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Assessment of Dry and Wet Milling using Fabricated Burr Mill

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ABSTRACT
Size reduction processes are utilized to produce watery paste vegetables common in most developing countries. The research was executed in two parts; the first part was a survey of workers and owners of pepper grinding machine in 3 markets Nigeria, to obtain information on experience working with the machine and functionality of burr mills using Structured questionnaire .The second part involved physical measurement of the dimensions, and other engineering parameters on five randomly selected pepper grinding machines from a lot in each market, About 25.4% of the respondents has being working with burr mill for 11-15 years, 23.7% has 16-20 years' experience while 10% of the respondents have spent above 20 years in business while 93.22% of the respondents use the machine more than three times daily. In view of this it could be deduced that the interaction of the working parts of the machine is un-ending in the sense that increase in the numbers of usage of the burr mill increases the level of wear of the working parts. The physical measurement of the component parts of the burr mill of existing machine compared to that of new machine showed that the level of wear and tear of the machines varies which is due to age of machine and frequency of usage.
Keywords: burr-mill, grinder, dry milling, wet milling.

INTRODUCTION

Agricultural or food materials are products from the farm which are either consumables or raw materials for industries. Its processing is a post-harvest operation that adds value to agricultural product (Mijinyawa *et al*., 2007).

Processing is a form of value addition its objective is to minimize the qualitative and quantitative deterioration of the materials after harvest. Taylor *et al*., 2008 Food processing and preservation is a branch of manufacturing that transforms raw animal, vegetable, or marine materials into consumable safe food product.

One of the major problems facing developing economies is that of engineering material development and processing. According to Ogwuagwu (2007) the evolution of modern and appropriate agricultural machines for food crop processing in the country has been hampered as a result of non-availability of appropriate engineering materials and processing facilities used in the production of farm produce processing machine which helps in the transformation of agro-based produce from one form into another.

Zeki (2009), processing helps to improve the palatability, nutritive value and shelf-life of the agro-produces.

Food processing is traditionally a woman's work in Nigeria. Even when in purdah (full seclusion), many women undertake food processing for income generating purposes within the confines of the family compound (Adekanye, 2007).

Food processing is an integral part of agriculture as most farm produce must undergo one form of conversion or the other either for storage or breaking down into smaller, workable units as a food source or raw material. In the process of changing agricultural materials from one form to the other with the used of fabricated processing machine, contact do occur between the produces and the machines been used.

Particle size reduction, milling or communition is a necessity for agro- materials to make them smaller before further processing or utilization. There exist different size reduction forces at work in various size reduction machines.

The reduction in size of agricultural products is brought about by mechanical means without change in chemical properties of the materials (Enrique, 2012). This improves the eating quality or suitability of foods for further processing and to increase the range of available products. Development of varieties of size reduction machines has resulted in the reduction or total removal of drudgery from processes which hitherto were tedious to accomplish. The size of agricultural products may be reduced in several ways. The main methods used are crushing, impact, shearing and cutting (Fellows, 2003).

According to Fellows (2003) , Earle and Earle (2004) size reduction operation can be divided into two major categories depending on whether the material is a solid or a liquid, they are grinding/cutting (solid

materials) or emulsification/ atomization (liquid materials). While
Scott *et al*. (2002) highlighted some of the most common reasons for reducing a material. Omobowale, 2010 stated that size reduction can present numerous challenges, some are industry specific while others depend on the material properties and mills designed to overcome these challenges are available using different type of mechanism to achieve reduction in size

Application of external high impact forces initiates fractures needed to reduce a material's particle size, from large particles or lumps into smaller particles. Giroux and Marouze (2006) in FAO (2007), observed that amount of particle reduction caused by an external force depends on the level of energy applied to the particle, the rate at which it is applied and the manner of application. Leland (2008) reported that application of size-reduction forces can be broken into four categories namely Impact milling, Attrition milling, Knife milling (cutting), Direct-pressure milling (crushing).

A material's physical and mechanical properties often determine the ease or difficulty in reducing the material to an appropriate particle size. The following material characteristics are some of the most common that can present milling challenges fibrous. non- friable, heat-sensitive, wet, fatty or Sticky and dense or hard materials.

High levels of process control must be maintained. Equipment failure or corrosion deposits that might be tolerated in other industries are unacceptable in the food industry. Product quality is the primary concern in food processing plants.

The Burr Mill

A burr mill or burr grinder is a device to grind hard, small food products between two revolving abrasive surfaces separated by a distance usually set by the user (Fellows, 2003). According to Perry and Green (1997), burr mill, plate mill or disc mill have two roughened chilled cast iron plates of 4''- 60'' (i.e. 102mm-1524mm) in diameter which rub together, one plate is stationary and the other one rotates on a shaft with operation speed usually less than 1200 rpm.

