DECLARATION

I hereby declare that this dissertation is my work towards the award of Bachelor of Science Degree.

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DEDICATION

This work is dedicated to Mr. and Mrs. Atubga and my siblings.

ACKNOWLEDGEMENT

I wish to first and foremost acknowledge the Almighty God who in His boundless mercy and love has brought me this far in life. To Him be all the glory and honour.

To my supervisors Prof. Ebenezer Mensah and Dr. George Obeng, I highly appreciate your constant supervision and guidance without which the completion of this thesis would not have been possible. To all other Lecturers of Agricultural Engineering Programme, I say thank you.

To my colleagues and course mates, I say thank you very much for all the love, support and friendship you showed me during my four year stay on campus for the taught and practical aspect of the programme.

Finally, I wish to express my appreciation to Technology Consultancy Center (TCC) KNUST, MIT D-Lab IDIN Project for funding the project and the drivers for transporting us throughout the project.

Finally, special thanks go to my parents who inspire me to pursue whatever is before me, without their continuous love and support this would not have been possible. I say a big thank you for all you have done for me.

ABSTRACT

Rice imports in Sub Saharan Africa accounts for more than 30% of the world's imports even though it grows a lot of rice. In considering the evaluation of the hand and foot operated threshers suitable for small-scale rice farms, the threshing speed, threshing losses, drudgery, threshing efficiency and threshing capacity were the key factors. This study therefore evaluated the hand and foot operated manual threshers to suggest the better method of threshing rice. The tests were carried out at "Nabewam" in the Ejisu Juabeng District of the Ashanti Region of Ghana to assess the hand and foot operated rice threshers. Materials used in carrying out the tests included plastic sampling bags, a weighing scale, a tachometer and a pressure monitor. The tests recorded the average speed in using the foot operated thresher to be 158.3 rpm, relatively higher than the average speed recorded in using the hand operated rice thresher which was 136.6 rpm. Loss recorded was 12% in using the hand operated rice thresher whereas loss recorded in using the foot operated thresher was 29.6%. The heart rate per kg in using the foot operated thresher was recorded as 32 beats/kg, whereas the hand operated rice thresher recorded a heart rate per kg of 35.8 beats/kg. The hand operated rice thresher had an efficiency of 88% whereas the foot operated thresher had an efficiency of 70.4%. The tests suggested that, the size of the foot operated rice thresher drum length should be increased from 450mm to 545mm, which is equivalent to the drum length of the hand operated rice thresher, to increase the threshing capacity. The test also suggested that the hand operated rice thresher should be covered at the top to prevent spillage losses.

ABBREVIATIONS

FAO	Food and Agriculture of the United Nations
IRRI	International Rice Research Institute
Kg	Kilogramme
rpm	Revolutions per minute
bpm	Beats per minute
mm	Millimeters
USDA	United States Department of Agriculture
rev/min	Revolutions per minute
kg/hr	Kilogramme per hour

Contents

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Rice, as a cereal grain is the most widely and commonly consumed food by an enormous part of the world's population. Rice a crop ranked third in worlds most produced crops, behind sugarcane and maize according to FAOSTAT (2012) data.

Rice provides caloric nutritional needs and hence, grown in different environments where water is readily available for irrigation. Rice requires sufficient water to grow. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures worldwide (Wikipedia, 2016). The soil used in growing rice should have a good water holding capacity. Silt clay, silt clay loam and clay are some of the soil textures that are suitable for rice production. The pH of the soil should be 6 or 7, but rice can also do well in a pH ranging from 4 to 8.

The cycle for rice is 190 days with its harvesting season lasting for 30 days in mid-September to October. In order to decrease moisture content of harvested paddy, the crop is left in the field and then bundled and threshed (Alizadeh and Bagheri, 2009). During 2014, global rice exports totaled US$ 24 Billion, representing a 21.3% improvement from 2010 to 2014, but a 2.9% decline from 2013 to 2014. Countries with the highest dollar value worth of rice exported during 2014 include India, Thailand, Pakistan, United States, Vietnam, Italy, Uruguay, Brazil and China, who contributed 86.3% of global rice exports.

Africa became a big player in international markets, accounting for 32% of global imports in 2006, at a record level of 9 million tons that year. Africa's emergence as a big rice importer is explained by the fact that during the last decade rice has become the most rapidly grown food in sub-Saharan Africa. Due to population growth, rising incomes and a shift in consumer preferences, the relative demand for rice is faster in Africa than anywhere in the world (Eklou *et al.,* 2008)

The main challenge of rice production in Africa is with its inferior quality as compared to the imported rice. Domestic rice is of uneven quality and has impurities.

In Ghana, the total area of hectares under rice cultivation is about 81,000 hectares (ha), with varieties including, IR-66, IR-72, Akpafu, ITA-304, TOX-3108 and B-189 (Manful *et al*., 1996)

Rice is usually harvested when the rice grains reach a moisture content of about 25%. After harvesting, threshing of the rice is done usually within two days. Threshing is the process of removing grains from the ear heads of crops. Threshing is continually done by hand in most parts of Ghana by beating, treading or by holding the rice crop against a rotating drum with spikes or rasp bars. Farmers in the beating process hold the crop by the sheaves and beat them against slatted bamboo, wooden platforms or any other hard surfaces and objects such as steel drums. But these processes have been observed to be labor intensive and slow thus, making locally produced rice uncompetitive, compared to the imported rice.

The general name for machines that involve the process of removing grains from ear heads of crops is a thresher. Threshers were first invented by Scottish mechanical engineer, Andrew Meikle for agricultural use (Wikipedia, 2015). In 1784, the thresher was invented to separate grains from stalks and husks. Mechanical threshers could be manually operated or motorized (Chukwu, 2008).

The manual rice threshers, which included the hand operated, and the foot operated rice threshers were evaluated to determine threshing speeds, losses and drudgery in the process of threshing. The hand and foot operated rice threshers were considered since the mechanically operated rice threshers are cost demanding for local farmers. The inefficiency of manual threshing and winnowing, seasonal drudgeries of the women and the children in West Africa worsens its losses: damaged and broken grains sensitive to the damage of storage and commercial low value. The policies which promote the local production as well increase the workload of the producers. So manual threshing and winnowing being already arduous require more labour (Azouma *et al.,* 2009).

In considering the evaluation of the hand and foot operated threshers suitable for small-scale rice farms, a number of key factors would be considered. These may include comparing their threshing rates, their threshing losses, their output quality and their ease of use as well.

The hand and foot operated rice threshing machines were tested with the aim of assessing the threshing performance and gathering feedback from farmers to evaluate the efficiencies of the hand and foot operated rice threshers to determine which will be suitable for local rice farmers.

1.2 Problem statement

In 2008, Ghana imported 340,000 MT of rice, which increased to 600,000 MT in 2015(USDA, 2016), due to the drudgery in threshing large amounts of rice traditionally. Hence, this project will evaluate the efficiencies of the hand and foot operated threshers to suit local rice varieties as well as improve the quality of locally produced rice and also reduce importation.

