycotoxin Management.*

Grain spoilage may also be as a result of microorganisms using the nutrients within the grain for their own growth and development. During the process they produce heat and increase the temperature of the surrounding grain, which may result in hot spots. Heat damage, significantly reduces grain quality [4]. If environmental conditions in the grain are favourable for microorganisms, the major storage mold species Aspergillus, Fusarium and Pencillium may produce mycotoxins, fumonism, and zearalenane. These could cause serious illness and even death when consumed by livestock or humans. However it will be pertinent to note that, the presence of mould does not mean mycotoxin will be present, but rather the potential environment for their development exists, given the right combination of temperature, moisture content and storage time. Even more frustrating is the fact that the absence of mould does not guarantee a mycotoxin-free commodity. This is because the growth of the mould may not be extensive enough to cause visible damage, but nevertheless it can still produce toxins .Generally, broken grain and dead grain is more vulnerable to fungal attack than whole grain. Stored grain dried rapidly at high temperatures, is more vulnerable to moulding than if it were gradually dried at low temperature. Grains stored for long periods of time are more vulnerable to moulds, fungi and other microorganism attack, than freshly harvested grain. Although moulds are diverse in nutritive requirements, all mould growth can be prevented by stocking dry grains with

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low moisture content, low temperature, and low oxygen environmental conditions. Mould affected grains could be treated, but instant release remains the best option

IV. GRAIN RELEASES

Grain could be released in bulk, through bulk loading bin or by bagging releases. Bagging is the act of packaging grains in bags for purpose of release. The choice of bags, capacity and inscription on the bags could be a policy decision made by either the beneficiary or the silo management. Detail preparations of personnel and all machines/equipment involved should be done, just like during receptions. One month withdrawal period for all chemical treatments should be observed. Detail analysis should be carried out on the grains by a reputable laboratory to determine its fit for consumption. In the absence of no issue the grains will be re-cleaned and sent to the bulk loading for either bulk release or bagging plant for bagging release. During the grain release proper, after other administrative jobs, the truck comes in and weighs before proceeding to the bagging plant for loading. The final weight is determined, after adjustment at the weighbridge by adding and removal of bags till the accurate weight is achieved. The truck leaves the silo facility after all necessary documentations are completed.

(A) Grain Storage loss estimation.

There is no specific percentage for storage losses but should be within the acceptable limit which is 5% according to FAO. Factors largely contributing to these losses includes, grain shrinkage, insect pest activities, seepage and ingress of water into the grain mass resulting in grain caking, grain mixing, pilferage and handling losses. Shrinkage losses refer to loss in volume and weight of grain in storage. This loss is basically due to reduction in the moisture content and respiration leading to dry matter loss. Reduction in moisture level can be estimated by the difference in moisture level during intake and release.

RD =%Reduction in weight= $\left(\frac{mi-mf}{100}\right) \times 100$

where mi = initial moisture content

mf = final moisture content

Thus loss in weight for β Metric Tonnes of grains = β×RD

(a) Grain respiration.

The magnitude of respiration of well dried grains as well as loss in weight due to metabolic activities is extremely low and could be neglected in this contest [14].

(b) Insect infestation.

Insect infestation as an index for storage loss estimation is very critical as insects can eat up the entire germs and endosperm of grains, reducing them to mere powder or grain dust. However the degree of loss at any given time depends on insect type, duration of attack, type of grain and the stored grain ecosystem Different methods of estimation Iincludes using the formular below.

LI=0.005×LD×WI

Where LI=insect infestation losses

LD=% damaged kernels as at the time of determination

WI=total weight of stock during reception.

Other causes of storage losses includes caking, mixing of grains during grain movement, accidental leakages/spillage, pilferage and grinding of grains by grain handling equipment.

V. WORKERS HEALTH AND SAFTEY IN THE BULK HANDLING OF GRAINS IN METALLIC SILOS

There are a lot of hazards associated with bulk handling of grains in metallic silos. Hazards which pose various kinds of threat to life, that is capable of worsening ailing health condition of workers, others may result in untimely death in a matter of seconds. However it will be pertinent to note that most of the accidents can be prevented by adhering to workers safety laws in the silo facility. In the developed countries of the world where these hazards are recurring decimals, there are records and data unlike the developing countries where there are naturally less number of silo facilities and no records. Companies/organizations may rather conceal cases of accidents and settle victims secretly than disclosing them. The causes of most of the accidents are due to human avoidable errors, ignorance, and non adherence to common silo safety rules and regulations. With periodic training and emphasis on the potential danger and precautions associated with a silo environment, good welfare and motivation, accidents and hazards associated with bulk handling of grains in metallic silos will be minimized as shown in Table :2.