Grain fed between the plates are crushed and sheared, the fineness of grinding is controlled by the size and quantity of burrs on the plate and the clearance between the two plates (Kaul and Egbo, 1985). The burr mill can also be referred to as attrition mill and could be powered manually, mechanically or electrically.

Galanty (2006) stated that choke feeding (overfeeding) of the grinder causes particles to rub together more intimately increasing temperature above that obtained for free feeding, also overfeeding reduces the effectiveness of the grinder. According to Culpin (1992) the power requirements of a typical burr (plate) mill at different milling capacity of two different fineness levels differs.

The local pepper grinding machine makes use of the principle of attrition milling in achieving size reduction of agricultural products introduced into it. Feyisetan (2009) stated that efficiency of a locally fabricated burr mill machine depends on the moisture content of the food-materials as well as its mechanical strengths of its constituent composition.

Traditionally size reduction is very tedious and drudgery and effect sets in with time thereby reducing the ability of man to work continuously without hindrances on large quantity of produce. In recent times particulate size reduction by the use of mechanical means is being achieved with burr mill hammer mill, roller mill e.t.c

According to Feyisetan (2009) locally fabricated burr mill have different constituent parts which when combined forms the machine, these basic features includes the hopper, auger and shaft, the grating unit etc. which reduce produce to workable sizes by cutting, grating, or crushing.

However there is dearth of information about the designs of some of these machines and mostly these grinding machines are produced by local fabricators without recourse to appropriate designs. This study was undertaken to establish the defects in design of the locally fabricated burr mill (pepper grinding machine) in relation to usage.

METHODOLOGY

The research was carried out in two parts consisting of a survey and physical measurement of basic working mechanism of the burr mill.

The use of survey/questionnaire was conducted in a total of three (3) markets. The main factors considered in the selection of the research locations were the scale of operation indicated by the numbers of burr mill used in reduction process of agro-materials and the numbers of people employed.

TABLE 1: LIST OF SURVEY LOCATION

Market	**Type of Milling**	**Total Numbers of People Employed.**
1	Dry and Wet Milling	120
2	Wet Milling	50

3	Wet Milling	30

Source: field survey 2012

Precision instrument digital caliper was used to measure the internal and external distances accurately. Measurement was taken at the locations as shown in Plate 1 with random selection of five pepper grinding machine per market for the physical measurement. Parameters measured on each burr mill include the thickness of the burr plate (stone), diameter of auger and shaft, the auger housing, the pitch etc.

Plate 1. (i & ii): Measurement of Working Mechanisms of dry/wet burr mill.

Plate 2: Questionnaire Collection

RESULTS

The power source for all burr-mill operated is a petrol or diesel engine, and 65% uses petrol for wet milling while 35% uses diesel for dry milling.

The numbers of years in business of the respondent are as represented in Figure1 which shows that 6.8% of the total respondent have being working with the burr mill for less than 5 years, 27.1% for the period of 6-10years, 25.4% with 11-15 years' experience, 23.7% with 16-20 years while 10% of the respondent has spent above 20 years in business.

The method employed in milling are as represented in Figure 2 which shows that 47.5% of the respondents carried out wet milling, 16.9% carries out dry milling while 35.6% carries out both wet and dry milling process.

Figure 3 the respondent used the machine more than three times daily with 93.22% of the total respondent giving assertion to that fact, while 6.78% depends on workload.

Figure 4, 50.85% of the respondent ascertained that they re-sharpen the burr plates weekly as a result of the bluntness of the plate after it has being used for consecutive numbers of time, 15.3% indicated that re-sharpening of the burr plate depends on the work load i.e. the quantity of the food material milled which means that the plate could be re-sharpened within the period of 1-2 days as corroborated by 3.4% that stated that the burr plate is re-sharpened within 3-4days.

For replacement of parts 50.8% replaces the auger of the machine after 6 to every 12-months, 33.9% replaces theirs after a year while 15.3% replaces before 6 months.