1.3 Justification

The performance evaluation of the hand and foot operated rice threshers will provide information that will be potentially used to produce cost effective and affordable threshers for poor local farmers, suitable for rice varieties in Ghana.

1.4 Main objective

The main objective of this study is to evaluate the performance of the hand and foot operated rice threshers.

1.5 Specific objectives

The specific objectives of this study are to:

1. To determine the capacity and threshing efficiencies of the hand and foot operated manual rice threshers.
2. To measure the drudgery associated with operating the hand and foot rice threshers.
3. To measure the threshing speed and losses during threshing, by the hand and foot rice threshers.

CHAPTER TWO

LITERATURE REVIEW

2.1 Threshing Operation

Threshing operation involves the detachment of paddy kernels or grains from the panicle. Depending on the influence of agronomic, economic and social factors, threshing is done in different ways. It can be achieved by rubbing action, impact and stripping. The rubbing action occurs when paddy is threshed by trampling by humans, animals or tractors. The impact method is the most popular method of threshing paddy. Most mechanical threshers primarily are the impact principle for threshing, although some stripping action is also involved. The difficulty of the process depends on the varieties grown, and on the moisture content and the degree of maturity of the grain.

Paddy threshers may either be the hold-on or throw-in type of feeding. In the hold-on type, paddy straws are held stationary while threshing is done by the impact on the particle from cylinder bars spikes or wire loops. In the throw-in type of machines, whole paddy stalks are fed into the machine and a major portion of the grain is threshed by the initial impact of the bars or spikes on the cylinder. The initial impact also accelerates the straw and further threshing is accomplished as the moving particles hit the bar and the concave. The third type, stripping has also been used in paddy threshing. Some impulsive stripping occurs ordinarily with impact threshing in conventional threshing cylinders. In the throw-in type of thresher, large amounts of straw pass through the machine. The primary aim of threshing machines is to reduce the labour required for the threshing process. Farmers indicated that the overall threshing rate is more important than the rate per person, as paddy must be threshed as soon after harvesting as possible. Once threshing rate is accurately determined, this may be used for an economic analysis of the threshing method (Selco foundation, 2013).

IRRI defines threshing losses as scattering loss, threshing loss and grain breakage (2009). While these losses may be significant for industrial scale machines, it was found that detailed measurement of these factors was not practical or particularly informative when testing small-scale machines. The farmers themselves are a good judge of threshing quality and therefore can be asked to evaluate the output and threshing loss instead of using quantitative measurements (Selco foundation, 2013). Threshing force; which is the force that separates a grain from the panicle has a great importance in evaluating losses over design, application of harvesting and threshing machines (Alizadah, 2011).

2.2 Manual threshing

Traditional rice farmers carry out threshing in different ways. These methods are however local, inefficient and laborious, besides, they are only suitable for small scale farming, they include; beating on hard or wooden object or screen, sometimes pedal operated threshing drums are employed in fairly big farms (Olumuyiwa *et al.*, 2014). One of the simplest systems for threshing rice is to pick up the sheaf of rice and strike or beat the panicles against a hard surface such as a tub, threshing board or rack; or beating the sheaves spread out on a threshing-floor with a flail or a stick or tramples it underfoot. The threshing-floors on which the sheaves are spread must have a hard, clean surface. The pedal-operated thresher consists of a rotating drum with wire loops which strip the grains from the panicles when fed by hand. It can be operated by women and can be used in hilly or terraced areas because of its portability. By using one of these methods of hand-threshing, a worker can obtain 15 to 40 kg of product per hour (Ola *et al*., 2009). Rural women have primary responsibility of running household, procuring fuel, fodder, water and care of children as well as other family members. Women play a significant and crucial role in agricultural operations; including different crop production activities, postharvest activities etc. (Kwatra *et al.,* 2010)

2.3 Threshing with hand-driven machines

Machines driven by a manual device or a pedal are often used to improve yields and working conditions during threshing. By means of the handle or pedal, a big drum fitted with metal rings or teeth is made to rotate. The rice is threshed by hand-holding the sheaves and pressing the panicles against the rotating drum. The hand-held sheaves must all be of the same length with the panicles all laid in the same direction, and the grains must be very ripe and dry. The machine must be continuously and regularly fed, but without introducing excessive quantities of product (Khan and Salim, 2005).

If the paddy obtained contains too many unthreshed panicles and plant residues, a second threshing must be followed by an effective cleaning of the product. Use of these threshing machines may require two or three workers. The interesting characteristics of manual threshers are their ability to generate and sustain required torque for a reasonable length of time and they do not suffer appreciable mechanical damage. The foot pedal is able to deliver a velocity ratio of as high as 1: 10 reaching an average speed of between 150 – 200 rev/min. Speed delivered equals pedal speed x velocity ratio.

The manual threshers were developed with the aim of having a thresher that will not run on petrol engine or electric motor but rely solely on human power, the various manual threshers share similar characteristics judging by their advantages and disadvantages (Olanrewaju *et al*., 2014).

According to Adewumi *et al,* the results of the performance analysis showed that threshing efficiency increased with an increase in cylinder speed and threshing efficiencies was found to be in the range of 54.5% to 100% (2007)

The machine must be continuously and regularly fed, but without introducing excessive quantities of product. Use of these threshing machines may require two or three workers.

Depending on the type of machine, the skill of the workers and organization of the work, yields can be estimated at a maximum of 100 kg/h. (Adewumi *et al*., 2007)

2.4 Threshing with animals or vehicles

If draught animals are available and there are large quantities of rice, threshing can be done by driving the animals in the form of harnessing; in that case, to threshing devices over a layer of sheaves about 30 cm thick. This operation, which is also called “treading out”, can equally well be accomplished with vehicles. This method of threshing rice is adopted in some Asian countries, using a tractor for power instead of draught animals. Paddy is obtained by running the tractor twice over sheaves of rice that are spread in layers on a circular threshing-floor 15-18 m in diameter. The sheaves must be turned over between the two passages of the tractor. If operations are alternated between two contiguous threshing-floors, yields of about 640 kg/h can be obtained.

2.5 Threshing with motorized equipment

Although they are gradually being replaced by combine-harvesters, motorized threshing-machines still have an important place in the postharvest production process, especially for their convertibility. By the simple replacement of a few accessories and the appropriate changes in settings, these machines can treat different kinds of grain (e.g. rice, maize, sorghum, beans, sunflowers, wheat, soybeans, etc.).

Yields depend on the type of machine, the nature and maturity of the grain, the skill of the workers and organization of the work, and they can vary from 100 to 5 000 kg/h

2.6 General Features of Threshers

Most, if not all powered paddy threshers are equipped with one of the following types of cylinder and concave arrangement: (a) rasp bar with concave (b) spike tooth and concave (c) wire loop with concave (d) wire loop without concave. Tests by the International Rice Research Institute, IRRI indicated that the spike tooth cylinders performed well both with the hold-on and the throw-in methods of feeding and its threshing quality is less affected by changes in cylinder speed. In the axial-flow thresher, the harvested crop is fed at one end of the cylinder/concave and conveyed by rotary action on the spiral ribs to the other end while being threshed and separated at the concave.

