DEVELOPMENT OF AN IMPROVED IAR SORGHUM THRESHER

BY

Nura Alhaji SALE

DEPARTMENT OF AGRICULTURAL ENGINEERING

AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA

MARCH, 2015

DEVELOPMENT OF AN IMPROVED IAR SORGHUM THRESHER

BY

Nura Alhaji SALE, B. ENG (BUK) 2009

M.Sc/ENG/5234/2011- 2012

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF
MASTERS OF SCIENCE DEGREE IN AGRICULTURAL ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING, FACULTY OF
ENGINEERING AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

MARCH, 2015

DECLARATION

I hereby declare that the work in this thesis titled “Development of an Improved IAR Sorghum Thresher” was performed by me in the Department of Agricultural Engineering under the supervision of Dr. M. A Gwarzo and Dr. U.S Mohammed

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at any institution.

Nura alhaji Sale **---------------------------** **-----------**

M.Sc/ENG/5234/2011- 2012 **Signature** **Date**

CERTIFICATION

This thesis titled “Development of an Improved IAR Sorghum Thresher” meets the regulations governing the award of the masters’ degree in Agricultural Engineering of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Dr. M. A. Gwarzo -------------------------- -------------------
Chairman supervisory committee (Signature) (Date)

Dr. U. S. Mohammed -------------------------- -------------------
Member supervisory committee (Signature) (Date)

Prof. M. L. Suleman -------------------------- -------------------
Head of Department (Signature) (Date)

Prof. Z. A. Hassan ------------------ -----------------
Dean, School of Postgraduate Studies (Signature) (Date)

DEDICATION

This work is dedicated to my parents Alhaji Sale Ibrahim Isah and Lami Yaya (Mama). I also dedicated the work to my family Sahura Lawan, Kadija Mu`a zu Ibrahim, Auwal Nura and Sale Nura Sale (Kalifa) for their support and encouragements throughout the entire study.

ACKNOWLEDGMENTS

In the name of Allah the beneficial the most merciful all thanks be to him the creator and sustainer of the world. To him we belong and to him we are seeking aid, support and forgiveness. May his infinite bounties and salutations be upon our noble prophet Muhammad (SAW), his household, companions and those who follow his guidance up to last Day.

My profound gratitude goes to my major supervisor, Dr. M. A Gwarzo who's moral Support, patience and diligence enabled me to complete this work. All the necessary Corrections he has given to me have made this work a success. My appreciation is also due to my co-supervisor, Dr. U. S Mohammed for his contribution throughout the work. I also thank the programmed leader Agricultural Mechanization Institute of Agricultural Research (IAR) Dr. M Isiaka for his support with materials and others for the construction of the prototypes. My appreciation goes to the workshop staff that assisted me in one way or the other during the construction of the machine, specifically Andrew Bako, Sunday Bature, Mr. Ola and Bashir Abdulsalam. Also my profound gratitude goes to my lecturers and colleagues in Agricultural Engineering Department for their contribution and support towards the completion of the work.

I also extend my appreciation to my colleagues in NAERLs for their advice and prayers. My special regard and appreciation go to my parent and family Alhaji Sale Ibrahim, Lami Yaya, Kadija Mu`azu Ibrahim, Sahura Lawan, Auwal Nura and Sale Nura Sale for their patients and support towards the completion of the work. May Allah blessed you all amen

ABSTRACT

Despite the high level of production of sorghum in Nigeria its threshing and cleaning operation remains among the major challenges to farmers especially in the northern part of the country. Efficient sorghum threshers are not available to Nigerian farmers. The prototype thresher developed at Institute for Agricultural Research (IAR) was associated with many problems such as: low out capacity, higher scatter loss and mechanical grain damage. To solve these problems a modified model was designed, constructed and evaluated. The major components modified include feed hopper, cylinder, concave and shaker. The machine performance was evaluated at various levels of moisture contents, cylinder speed and feed rates. The results showed that threshing efficiency, cleaning efficiency and throughput capacity of the modified thresher were 99.98, 99.95 % and 253.96kg/h respectively while those for scatter losses and mechanical grain damage were 5.45 and 3.70 % respectively. This indicate the percentage increase of 0.98, 6.95 and 56.96 % for threshing efficiency, cleaning efficiency and throughput capacity respectively and decrease in scatter loss and grain damage of 5.98 and 3.84 % respectively. The best combinations of the independent variables for optimum operations were 13 % moisture content, 12.67 m/s cylinder speed and 5 kg/min feed rate. The optimum performance values obtained were of 297 kg/h throughput capacity, while threshing efficiency, cleaning efficiency, scatter losses and mechanical grain damage were 99.8, 99.5, 5.09, and 3.4 % respectively.