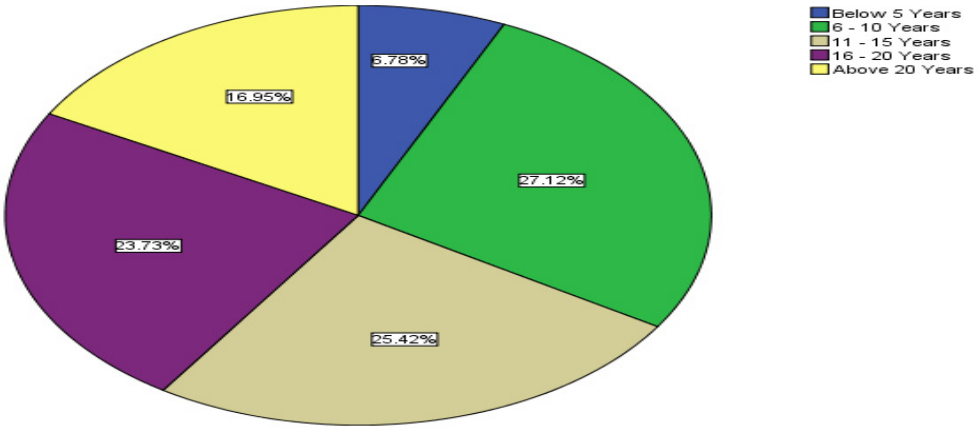

Figure 1: Numbers of years in business of the respondents

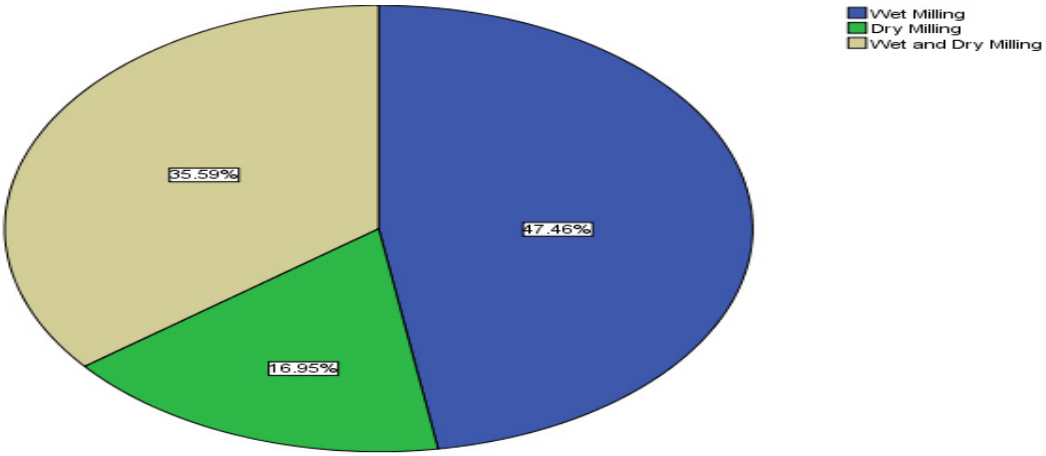

Figure 2: Numbers of people involved in different types of milling process.