Paddles at the exit end throw out the straw and the grain is collected at the bottom of the concave after passing through a screen cleaner. Several versions of the original IRRI design of the axial-flow thresher have been developed in most countries to suit the local requirements of capacity and crop conditions. Thus, there are small-sized portable ones and tractor PTO-powered and engine-powered ones. Many custom operators in Asia use the axial flow threshers to satisfy the threshing and grain cleaning requirements of rice farmers.

2.7 Mechanics of Grain Threshing

The process of mechanical threshing involves the interaction of machine and crop parameters for the separation of the seed from the pod. Threshing is carried out between a stationary concave and a rotating cylinder. Different configurations of threshing devices have been used. The two types generally employed in present day stationary threshers and combines are rasp bar cylinders and spike tooth cylinders. The latter are used almost exclusively in pea threshers. Also, rubber covered flat bars have been employed on cylinders and concaves for threshing small seed legumes such as crimson clover, giving less damage and less unthreshed loss than the conventional spikes.

High-speed motion pictures have shown that the main threshing effect in peas or cereals results from the impact of the cylinder bars at high speeds with the pods. The primary function of the concave appears to be that of holding and presenting the material to the cylinder bar for repeated impaction. A spike tooth has been shown to have a more positive feeding action than a rasp bar cylinder does not plug easily, and requires less power.

However, rasp bar cylinders are readily adaptable to a wide variety of crop conditions; are easy to adjust and maintain, and relatively single and durable.

Various parameters are in use for evaluating the performance of threshers and determining and retaining the quality of the through-put. The parameters include; threshing effectiveness, grain damage, sieve effectiveness, cleaning efficiency and seed loss. Studies have shown that threshing effectiveness is related to the peripheral speed of the cylinder, the cylinder-concave clearance, the number of rows of spikes, the type of crop, the conditions of the crop (in terms of the moisture content and stage of maturity), and the rate at which material is fed into the cylinder.

Cylinder speed is the most important machine operating parameter that affects seed damage. Increasing the speed substantially increases seed damage. Reducing the cylinder concave clearance tends to increase seed damage but the effects are generally rather small in comparison with the effect of increasing cylinder speed. Susceptibility to damage varies greatly among crops.

Threshing trials conducted on soya bean and cowpea pods in a rasp bar cylinder thresher showed that visible grain damage was greater in cowpea for the same cylinder speed and concave clearance, and this affected seed germination. The seeds of some dicotyledonous plants such as beans may be damaged excessively at low cylinder speeds, whereas those of non di-cotyledons can withstand very high cylinder speeds without appreciable damage. It has been asserted in literature that mechanically damaged grains do not keep well in storage and are prone to fungal and bacterial infections when stored. The field emergence of such damaged seeds is generally poor.

2.8 Drudgery

High work stress has repeatedly been associated with increased risk for cardiovascular disease. This association could derive in part from detrimental effects on blood pressure (BP) by recurrent autonomic nervous system reactivity to work-related stressors. Evidence for such work-stress effects comes from ambulatory BP studies, which show increased blood pressure levels in subjects with high work stress. Work stress in these studies was usually defined as job strain according to the model of Karasek and coworkers (Tanja *et al*., 1999). The commonly performed agricultural activities in India were weeding, cutting/ uprooting, transplanting, threshing and mannuring. Drudgery is generally conceived as physical and mental strain, agony, monotony and hardship experienced by human beings while all of women in this regard are alarming as they continue to be constrained by illiteracy, malnutrition and unemployment. Many believe that women's involvement in agricultural tasks and large is a source of heavy burden of drudgery on them Observation of heart rate is a simple and a reliable method of analyzing the workload on the person. The physiological cost of work is expressed in terms of increased heart rate and oxygen consumption (Karnataka, 2006). The average working heart rate (HR work) of the subjects when the paddy threshing was done manually by beating ranged between 143 to 166 beats/min. with a mean HR value of 154.5 beats/ min. The corresponding HR values with the use of manual paddy thresher ranged between 120-125 beats/min. with a mean value of 122.5 beats/min (Kwatra *et al.,* 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment site

The study was conducted at Nabewam, Konongo, in the Ashanti Region.

Fig3.1 Map of Nabewam

3.2 Sources of rice samples

Rice grain samples were obtained from rice farms at Nabewam in the Ashanti Region of Ghana. Test samples were from the 2016 growing season.

