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Comparative Studies of Material handling time for Maize (*Zea Mays. Linn.*) and Sorghum (*Sorghum Bicolor .L. Moench*) in a typical 50 Metric Tonnes (MT)/hr Silo

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Abstract- **This study evaluated and compared the material handling time for one tonne of maize and one tonne of sorghum in a typical 50MT/hr silo facility. Twenty trucks each of white coloured hybrid 9021 maize and sorghum Samsorg-14 procured from Mariga market near Minna, and supplied to Food and Strategic Reserve Silo facility in Minna, by Government grain buyers agent were used for this research. Laboratory analysis was carried out on each of the consignments of grains on arrival at the facility, to check its adherence to F.A.O standard for grains procured for storage. The consignments that met the standards were used for this research. The accepted trucks with consignments were weighed in the weighbridge and the weight recorded as gross weight. The trucks proceeded to the grain intake pit immediately where the bags of grains were cut open for discharge into the grain intake pit. Before the material handling equipment were energized for transport of the grains into the silo bins, the intake pit was filled to its brim and that same level of grains was maintained throughout the discharge period. At the end of the discharge, the empty bags and the rejected/ bad grains, the cores and fines, dust collected from the aspirator/cyclone, and other foreign materials that came with the grains were carefully gathered and loaded back into the truck for final weighing known as the tare weight. The quantity of grains transported into the silo bins (net weight) was determined by subtracting the tare weight from the gross weight. During the discharge, the time taken from the point the intake pit conveyor was energized to the last batches of grains to enter the silo bins were recorded as the handling time. The result shows that the average material handling time for 1 MT of the grains in a 50 MT per hour design silos facility is approximately 2.0 and 4.0 minutes for sorghum and maize respectively. Sorghum exhibits a relatively low handling time, about half the handling time for maize. This may be due to its relatively high bulk density, sphericity, lower co-efficient of static friction and relative particle size. Design capacities/handling time of processing/storage facilities should be generic or crop specific.**

Keywords – Material handling time, comparative studies, maize and sorghum.

I INTRODUCTION

Maize (*Zea mays .L.*) and sorghum (*Sorghum Bicolor .L. Moench*) are members of grass family P*oeceace* (*Gramineae*) cultivated mainly for their edible seeds. The generic species were wild grasses improved through successive breeding and later domesticated by man. They are gluten-free cereal grains, which provide major important dietary nutrients such as carbohydrate, proteins, vitamins, minerals as well as phyto-chemicals for human and animal consumption. Other uses of maize and sorghum include seed for planting, production of bio-fuel, economic commodity for trade and agribusiness, farm manure, raw materials for industries and stalks used as construction materials [1]. They are the most important staple crops in SSA and are among the most versatile emerging cereal crops worldwide having wider adaptability under varied agro-climatic conditions [2]. Maize and sorghum are the most planted and stored cereal grains in Nigeria, and are mainly produced from the Northern Guinea Savannah agro ecological zone of Nigeria, adjudged the grain belt of Nigeria [1].

Maize originated from North America, domesticated around 500BC and spread to other regions of the world thereafter. It was brought to Africa around 1500AD by slave traders, and spread to all corners of the continent within the period of 500 years, but it is now Africa's most important cereal crop [3]. Maize is the most widely cultivated cereal grain worldwide, on yearly basis than any other grain. World annual production of maize in 2019 is estimated at 785 million metric tonnes (MMT), with the largest producer, the United States, producing 42%. Other

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top producing countries include China, Brazil, Mexico, Indonesia, India, France and Argentina [3]. Africa produces 6.5% of world production, and the largest African producer is Nigeria with nearly 14 million tonnes, followed by South Africa. However, Africa imports 28% of its maize requirement from countries outside the continent [4]. A typical maize kernel as presented in Figure 1a is oval in shape with tapered protruding mouth, and flattened near cylindrical posture. At 13% moisture content its length is between 1 to 1.5cm, width 0 to 1.0cm, surface area 150.92m^2, porosity 37% and coefficient of static friction at 13% moisture content is 0.67for galvanized steel [5] [6].