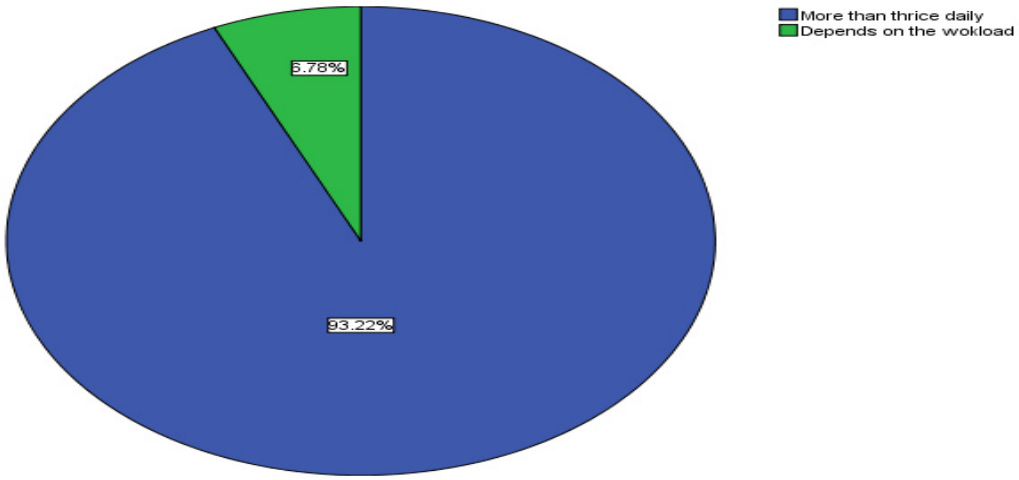

Figure 3: Frequency of use of the Burr Mills

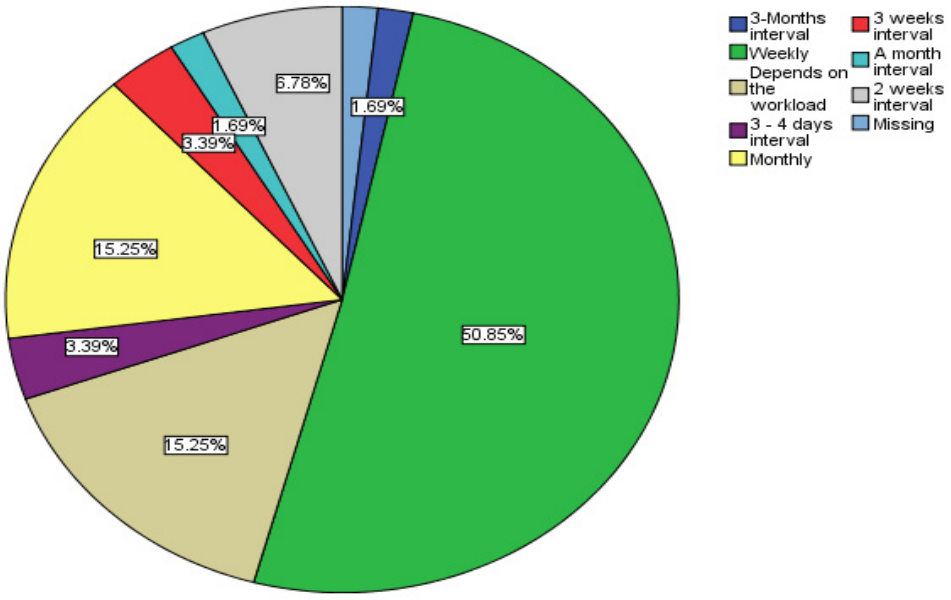

Figure 4: Frequency of Burr Plate Re-sharpening.

DISCUSSION

Cost and availability is the determining factor in the choice of type of power source. Petrol gas is cheaper than the diesel oil, while diesel oil is considered in powering burr-mill for dry/hard materials.

In Figure 2 observation made indicates that the materials that were reduced with these machines differs, wet milling is used to create throughput with addition of water like grounded beans for making bean cake, grinding of maize to pulp for making pap (oji), grounded vegetable (pepper, tomatoes etc.) for stew making etc. while dry milling is used majorly for making dried grounded food materials like yam-flour, grounded pepper etc. with no addition of water.

From Figure 3 it could be deduce that the frequency of use of the burr mill varies, the number of times that the machine was used depends on the numbers of sales made in a day and the quantity of produce ground at a time. The interaction of the working parts of the machine is un-ending in the sense that increases the numbers of usage of the burr mill hence level of wear of the working parts. Figure 4 burr plate re-sharpening as a result of the number of use of the burr mill and also the continuous interaction of the abrasive surface of the burr plates when under usage.

Type of milling contributes to the amount of wear of the machine as shown in figure 4, the machines requires a lot of energy to reduce a hard dried materials when compared to moisture- laden food materials resulting into high level of abrasion between the working parts of the machine.

Mechanical Wear due to Machine usage

The measured parameters of the working mechanism of the pepper grinding machine from the three different markets are as presented below:

Table 2: Data for Market 1, 2, 3

	Average Usage per day	Year of Machine (months)	Burr plate thickness	Auger Diameter	Auger Housing
New Machine			9.47	73.85	75.65
Machine 1	15	20	6.32	67.25	76.95
Machine 2	20	16	5.64	54.70	74.85
Machine 3	17	12	4.69	67.81	76.15
Machine 4	18	6	8.71	67.15	75.75
Machine 5	16	14	6.13	64.40	70.25
Machine 6	10	12	5.08	71.35	78.25
Machine 7	12	6	6.50	72.85	76.85
Machine 8	11	6	5.85	70.95	77.92
Machine 9	15	14	6.85	70.25	78.75
Machine10	13	18	8.25	68.85	79.35
Machine 11	7	36	6.75	60.85	70.69
Machine 12	9	24	6.02	65.35	71.63
Machine 13	8	10	7.12	68.45	72.00
Machine 14	10	8	7.35	72.53	78.00
Machine 15	10	30	8.21	55.75	77.45

Source: Field survey 2012

Table shows the frequency of use of the randomly selected machines and its years of use (expressed in months) in relation to the level of wear of the diameter of the auger, including that of the burr plate thickness.

An on the spot assessment and inspection observed that there were various burr mill components that had been disposed which includes the burr plate and the auger-shaft as a result of wear.

Effect of Frequency of Use on the Burr Plate

Figure 5, 6 & 7 shows the variation in the data generated from the three markets respectively.

Wear of the burr mill is in correlation with the frequency of usage that is, having a corresponding effect on the thickness of the burr plate. Newly fabricated pepper grinding machine has a burr plate with thickness of about 9.47mm which reduces with time and frequency of use. It is evident from the chart that as the number of usage of the pepper grinding machine increases, there is a corresponding reduction in the thickness of the burr plate to as low as 4.69mm in thickness.