3.3 Materials

Hand operated rice thresher

Foot operated rice thresher

Plastic sampling bags

Unthreshed rice

A weighing scale

A tachometer

A pressure monitor

A bucket

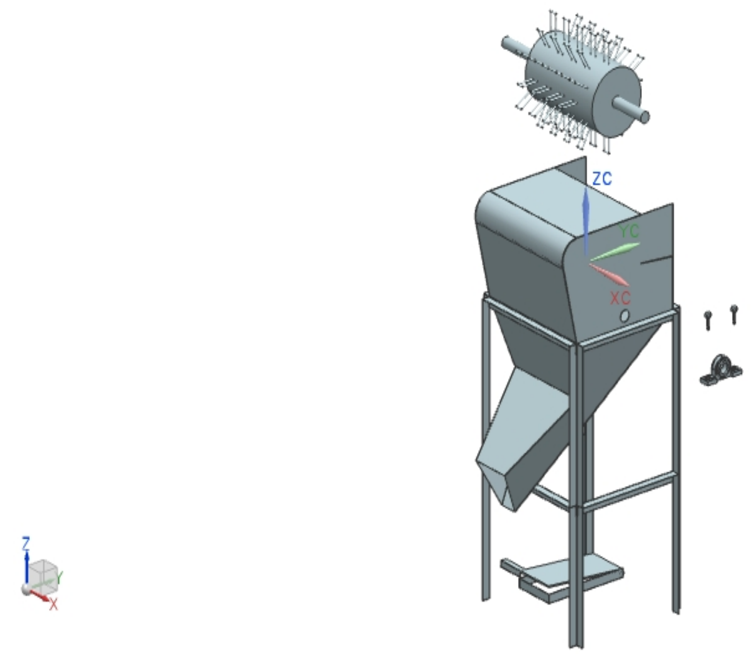

Fig3.2 The foot operated rice thresher in 3D

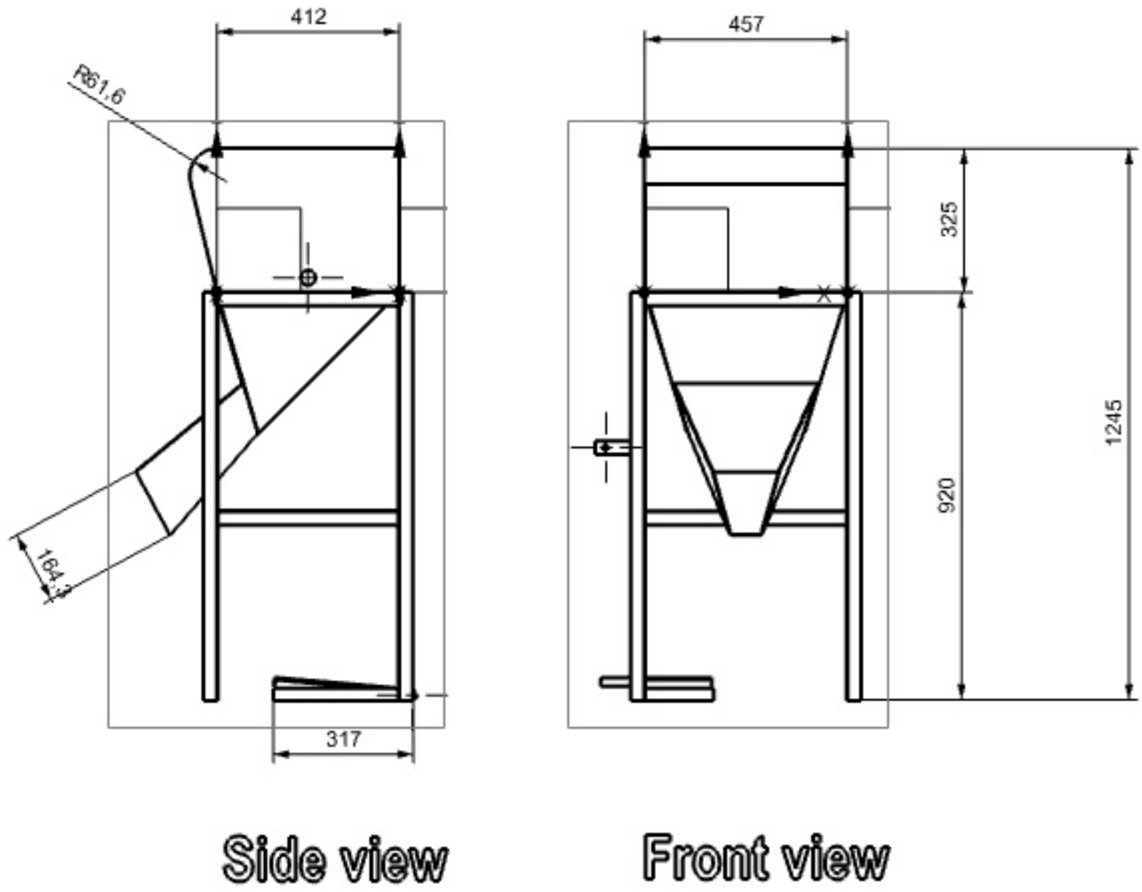

Fig3.3 The foot operated rice thresher in 2D

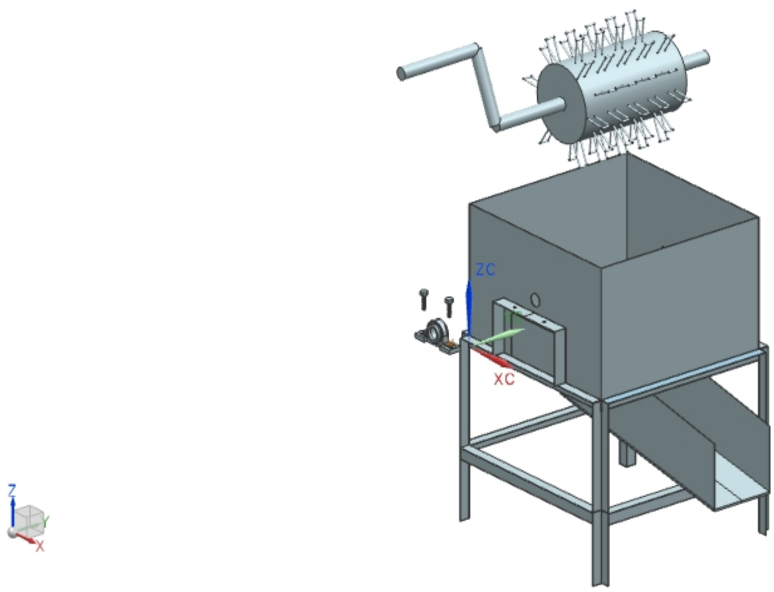

Fig3.4 The hand operated rice thresher in 3D

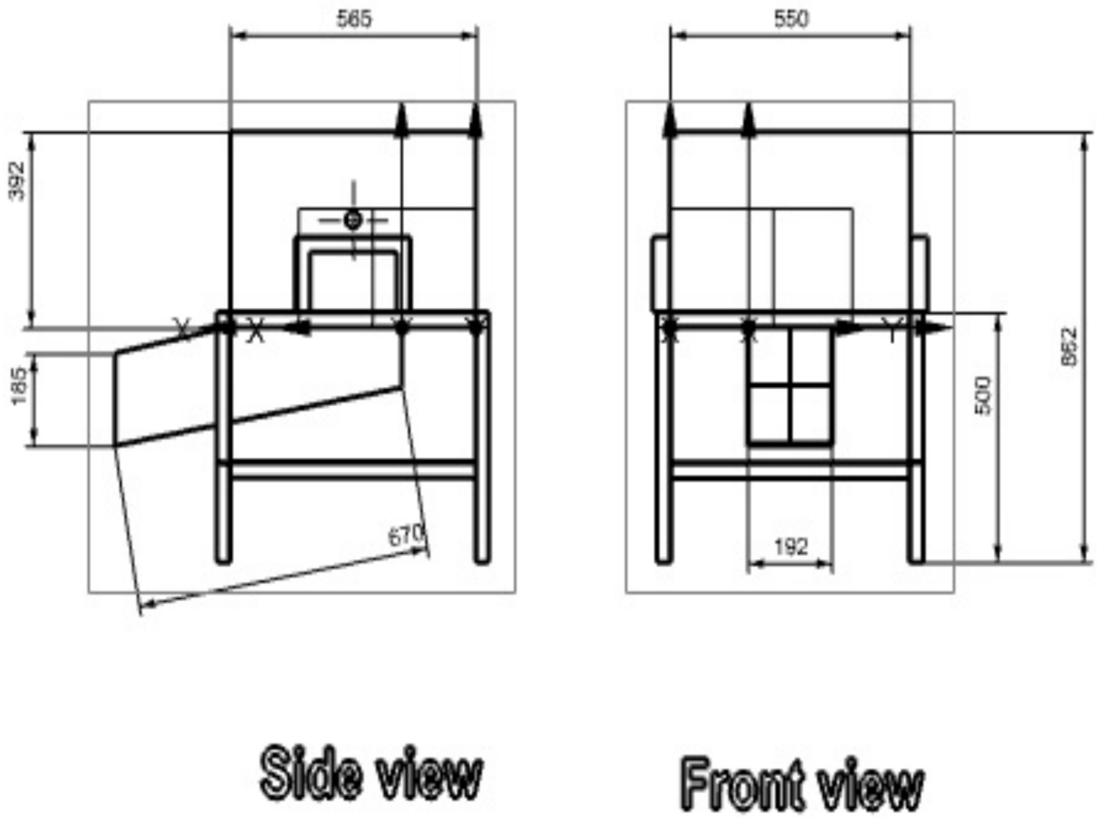

Fig3.5 The hand operated rice thresher in 2D

3.4 Threshing process

The hand and foot operated manual threshers were developed at the RTF center in Konongo in the Ashanti region.