Table: 2. Different hazards associated with bulk handling of grains in metallic silos and their precautionary measures

S/N	Hazards Associated With Bulk Handling Of Grains	Precautionary Measures
1	Getting trapped in flowing or stationary grain	Workers should work as a team; they should be weary of cavities and unstable piles and should never enter the metallic silo bin alone
2	Accidents with mechanical moving parts/electrocution	All machine and equipment covers should be intact at all times. The use of energizing signal alarm or lock keys should be used at all times. All cables should be periodically checked for rat eaten up cables that could bridge the system.
3	Hazards associated with handling of chemicals	Wearing of relevant protective gears before embarking on any task should be made mandatory.
4	Dust exposure/explosion	There should be no smoking around silo bins. all dust should be cleaned and disposed properly.
5	Fire incidence/outbreak	There should be no smoking in the silo complex. Silo workers should fire trace and cut bush around and within the facility, rake the together and burn.

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6	Loading and unloading	Grains should be properly stacked. There should be proper supervision during loading and unloading. Qualified drivers only should be allowed to drive inside the silo facility.
7	Climbing and falling hazard	Enough cart ways should be provided for servicing and repairs of machines. Wearing of relevant protective gears.

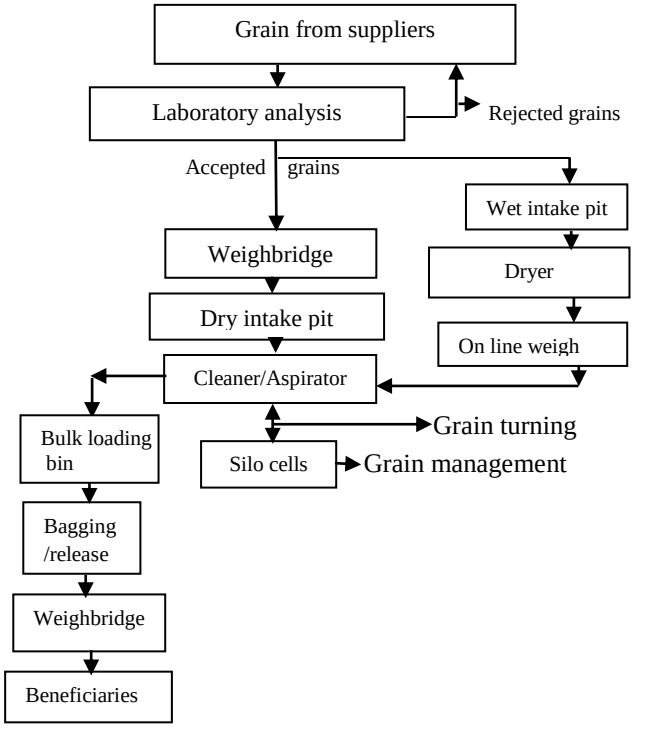

Figure: 2. Process flow chart for reception and release of grains in metallic silo facility.

a. Grain reception procedures -consignment- Laboratory analysis Weighbridge Dry/wet intake pits -Cleaner/aspirator -Silo cells.
b. Grain turning -Silo cells cleaner/aspirator Silo cells
c. Grain releases -Silo cells -Cleaner/aspirator-Bulk loading bins -Bagging plant -Weighbridge beneficiaries.

VI. CONCLUSIONS AND RECOMMENDATIONS

(A) Conclusions

In most developing countries, the storage of grains poses a serious threat to all year round availability of grains and to food security generally. This is due to persistent enormous storage losses recorded over the years. This situation often forces millions of rural peasant farmers/small producers of cereal grains to sell their grains at the time of harvest, with the disadvantage of low market prices Researchers have often tried to improve or modernize the existing inefficient and inadequate traditional or modern storage structure, but limitations of acceptance, cost and application of various technologies and the technical knowhow is always an impediment. However, the storage of grains in metallic silos using IBGM has significantly showed that it could be reliable in the storing of grains in commercial quantity with minimal storage losses.

Its peculiar problems of moisture migration, insect infestation and seepage could be controlled through effective integrated grain management.. Though alternative system of storage/ structures like, concrete, ceramics and wooden silos has performed better in terms air current and prevention of moisture migration, Cost of maintenance and durability of these structures continue to be an issue. Non chemical based storage with hermetic structures has showed serious promises for the future, but it's largely lacking in capacity especially for mega bulk storage.

Since the world population is increasing at an alarming rate especially in the developing countries, there is an expectation of a significant increase in food production, especially grain and paddy crops, as well as storage facilities to carter for this population. The efficient and effective storage structure that will guarantee the much needed capacity, of this imminent increase in production of grain and paddy crops, and the much publicized food security is metallic silos.

(B) Recommendations

To ensure a successful and effective integrated management of bulk grains in metallic silos, the following recommendations are made.

1. There should be strict adherence to grain reception procedure/standards without compromise.
2. Silo facility manager should adhere strictly to integrate pest management practices (IPM)
3. There should be regular monitoring /control of climatic variables that could affect storage
4. Silo facility management should ensure that health and safety of workers are guaranteed/ insured, in view of the accidents / hazards associated with integrated management of bulk grains in metallic silos. Seminars should be organized for worker regularly on workers health and safety in integrated grain management and emergency action plan and the potential dangers associated with bulk grain storage in metallic silos.
5. The silo management should adopt planned preventive maintenance for all the grain equipment and machines used in the silo complex to eliminate or minimize down time due to repair of equipment/machines during operations.
6. Staff welfare should be of paramount interest to silo management.

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