Edge bluntness due to grinding is remedied by periodic re-sharpening of the burr plate thereby having corresponding effect on the thickness which in time reduces to the point of replacement. This is seen to be a design problem due to the continued reduction of the burr plate thickness that results into the throughput not having uniform sizes as well as the cost of re-sharpening the burr plates whenever it becomes blunt which might add up capital expenditure to a level that may be out of reach to the user of the pepper grinding machine.

The same trend is noticed in the three markets data which means that taking a single market data can be used to represent those of the remaining markets with little exception to the time of usage due to the level of patronage of these markets. This is corroborated by figure 7 which shows that the level of usage of pepper grinding machine in third market is slightly lower when compared to that of second and first; therefore the effect of reduction of burr plate thickness may take longer than the remaining markets.

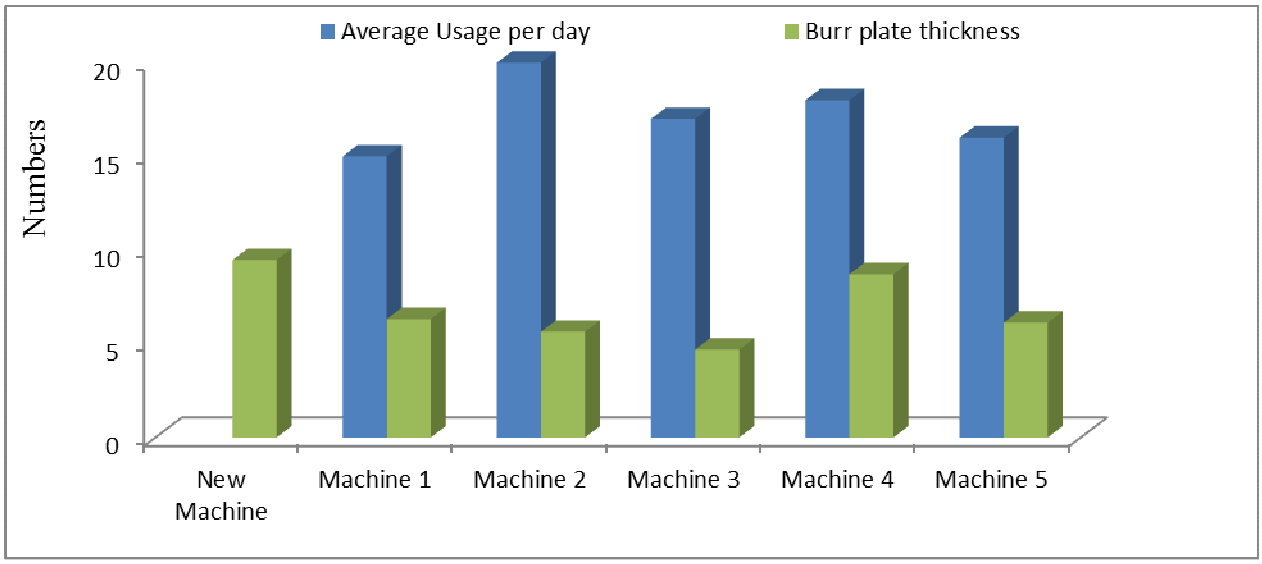

Figure 5: Representation of experimental data from market 1

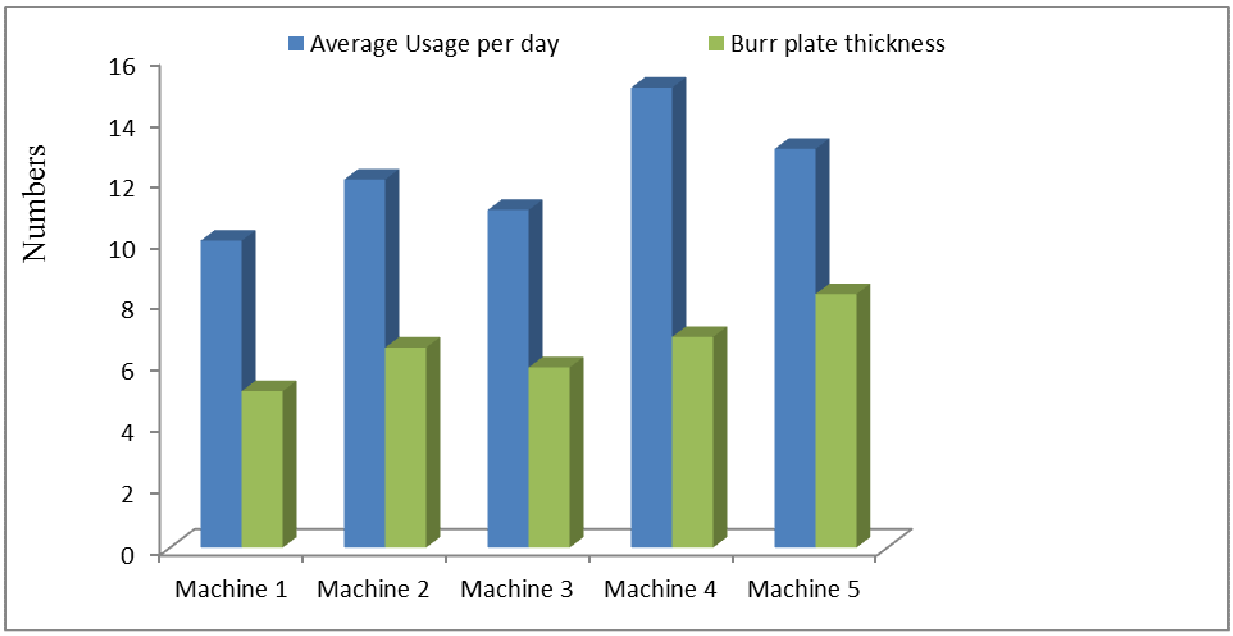

Figure 6: Representation of experimental data from Market 2.

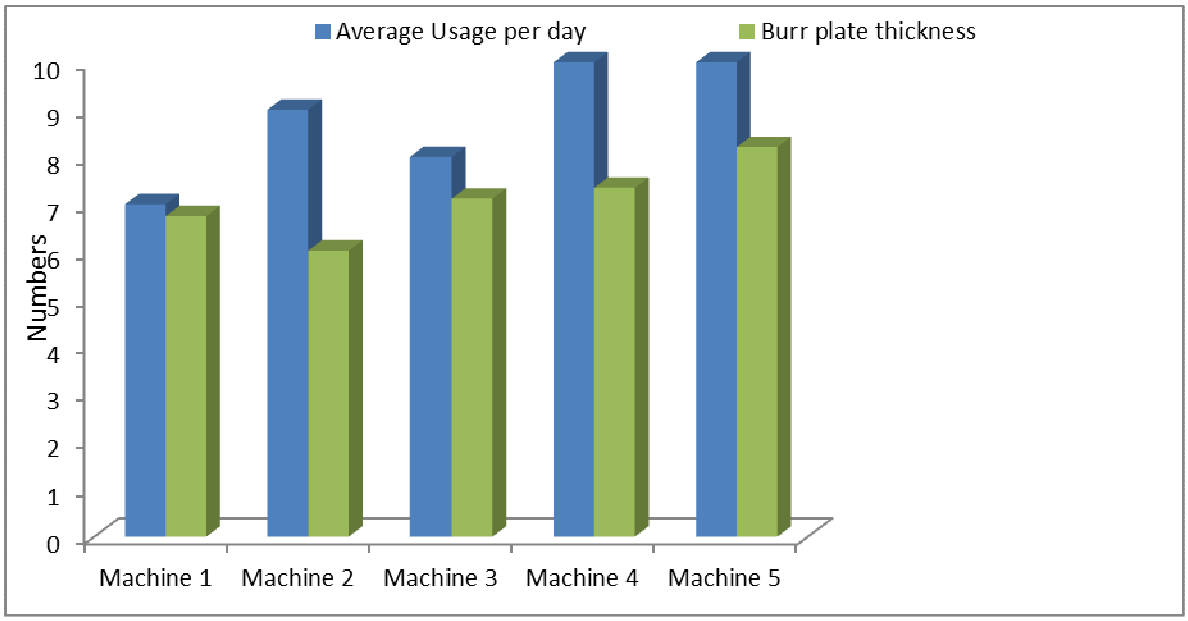

Figure 7: Representation of experimental data from Market 3

Effect of Age of Pepper Grinding Machine on Auger

The auger functions in the transferring of the introduced agricultural-material from the lower end of the hopper into the grinding chamber that consists of the burr plates. The auger is enclosed in the auger housing which is provided with a clearance in-order to allow for easy passage of the auger. Irrespective of the clearance it is observed from the three market that the outer diameter of the auger reduces with time due to the insufficient clearance in the design, this is corroborated by the measured data from the randomly selected pepper grinder as represented in the Figures 8, 9, 10 considering the diameter of auger in relation to the year of machine and frequency of usage.