To thresh the rice, a stalk was placed on the rim of the thresher by one individual and rotated by the handle by the operator to thresh the rice in the case of the hand operated thresher and in the case of the foot operated thresher, the operator kept applying force on the foot pad to cause the threshing process to be carried out when the rice stalk was placed on the rim of the thresher by an individual. In the process of threshing, the rice stalk was also turned in order to have the wire loops of the thresher thresh all the grains on the stalk. The moisture content of the rice before threshing and the speed of the rotating rim play important roles in the determination of the efficiency of the thresher.

3.5 Determination of loss percentage

The following relationship was used to calculate the percentage losses of the hand and foot operated rice threshers

$$\text{Scattering losses percentage} = \frac{\text{Scattered grains(kg)} \times 100}{\text{Total seed(kg)}}$$

$$\text{Un-stripped grain percentage} = \frac{\text{Un−stripped grains(kg)} \times 100}{\text{Total seed(kg)}}$$

Hence, total loss %= Scattering losses percentage + Un-stripped grain percentage

3.6 Determination of capacity

The following relationship was used to calculate the capacity of the hand and foot operated rice threshers.

Threshing capacity= $\frac{\text{Total grain input(kg)} \times 60}{\text{Total time in minutes(kg)}}$

3.7 Determination of efficiency

The following relationship is used to calculate the efficiencies of the hand and foot operated rice threshers according to Tamiru and Teka (2015).

Threshing efficiency= $\frac{\text{Threshed seed(kg)} \times 100}{\text{Total seed(kg)}}$

3.8 Drudgery determination

The relationship below is used to calculate the drudgery in using the hand and foot operated rice threshers according to Mohanty *et al.* (2008).

ΔHRKG= [ΔHR/C].60

Where,

ΔHRKG= Increase HR/kg of grain threshed, beat/kg

ΔHR= (Mean working HR- Resting HR), beats/min

C= Capacity of the thresher, kg/h

3.9 Method

3.9.1 Traditional threshing

Before the process of threshing rice traditionally using the "BAMBAM" box, the initial body pressure readings of the farmer were taken using the pressure monitor, so as to be able to compare the readings to determine the drudgery involved in the process. The pressure readings included the farmer's systolic pressure, diastolic pressure and pulse. In the process, the farmer threshed an amount of 10kg for 7 trials, within which initial and final pressure readings were recorded with rest periods of 3 minutes so as to prevent a situation where there would be stresses from previous trials affecting subsequent readings.

After the 7 trials, the total amount of rice collected in the "BAMBAM" box were recorded, as well as the scattered rice grains, which together aided in determining the losses, efficiency and output of the method of threshing.

With this process, the amount of rice grains attainable from unthreshed rice samples was estimated to make it possible to determine threshing efficiencies.

3.9.2 Hand and foot operated threshing

Before these processes of threshing were carried out, the initial pressure readings of the farmer were taken and an amount of 1kg of rice was threshed for 10 trials using the hand and foot operated rice threshers each, within which initial and final pressure readings were taken as well as the speeds of the threshing drum, with the aid of a tachometer. Rest times were taken to be 3 minutes between trials and the total time used in threshing were also recorded using a stop watch, which aided in determining the threshing rate for the processes.

3.10 Data Analysis

The data collected were analyzed using Microsoft Excel. The data was used to plot graphs of values recorded from field tests carried out on the hand and foot operated rice threshers.

CHAPTER FOUR

RESULTS AND DISCUSSION

The rice threshers were installed on a level hard surface ground. Sufficient quantities of the Jasmine rice were made available for threshing. In the process of threshing, the threshing efficiency, the threshing speed, drudgery and losses involved in threshing rice using the hand and foot operated rice threshers were measured, recorded and compared.

4.1 Threshing speed

The speeds for which the hand and foot operated threshers operated for 10 test trials were recorded using a tachometer and compared.