Table of contents

4.1.1. Effect of Moisture Content on Threshing Efficiency and Grain Damage

LIST OF TABLE

LIST OF FIGURES

LIST OF PLATE

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1. General Background

Threshing and cleaning operation is a necessary step before processing of grains into flour for domestic or industrial uses. In addition annual yield evaluations by farmers are only possible after threshing operations. The by- products of threshing such as chopped straws and chaff could be accumulated in stack and be saved for future use as animal feed.

Nigeria heavily relies on imported technology in areas of machinery and equipment (Bashir and Dauda, 2003). These machineries have only made limited impact on increased food production due to several problems such as regular break down. Experience has shown that, a number of these machinery and equipment break down as early as few days after commissioning due to improper usage (Yisa, 1999). Over the years different mechanical means of shelling were imported in moderate quantities which include: Power threshers of various make and models such as Noguerira, lion, Midget, Alva Blanch (IAR, 1987). Smaller quantities of combines such as Donia D500, Laverda 8850, MF8640, John Deere 855, etc existed in the Nigerian market (Ali, 1999). However various tests conducted at the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria revealed various defects in performance of these machines. Seed losses were of unacceptable levels and cleaning efficiency was unsatisfactory.

Sorghum is produced in large quantity in Nigeria up to about 6.851 million tons per year (NAERLS, 2012). It is the second largest cereal crop cultivated after maize in Nigeria (FAO, 1979), and it has a great market potential for domestic and industrial uses. Sorghum can produce yield in areas where other crops may fail, because of its draught resistance qualities. It is the crop of choice for dry region and areas with unreliable rainfall. Nigeria is one of the major sorghum producing countries in the world ranking as the second largest sorghum producer in the world (USAID, 2006). Sorghums are of different varieties.as Akinyosoye (1993) reported that the commonest types of sorghum varieties in Nigeria are: “Kaura”, “Farfara” and “Mori” which are grown almost across northern part of the country.

Despite the food and nutritional value of sorghum, it attracts large international and domestic demand. However, it`s threshing and cleaning have remained serious problems to the farmers (Joshi, 1981). The main problem associated with the threshing and cleaning of sorghum in Nigeria is the use of traditional methods of seed separation from stalk which are uneconomical, time consuming, injurious to the finger and fatigue associated(Mishra and Desta, 1990). Manual threshing of sorghum is classified as heavy work load in terms of energy expenditure (Ali, 1986). Not only are these threshing techniques time and human energy consuming but also damaging to the crops kernels. The time required for threshing depends on variety, moisture content of the grain, and the method of threshing. It has been recorded that about 35 laborers are required to thresh about 300-400 kg of sorghum manually (Mishra and Desta, 1990). However, traditional method of sorghum threshing is widely used and account for more than 80 % of the grown sorghum crop in Nigeria (FAO, 2007). This problem remains a serious challenge to farmers in Nigeria and discourages most of them to fully engage in commercial production of sorghum. These problems indicate the need for development of simple sorghum threshers that will reduce the farmers' difficulties encountered using the traditional methods. The Institute for Agricultural Research (IAR) has developed a prototype sorghum thresher aimed at solving these difficulties. The IAR prototype sorghum thresher was evaluated and the following performance indices were obtained: throughput capacity 110 kg/hr, threshing efficiency 99 %, cleaning efficiency 93 %, mechanical grain damage 7.54 % and scatter losses 11.4 %. This research work is aimed at improving its throughput capacity, mechanical grain damage and scatter losses to more acceptable levels.

1.2 Problem Statement

Agriculture is the main occupation of people in Nigeria and is identified as a major driver of growth in the Nigerian economy. It plays a crucial role in the development of living standards of the citizens. Nigerian farmers are not able to grow enough food for its population (Yusuf, 2011). Despite the high production of sorghum in Nigeria especially in the northern part of the country, studies by Mustapha (2008) revealed that threshing of sorghum is still by manual method. This includes: spreading the sorghum heads on the ground and beating them strenuously with sticks at different spots in or near the farm or using pestle and mortar or by putting the sorghum head inside bag and beating with sticks. All these processes result in drudgery and grain losses. Odigboh (2004) gave post harvest losses estimate in Nigeria to be up to 25 % for food grains.

FAO (2003) explained that one approach of increasing food supply is by reducing heavy losses of food grains at post harvest stage. Ojha and Micheal (2003) also pointed out that indigenous threshing of sorghum is one of the time consuming, laborious and uneconomical activities. NAERLS (2012) reported that traditional farm tools still dominate agricultural production and processing in Nigeria which limit productivity and discouraged of youth in agriculture.