The trend from the Figure 8 shows that the diameter of the augers of the randomly selected pepper grinding machine reduces with time when compared to the diameter of a newly fabricated pepper grinding machine which is as a result of the continues interaction (Abrasion) between the auger housing and the auger diameter itself. Figure 9 & 10 also shows the same trend as showed by that of Figure 8, whereas from Figure 10 it could be deduced that the numbers of years of the machine is considerable higher than that of the remaining markets this is due to the lesser patronage of this market and most owners of the machine living below the $2 benchmark making it difficult to get money to purchase a new machine thereby resulting into continues reduction of the diameter of the transferring auger. Therefore the higher the year of use with regards to the frequency of used the lesser the diameter of the auger becomes which might result into shaft breakage etc.

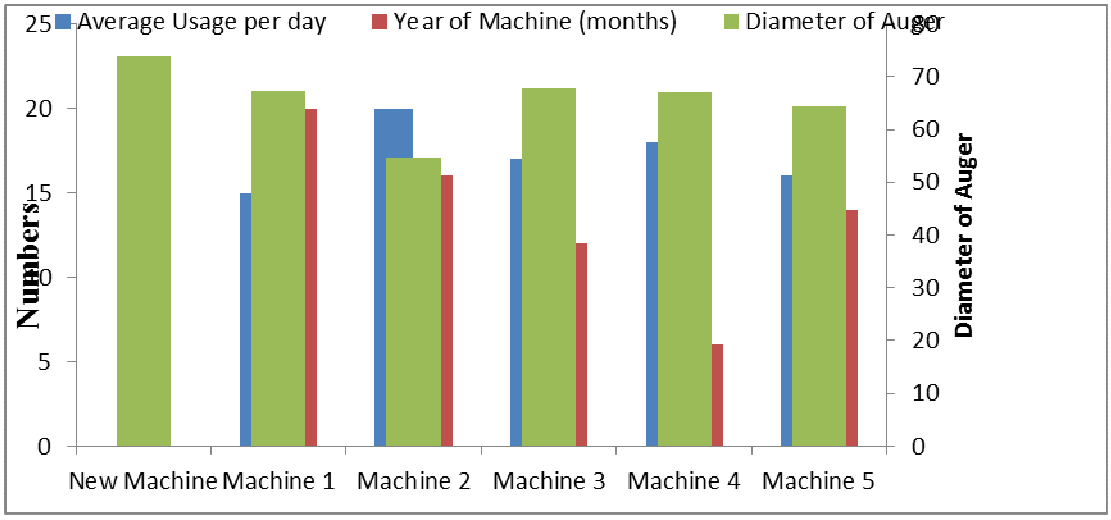

Figure 8: Auger diameter in relation to year of usage in Market 1

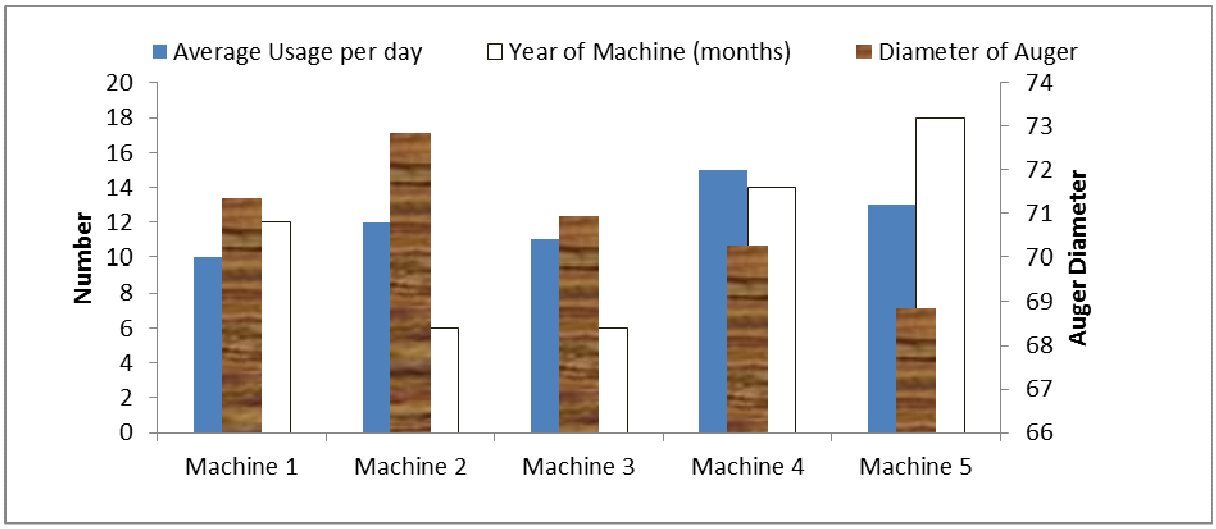

Figure 9: Auger diameter in relation to year of usage Market 2

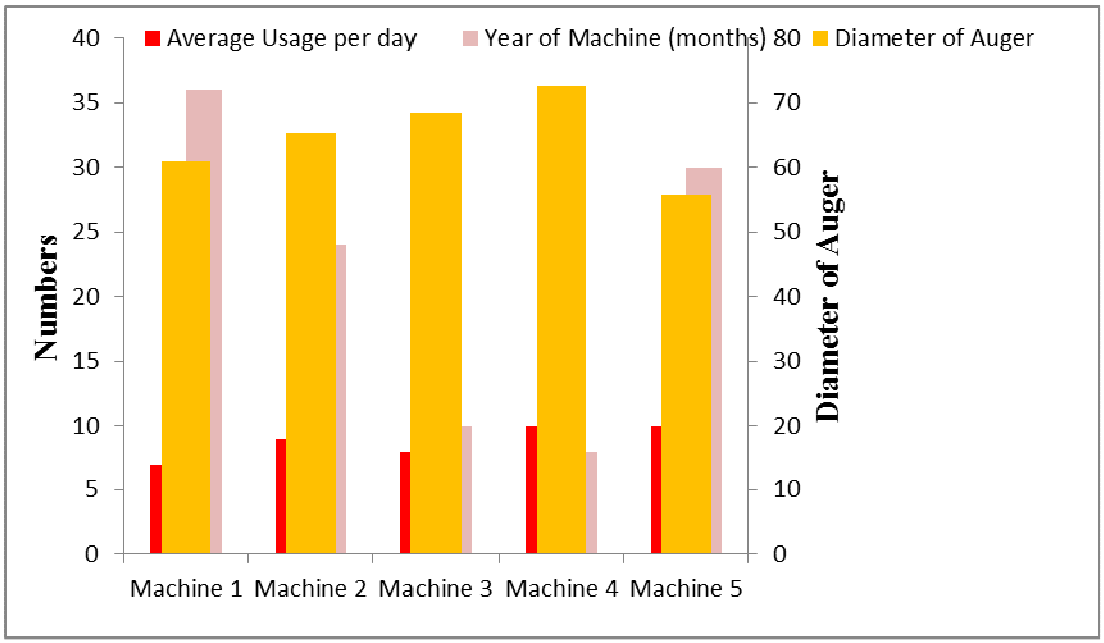

Figure 10: Auger diameter in relation to year of usage Market 3.

Plates 3, 4 and 5 helps extensively in the observation made on the different level of wear and tear that occurred on the auger of a typical pepper grinding machine. In Plate 3 and 4 it was discovered that the rod used in making the auger has worn to the point that it became smooth thereby resulting to reduction in auger diameter when compared to that of Plate 5 which shows a new auger shaft. Also Plate 4 shows that the auger is undergoing defects which is due to usage with a wear-off part of the auger, causing a discontinuation in the overall strength of the auger which when subjected to an excessive workload could result into breakage of the shaft. On inspection there is reduction in the helix of the auger with time coupled with an increase in the auger