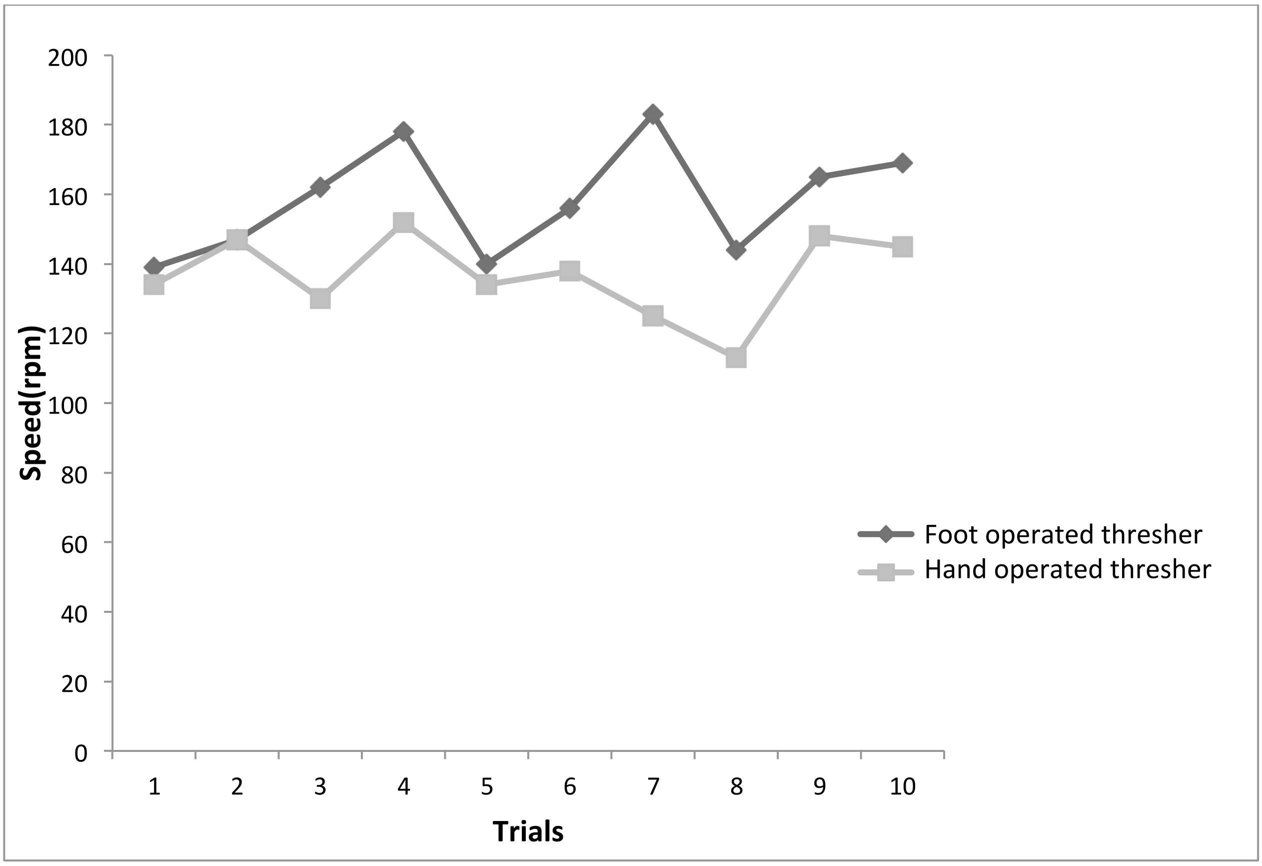

Figure 4.1 Comparison of speeds of the foot and hand operation of thresher

During the experiment, the threshing speed of the foot operated rice thresher ranged from 139rpm to 183rpm with an average speed of 153.8 for ten test trials, whereas the threshing speed of the hand operated rice thresher ranged from 113rpm to 152rpm with an average speed of 136.6rpm also for ten test trials, indicating that the foot operated rice thresher would be favourable if higher threshing speeds would be required. Also from the recorded speeds(Figure 4.1) , the coefficient of variation for the speeds of the hand and foot operated rice threshers were found to be 0.08 and 0.09 respectively which showing that, the hand operated rice thresher was able to keep threshing speeds constant for test trials as compared to the foot operated thresher.

4.2 Drudgery

The systolic pressure readings for using the hand and foot operated rice threshers were recorded for 10 test trials and compared.

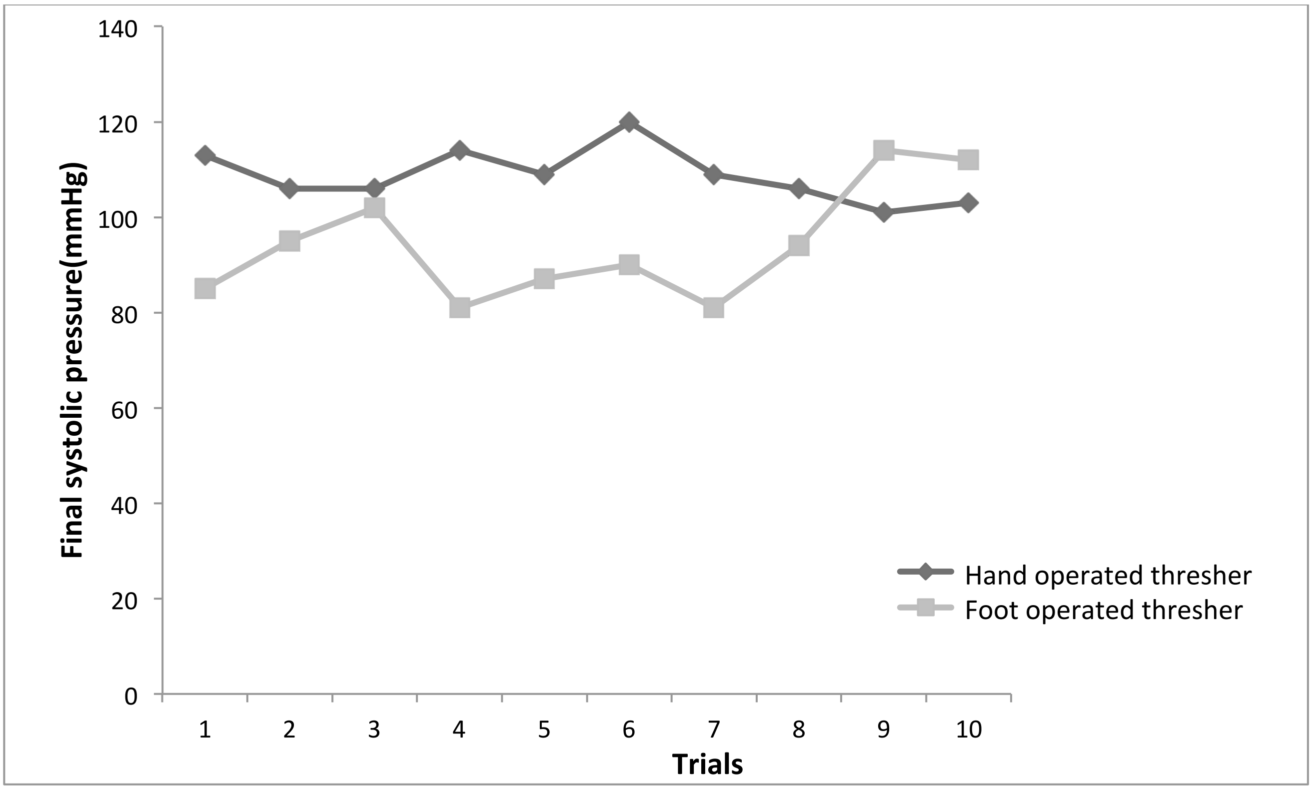

Figure 4.2 Comparison of systolic pressures of the hand and foot operation of thresher

Before the experiments were carried out, the initial systolic pressure reading of the 45 year old operator was 72mmHg. During the experiment, the systolic pressure readings recorded in using the foot operated rice thresher ranged from 81mmHg to 114mmHg for ten test trials whereas the systolic pressure readings recorded in using the hand operated rice thresher ranged from 101mmHg to 120mmHg after 10 test trials. Since systolic pressure indicates a measure of stress, the figure above (figure 4.2) indicates that the hand operated rice thresher will inflict more stress on an operator than the foot operated rice thresher for initial trials and shows that the foot operated thresher could be more stress inflicting over a number of test trials.

The diastolic pressure readings for using the hand and foot operated rice threshers were recorded for 10 test trials and compared.