Sorghum bicolor originated from the dry lands (Sahel) region of Africa towards the Middle East and spread all over the world. It was domesticated between 4500-1000BC [7]. Sorghum is an important cereal crop which is grown globally for food and feed purposes. It is most widely grown in the semi-arid tropics where water availability is limited and frequently subjected to drought. It constitutes the main food grain for over 750 million people who live in the semi arid tropics of Africa. World annual production of sorghum in 2019 is estimated at 58.33 million metric tons, USA is the highest producer with 7,8MMT followed by Nigeria, Mexico and Ethiopia with: 6,9MMT; 5,0MMT and 5.0 MMT respectively [4]. Annual production in Nigeria is estimated at 12MMT [1] Due to generic diversity, sorghum seed varies in shapes and sizes. A 1000 kernel weight varies from 30 to 80g at 13% moisture content (wb). A single seed weighs 25mg to 30mg, 3mm to 5mm in length, 2mm to 3mm in width and 2.5 to 3.0mm thicknesses as presented in Fig 1b. [3]. Sorghum kernel is typically round in shape with protruding head with the sphericity normally distributed about 0.92 [8]. The co-efficient of static friction of sorghum for steel surface using regression equation from [9]. $\mu = (0.144+ 0.014)\ M$, is 0.32 at 13% moisture content.

Figure 1(a) Maize

1(b) Sorghum grain

Materials handling is the science and art involving the moving, packing and storing of substance in any form, and includes the preparation, placing and positioning the material to facilitate their movement or storage [11]. Material handling of grains could be carried out manually, in semi-mechanized form or in completely mechanized form. Post harvest handling operations of cereal grains especially maize and sorghum are labour intensive and time consuming. Presently, majority of the operations are done manually in Nigeria and other developing countries, but mechanization of this process using different types of material handling equipment will not only add value to the process and product, but will as well minimizes the handling time. Though ergonomics has been used to modify manual handling tasks, it is still far from the potentials/gains of mechanization of material handling process. Each grain or seed has a unique morphology/physical features that characterizes the member of that family or specie. The morphology of any seed/grain surely affects handling, and determines the behaviour and disposition of the individual grain/seed during handling, or under an external force that tends to move it.

Informations on physical properties of cereal grains, like other agricultural materials, is vital especially in terms of design of the equipment for grading, handling, processing and storage of the grains [10]. To design machines for cleaning, grading, sorting and packing etc, size and shape characteristics such as geometric mean diameter and sphericity are critical parameters [12]. In the transportation of grains from one grain handling equipment to another or in a unit processing or storage facility, certain parameters/characteristics influence the rate of handling, These characteristics include moisture content, bulk density, particle size, angle of repose, weight of the grains, abrasion of the grains against contact surfaces and ease of flow of the grains (coefficient of static friction), sphericity, percentage of foreign material in grains and the type of material handling equipment/ their designed capacities. The material handling time influences wear and tear on machines, planning/work design, cost of running a facility, design capacity rating and efficiency of an entire system. The ability of a facility to run on its designed capacity are always lacking due to wear and tear, equipment/plant age, lack of planned maintenance schedule, as well as lack of proper equipment matching. The knowledge of the handling time of a particular grain type in a processing or storage facility enhances proper planning, work design as well as ergonomics of the facility. It reduces cost of running a facility as well as the reduction of down time [13]. It could also serve as a standard for reference. Design capacity of a facility is expected to be discrete for different crops, but presently most facilities have just a figure for the design capacity.

Table 1: Acceptable standard for maize and sorghum for storage in the tropics

S/N	Parameters	(Maize)	(Sorghum)
1	Moisture content (wb)	≥13%	≥13%
2	Hectolitre weight(bulk density)	≥65-75kg/H	≥52-72kg/H
3	Foreign matter	≥1%	≥1%
4	Insect damaged grains	≥1%	≥1%
5	Mechanically broken grains	≥1%	≥1%
6	Mould infested grains	≥1%	≥1%
7	Colour	≥1%	≥1%

Source, [14].

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The silo facility where this study was carried out is 28 years post commissioning, and has a total capacity of 25,000 metric tonnes (MT) comprising 10 silo cells of 2,500MT each. The silo cells are made up of galvanized corrugated steel silo bins being fed from the top. The material handling equipment used for grain reception includes chain conveyors, metallic bucket elevators with metallic cups, a cleaner and aspirator as presented in Figure.2. Others are multiple sluice gates which aids the control of direction of movement/flow of grains from one location to another. The control panel is semi-automated with manual control buttons. The material handling equipment was matched at the installation of the facility but subsequent maintenance and rehabilitation of the facility is capable of distorting the matching. The silo facility is installed at 50 tonnes per hour capacity with equipment sequence as shown in Figure 2. The conveyors are typical chain conveyors with a total length of about 300m while the elevators have a total length of 350m. The cleaner is attached to an aspirator which complements the cleaning by sucking light materials in flight before it enters the cleaner using aerodynamic principles. Also attached to the cleaner are a magnetic separator and a destoner for picking up of the metallic materials and stones in flight with the grains respectively. The foreign material accompanying the grains are collected at 3 points which include the receiving/intake pit, and in the cleaner outlet for large particles while the lighter particles are collected in the cyclone connected to the aspirator.