housing clearance which allows leakage through the covering plate of the internal diameter of the auger housing made possible due to wear and tear that had occur at this part of the machine. Also the shaft outlet on the covering plate was discovered to have impacted some level of wear and tear on the shaft diameter at that point, this defect gives rise to ground produce loss both in the wet and dry milling.


Plate 3: Auger in a Wet Milling Machine. Plate 4: Auger in a Dry Milling Machine

Plate 5: Newly Fabricated Auger Shaft.

CONCLUSIONS

It could be concluded that the selected materials of construction of the working mechanisms of the grinding machine which is part of design consideration of the machine are susceptible to wear and tear.

The auger-shaft incorporated in the pepper grinding machine is subjected to wear and tear when in use. Wear and tear level is in respect to usage years of the machine which is in direct relation to the reduction in the auger diameter; this is as a result of the interaction between auger and its housing due to insufficient housing clearance while the level of wear is adjudged to be construction material susceptibility to wear.

Little or no attention is given to the level of wear of the auger by the operator of the machine until an unexpected breakage occurred. The broken auger-shaft is amended if the point of breakage is the helix part, but if not the whole shaft is replaced.

There is reduction in burr plate (stone) thickness with time as a result of the bluntness of plate abrasive surface after use over a considerable number of times. Periodical re-sharpening of plate in order to maintain its sharpness is undertaken to achieve uniform throughput of the introduced produce. When re-sharpening of the plate results in uneconomical situation where more power is required to reduce agro-produce total replacement of plate is considered.

Noise pollution resulting from the working parts of the machine impedes the hearing aid of operators.

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