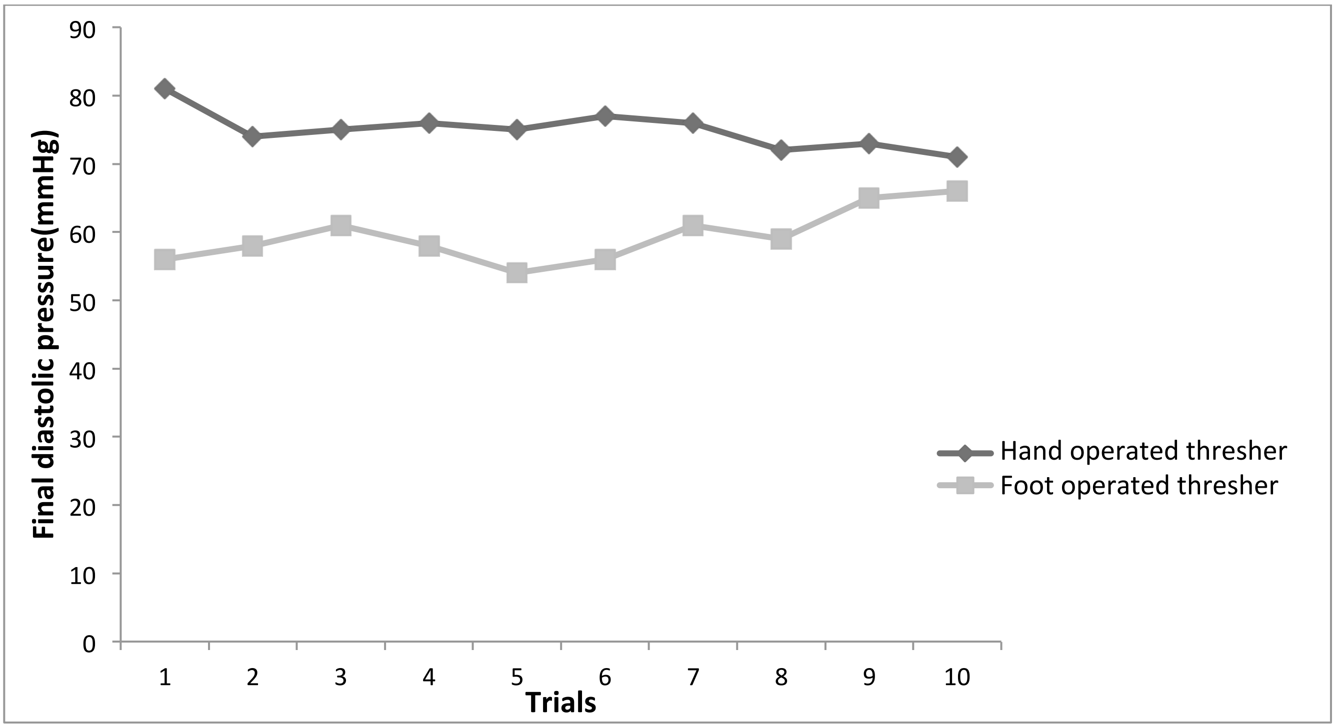

Figure 4.3 Comparison of diastolic pressure of the hand and foot operation of thresher.

Before the experiment, the initial diastolic pressure reading of the operator at rest was 49mmHg. During the experiment, the diastolic pressure readings recorded in using the foot operated rice thresher ranged from 54mmHg to 66mmHg for ten test trials whereas the diastolic pressure readings recorded in using the hand operated rice thresher ranged from 71mmHg to 81mmHg after 10 test trials. Since diastolic pressure also indicates a measure of stress, the figure above (figure 4.3) also indicates that the hand operated rice thresher inflicts more stress on the operator than the foot operated rice thresher for the recorded test trials.

The pulse readings for using the hand and foot operated rice threshers were recorded and compared

Table 4.1 Comparison of pulse of the hand and foot operation of thresher

Thresher	Pulse (bpm)	Mean pulse (bpm)	Capacity (kg/hr)	Heart rate/kg (beats/kg)
Hand operated	86-69	76.8	43.25	35.8
Foot operated	80-67	72.7	40.68	32

The table above shows the trend in the rise of heart rate per kg of threshed rice. The heart rate per kg in using the foot operated thresher was 32 beats/kg, whereas the hand operated rice thresher recorded a heart rate per kg of 35.8 beats/kg. This showed that, to thresh 1kg of rice using the foot operated thresher, heart rate increases by 32 beats and thus, less drudgery inflicting than the hand operated rice thresher, which causes a 35.8 increase in heart rate to thresh 1kg of rice. The heart rate of the operator at rest was recorded to be 51 beats/min.

4.3 Threshing capacity

The threshing capacities for the hand and foot operated rice threshers were calculated and compared.

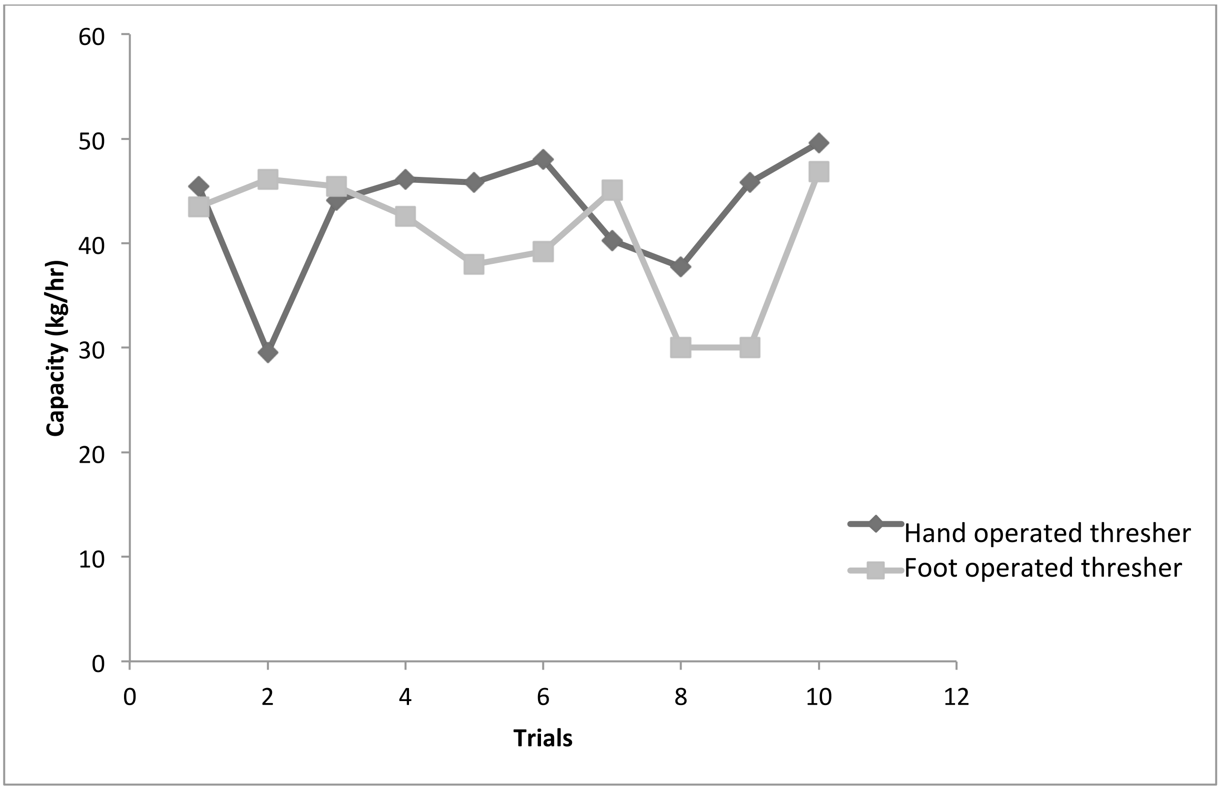

Fig 4.4 Comparison of the threshing capacity of the hand and foot operation of thresher

From the experiment, the foot operated rice thresher had an average threshing capacity of 40.68 kg/hr after 10 test trials, with capacity readings ranging from 30 kg/hr to 46.15 kg/hr, whereas the hand operated thresher had an average threshing capacity of 43.25 kg/hr after 10 test trials, with readings ranging from 29.5 kg/hr to 48 kg/hr, indicating that the hand operated rice thresher will be able to thresh 43.25kg of rice in an hour, whereas the foot operated rice thresher will thresh 40.68kg of rice in an hour. Thus, making the recorded capacity readings fall within the range stated by Adewumi *et al*. (2007).