The material handling equipment is driven by appropriatley rated electric motors including the sluice gates. Before the reception of a particular grain into the silo facility. The matertal handling equipments are normally run to empty residual grains in transit. All elevator booths are cleaned to avoid residual grains, and the cleaner sieve is normally changed to that designed for the particular crop. The intake pit is 4m by 1.5 m rectangular sized. The actual intake into the intake pit conveyor is regulated by a roof cover provided to prevent direct feeding and only allows for transverse feeding of the conveyor. The major foreign matters that accompany grains produced in Nigeria include grain cups, chaff, grain dust, remains of the husk, immature and broken grains.

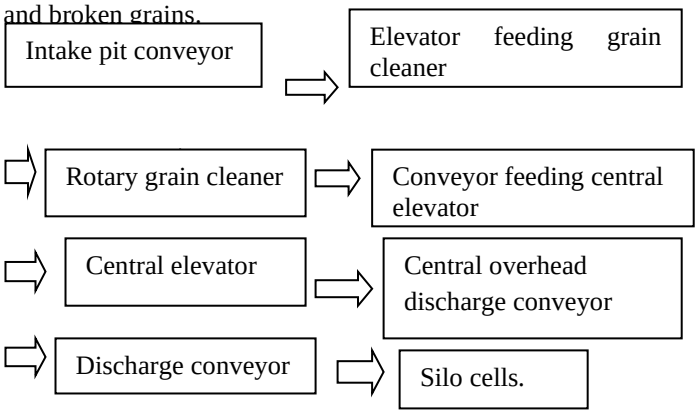

Figure 2: Material handling flow diagram for reception of grains into the silo facility

II MATERIALS AND METHODS

10 Trucks of White Sorghum Samsorg-14 and white maize hybrid 9061 each were delivered to Food and Strategic Reserve Silo Complex Minna, Nigeria. The grains delivered are from the penultimate year harvest and were sourced from Mariga grain market near Minna. The grain history revealed that it was produced from conglomerates of farmers who uses semi-mechanized system of production and handling. The land clearing was done manually, but the ploughing was by means of a tractor. Planting, fertilizer application as well as harvesting was done manually. The crops dried naturally in the field before harvesting and threshing. The cleaning was done using a locally manufactured mini cottage thresher and pre-cleaner. Prior to the reception of the consignment in the Silo facility, random sampling of the grains was carried out where samples were taken from one fifth of the entire bags which made up the consignment and were taken to the laboratory for analysis of the physical properties including moisture content and bulk density to check its adherence to [14] grain reception standards in the tropics.

After the analysis, if the result meets up with the stipulated standard, the truck proceeds to the weighbridge for initial weighing which is the gross weight, which implies the weight of the truck and the consignment. After the gross weight is taken the truck proceeds to the intake/receiving pit where all the bags of grains will be cut open into the intake pit hopper for onward transportation to the cleaner and through other material handling equipment eventually and delivered into the Silo bin. At the intake pit 100% inspection and sampling of grains are also carried out resulting in rejection of some bags of grains that do not meet up to the standards through visual checks. Throughout the discharging period, precautions are taken to keep the intake hopper filled to its brim at all times. The time taken for the handling of each truck is recorded by rating the time taken from the discharge of the first bag to the time taken for the last batch of grain from the last bag to enter the Silo bin.

III RESULT AND DISCUSSION

Material handling time

The result of this research shows that the average material handling time for 1 tonnes of sorghum in a typical 50MT/hr design silo facility is approximately 2.0 minutes, while that of maize is 4.0 minutes as presented in Table 1. From the result of this research it takes approximately twice the time taken to handle 1 MT of sorghum to handle 1MT of maize grains in the same silo facility. The handling time recorded for both crops can be said to be dependent on the major physico-dynamic properties of the grains such as coefficient of static friction which are 0.67 and 0.32 at 13% moisture content for maize and sorghum respectively. The result of coefficient of static friction again shows that the value for sorghum is about twice that of maize. Another implication of this result is that different crops have their individual material handling times which are determined by its physico-dynamic properties. Since different grains/seeds

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have different pysico-dynamic properties it is expected that their handling time will as well differ. In view of this, each processing and storage facility is expected to have its specific tonnes per hour design capacity for individual crops and not a generalized value. Figure 1 shows the average material handling time for 1 MT of sorghum and 1 MT of maize as shown in this research, Figures 4 and 5 represents the normal probability plot for both grains. From the result, there is a strong linear relationship between the residual, theoretical values and standard normal distribution, which means that it is also reasonable to infer that there are no outliers in the data set.