Efficient sorghum threshers at affordable price are not available to Nigerians farmers especially in northern part of the country where large amount of sorghum are being produced. On enquiry the farmers revealed that threshers were not available (Lawan, 2008).Yusuf (2011) reported that lack of suitable machinery packages for the operations remain among the major problems of agricultural mechanization in Nigeria. Despite the effort of importing different types of threshers over the years such machines have low adaptability to the farming system, difficulty in maintenance, lack of spare parts or costly beyond the reach of farmers (Lawan,2008).

For these reasons several prototypes sorghum threshers have been developed at Institute of Agricultural Research, Samaru, Zaria purposely to address the problems but yet some of these problems still exist or persist. Most of the problems associated with such prototypes threshers are low operating performance such as high grain losses and mechanical grain damage, low throughput capacity, low threshing and cleaning efficiencies. Although some of the above mentioned problems have been addressed by the previous IAR prototype sorghum thresher; but there is still room for improvement. The main problems of the present IAR prototype sorghum thresher were low throughput capacity, high scatter losses and mechanical grain damage beyond acceptable levels to farmers. This research work is aimed at addressing such problems by redesigning some of the components to improve on the performance.

1.3 Justification

There is a growing need to provide Nigerian farmers with an appropriate sorghum thresher with higher throughput capacity, low scatter losses and mechanical grain damage. This will reduce the crop losses in threshing thereby increasing the economic return to the farmers. Similarly efficient power operated sorghum thresher will also eliminate the large drudgery involved in manual method of threshing. This will certainly encourage more farmers including youth to engage in sorghum crop production thereby reducing unemployment. Also by increasing the ability and capacity of the present IAR prototype sorghum thresher will assist the farmers to thresh large quantity of sorghum per unit time and reduce the heavy losses at post harvest stage thereby increasing food availability to the nation. The use of locally available materials will be one aspect necessary to reduce the cost of producing the sorghum thresher so that small scale and average income farmers can obtain and use the machine.

1.4 Aim and Objectives

The aim of this work is to improve the existing IAR prototype sorghum thresher and evaluate its performance. The specific objectives are:

I. to redesign and construct the hopper, threshing and cleaning units of the existing prototype
II. to evaluate the performance of improved prototype.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origins and History

Sorghum *(Sorghum bicolor (L*.), *Moench*) is a genus of grasses raised for grain and fodder. The plants are cultivated in warmer climates around the world and species are native to tropical and subtropical regions of all continents. Sorghum is the world's fifth most important cereal crop after maize, rice, wheat and barley. It is the dietary staple of more than 500 million people in more than 30 countries. It originated in Africa, with the primary source of origin believed to be around the Ethiopian Highlands and Southern Sudan. It was cultivated in Egypt in antiquity. It appears that sorghum moved into eastern Africa from Ethiopia around 200 AD or earlier. It was carried to the countries of eastern and southern Africa by the Bantu people, in whose migration it played a critical role. Sorghum was taken from Africa to all continents. Sorghum spread to India probably during the first millennium BC. The spread along the coast of Southeast Asia to China may have taken place about the beginning of the Christian era. Grain sorghum got to America as "guinea corn" from West Africa together with slave traders in the middle of the 19th century. Its importance there and in Australia was only recognized in the 20th century (Taylor, 2002).

2.2. Classification and Characterization

The genus Sorghum is characterized by spikelet's borne in pairs. Sorghum is a perennial grass treated as an annual, and can be harvested many times if planted in the tropics. Sorghum is known under a variety of names: great millet and guinea corn in West Africa, kaffir corn in Southern Africa, durra in Sudan, matama in eastern Africa. Scientifically, sorghum belongs to the order of Poales and the Poaceae family. Sorghum bicolor is the primary cultivated sorghum grass (Taylor, 2002).

2.3 Sorghum Kernel

The sorghum kernel varies in colour from white through shades of red and brown to pale yellow to deep purple-brown. Kernels are generally spherical but vary in size and shape. The percentages of the seed components are endosperm (82%), embryo (12%) and seed coat (5-6%).

The plant is very high in fiber and iron, with a fairly high protein level as well. Brown-seeded types are high in testa tannins. Much sorghum is pigmented by polyphenolic compounds which have anti-oxidant properties (Taylor, 2002).

2.4 Production and Agronomic Aspects of Sorghum

World annual sorghum production is over 60 million tons, of which Africa produces about 20 million tones 3. This makes sorghum, quantitatively the second most important cereal grain in Africa after maize. Table 1 shows the major sorghum producing countries of Africa. It can be seen that sorghum production takes places across the continent, with the northern African countries of Nigeria, Sudan, Ethiopia and Burkina Faso accounting for nearly 70% of Africa's production.