4.4 Threshing losses

The threshing losses for the hand and foot operated rice threshers were calculated and compared with results showing that the foot operated rice thresher had scattering losses of 0% after 10 test trials, whereas the hand operated rice thresher recorded scattering losses of 5% after 10 test trials, indicating that the hand operated rice thresher gave more room for scattering losses to occur, thus making the foot operated rice thresher preferred if scattering losses are to be kept at it's lowest possible level.

Rice grains that were un-stripped were also classified as losses. 10kg of rice straw contained 3.89kg of rice grains. The hand operated thresher recorded 7% of un-stripped grains, whereas the foot operated rice thresher recorded 29.6% of un-stripped grains indicating that, the hand operated rice thresher was able to thresh more rice grains from straws as compared to the foot operated thresher.

The hand operated thresher thus provided a total loss of 12%, whereas the foot operated rice thresher gave a total loss of 29.6%.

4.5 Threshing efficiency

The threshing efficiencies for the hand and foot operated rice threshers were calculated and compared.

Table 4.2: Efficiencies of the hand and foot operated rice threshers

Thresher	Mass of threshed rice (kg)	Mass of scattered losses(kg)	Mass un-stripped losses (kg)	Efficiency (%)
Foot operated rice thresher	2.8	0	1.18	70.4
Hand operated rice thresher	3.5	0.2	0.28	88

From the experiment, the foot operated rice thresher recorded an average efficiency of 70.4% after 10 test trials , whereas the hand operated rice thresher rcorded an average efficiency of 88% after 10 test trials, indicating that the hand operated thresher was much effective in threshing rice grains from straws than the foot operated thresher. Thus, readings fell within the range recorded by Adewumi *et al*. (2007).

Table 4.3 Summary data showing measured variables

Parameters	Hand	Foot
Amount (kg)	10	10
Total losses (%)	12	29.6
Efficiency (%)	88	70.4
Average Speed (rpm)	136.6	158.3
Capacity (kg/hr.)	43.25	40.68
Total threshing time(min)	14.17	15.13
Output (kg)	3.5	2.8
Systolic pressure (mmHg)	101-120	81-114
Pulse (bpm)	69-86	67-80
Mean pulse (bpm)	76.8	72.7
Heart rate/kg (beats/kg)	35.8	32
Diastolic pressure (mmHg)	71-81	54-66

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

The evaluation of the hand and foot operated threshers revealed the following.

1. The foot operated rice thresher had a capacity of 40.68kg/hr., whereas the hand operated rice thresher had a capacity of 43.25kg/hr.

   Also, the foot operated rice thresher had an efficiency of 88% as compared to the hand operated rice thresher with 70.4% efficiency.

2. The heart rate per kg in using the foot operated thresher was recorded as 32 beats/kg, whereas the hand operated rice thresher recorded a heart rate per kg of 35.8 beats/kg.

3. The foot operated rice thresher recorded an average speed of 158.3rpm in operation, whereas the hand operated rice thresher recorded an average speed of 136.6rpm. Also, the foot operated rice thresher recorded 29.6% losses during operation whereas the hand operated rice thresher recorded 12% losses.

5.2 Recommendations

- For the hand operated thresher, it is recommended that the top of the thresher should be covered to prevent spillage losses.
- For the foot operated thresher, it is recommended that the threshing drum length should be increased from 450mm to 545mm, which is equivalent to the drum length of the hand operated thresher, to increase the threshing capacity of the rice thresher.

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APPENDICES

Appendix 1: Tables of recorded data

Table 1 Readings of the hand and foot thresher speeds

Trials	Foot operated thresher Speed(rpm)	Hand operated thresher Speed(rpm)
1	139	134
2	147	147
3	162	130
4	178	152
5	140	134
6	156	138
7	183	125
8	144	113
9	165	148
10	169	145
Mean	158.3	136.6
Standard Deviation	14.89	11.39
Coefficient of variation	0.09	0.08

Table 2 Readings of the systolic pressure in using the hand and foot threshers

Trials	Hand operated thresher Final systolic pressure(mmHg)	Foot operated thresher Final systolic pressure(mmHg)
1	113	85
2	106	95
3	106	102
4	114	81
5	109	87
6	120	90
7	109	81
8	106	94
9	101	114
10	103	112

Table 3 Readings of the pulse in using the hand and foot threshers

Trials	Foot operated thresher Final pulse(beats per minute)	Hand operated thresher Final pulse(beats per minute)
1	80	70
2	67	76
3	75	76
4	74	75
5	72	83
6	74	80
7	70	69
8	69	86
9	73	80
10	73	73

Table 4 Readings of the diastolic pressure in using the hand and foot threshers

Trials	Hand operated thresher Final diastolic pressure(mmHg)	Foot operated thresher Final diastolic pressure(mmHg)
1	81	56
2	74	58
3	75	61
4	76	58
5	75	54
6	77	56
7	76	61
8	72	59
9	73	65
10	71	66

Table 5 Readings of the systolic, diastolic and pulse of using the traditional method of threshing

Trials	Final Systolic pressure (mmHg)	Final Diastolic pressure (mmHg)	Final Pulse (beat per min)
1	110	81	82
2	122	78	61
3	113	72	66
4	118	71	58
5	120	70	57
6	122	64	59
7	119	70	56

Table 6 Readings of the capacity of the hand and foot operated rice threshers

Trial	Input (kg)	Hand operated rice thresher		Foot operated rice thresher	
		Time (minutes)	Threshing capacity (kg/hr)	Time (minutes)	Threshing capacity (kg/hr)
1	1	1.32	45.45454545	1.38	43.47826087
2	1	2.03	29.55665025	1.3	46.15384615
3	1	1.36	44.11764706	1.32	45.45454545
4	1	1.3	46.15384615	1.41	42.55319149
5	1	1.31	45.80152672	1.58	37.97468354
6	1	1.25	48	1.53	39.21568627
7	1	1.49	40.26845638	1.33	45.11278195
8	1	1.59	37.73584906	2	30
9	1	1.31	45.80152672	2	30
10	1	1.21	49.58677686	1.28	46.875
Average	1	1.417	43.24768246	1.513	40.68179957

Appendix 2: Field images

Fig 1. A foot operated rice thresher

Fig 2 A hand operated rice thresher

Fig 3 Threshing of rice traditionally