Table 1: Material handling time for 1metric tonnes (MT) of Maize and Sorghum

Truck number	Material handling time for 1 MT of maize (min)	Material handling time for 1 MT of sorghum (min)
1	4.5	2.1
2	4.0	1.9
3	4.6	2.1
4	3.8	2.2
5	3.7	1.6
6	3.9	1.5
7	4.0	2.5
8	3.8	2.1
9	4.5	2.3
10	3.5	2.1
11	3.8	2.2
12	3.3	2.3
13	3.5	2.1
14	4.2	1.9
15	3.5	2.2
16	4.7	2.0
17	3.8	2.2
18	4.5	2.3
19	4.2	2.4
20	3.9	1.9

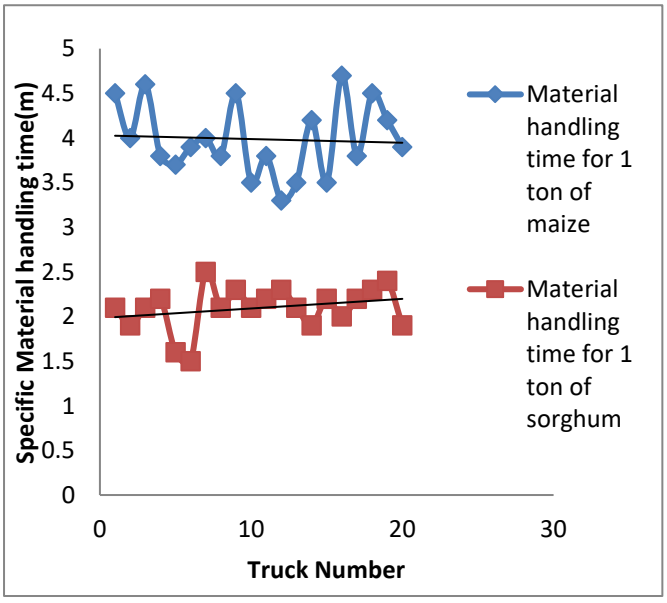

Figure 4: The material handling time for 1 MT of maize and 1MT of sorghum in a typical 2500MT capacity, designed 50MT/hr silo capacity respectively.

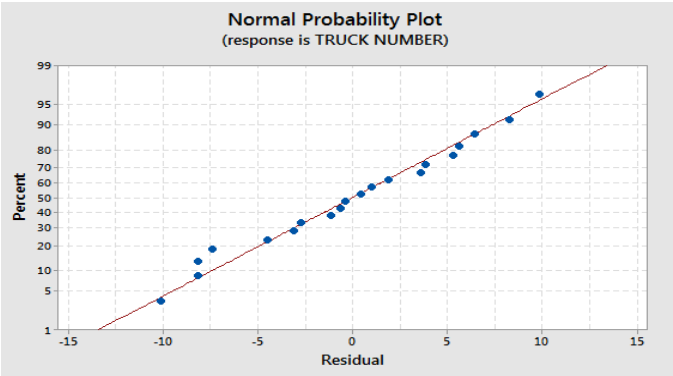

Figure.5: Normal probability plot for the handling time for the 20 trucks of maize

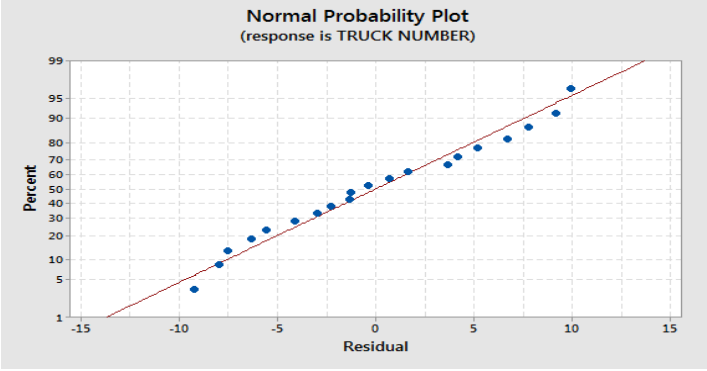

Figure 5: Normal probability plot for the handling time for the 20 trucks of sorghum

IV CONCLUSION

(i) From the result of this research, it could be concluded that it takes twice the time for handling a metric tonnes of sorghum to handle 1 metric tonne of maize in the same silo facility. Though this research was carried out in a. typical 50MT/hr design silo facility, the time taken to handle any crop is dependent on a lot of factors. The value may differ from one facility to another but for a particular silo facility; the result of this research may apply.

(ii) Each processing and storage facility is expected to have different specific handling times for individual crops and not a generalized value.

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