Table 2.1. Countries in Africa with an annual production of sorghum (2001 data)

Country	Production (tonnesX10^3	Percentage (%)
Nigeria	7081	33.8
Sudan	4470	21.4
Ethiopia	1538	7.3
Burkina Faso	1372	6.6
Egypt	862	4.1
Tanzania	736	3.5
Niger	656	3.1
Mali	517	2.5
Chad	497	2.4
Cameroon	450	2.1
Uganda	423	2.0
Mozambique	314	1.5
Ghana	280	1.3
South Africa	211	1.0
Rwanda	175	0.8
Benin	165	0.8
Togo	141	0.7
Senegal	140	0.7
Kenya	133	0.6
Zimbabwe	103	0.5
Somalia	100	0.5

Source: Taylor, 2002

The problem of food shortage in sub-Saharan Africa is to a large extent due to the fact that much of the region is characterized by semi-arid and sub-tropical climatic conditions. Africa is the only continent that straddles both tropics. Sorghum is crucially important to food security in Africa as it is uniquely drought resistant among cereals and can withstand periods of high temperature. A yield trial of 30 entries in Zimbabwe (28 sorghum genotypes and 2 maize hybrids) showed that under irrigation the maize hybrids ranked 11 and 22, whereas under drought conditions they ranked 28 and 305. Sorghum was produced in areas where the annual rainfall is in the range 500-700 mm per year. Hence, most of the countries in Africa where sorghum is significant arable crops are arid and areas at risk of desertification. It can also be seen that sorghum is also an important crop in east Africa where overall there is good rainfall. This is related to the fact that the rain in sub-tropical Africa is intermittent and characterized by brief periods of very high rainfall. In fact sorghum is not only drought-resistant, it can also withstand periods of water-logging. In Kenya, the result from the trials of KAT 369 improved sorghum variety during the short rainy season showed higher yield compared to maize. The precise reasons for sorghum’s environmental tolerance are not fully understood, and are undoubtedly multi factorial. Sorghum often has very deep penetrating and extensive roots. Apparently it conserves moisture by reducing transpiration when stressed by leaf rolling and closing stomata; higher than normal levels of epicuticular wax appear to be of importance in this respect. Sorghum also appears to have a high capacity for osmotic adjustment to stress and maintain turgor pressure in cells. Certain sorghum varieties also posses “stay green” genes that enable them to continue to photosynthesize, post-flowering during drought. Further research into the mechanisms of sorghum’s environmental tolerance will clearly be highly beneficial. Over the past 25 years sorghum production has increased steadily in Africa, from 11.6 million tons in 1976 to 20.9

million tons. However, it can be seen that the increase in production has been as a result of increasing the land area under cultivation and there has been no overall improvement in yield. Average yields remain below 1 tons/ha. This is because sorghum cultivation in Africa is still mainly characterized by traditional farming practices; with low inputs (no inorganic fertilizer or pesticides) and traditional varieties or landraces. Such low yields mean that there is often no surplus sorghum, without which processing industries cannot be created. However, where intensive agriculture is practiced with improved varieties or hybrids, yields are much higher and comparable with other major cereals, for example in South Africa the average commercial yield in 2001 was 2.34 tons/ha compared to 2.49 tons/ha for maize. Obviously continually increasing cultivation area is environmentally highly damaging and in the long-term unsustainable, and efforts must be intensified to improve sorghum agriculture in Africa. Higher yields are essential, not only for rural food security but also for increasing commercialization.

2.5 Physical Characteristics of Sorghum

Simonyan and Yiljep (2008) have given the physical characteristic of sorghum grain and other materials as presented in Tables 1 and 2 below:

Table 2.2. Axial dimensions of sorghum grains

MC_{wb} (%)	Major axis,L_1, (mm)	Medium axis,L_2, (mm)	Minor axis,L_3, (mm)	Arithmetic mean, $(L_1+L_2+L_3)/3$,(mm)	Geometric mean, $(L_1L_2L_3)^{1/3}$ (mm)	Equivalent diameter, De, (mm)
8.9	3.70± 0.29	3.18±0.30	3.08±0.22	3.32	3.31	3.31
10.9	3.81±0.22	3.29± 0.18	3.09±0.24	3.40	3.38	3.41
12.3	4.04±0.04	3.50± 0.03	3.61±0.05	3.72	3.71	3.71
14.6	4.45± 0.07	4.39± 0.12	3.40±0.38	4.08	4.05	4.06
16.5	4.62± 0.06	4.53±0.01	3.44±0.07	4.20	4.16	4.18

Source: Simonyan and Yiljep (2008)

Table 2.3. Some physical properties of sorghum grain and straw materials

Sample	Mass, (g)	Projected area, (mm^2)	Particle density,(g/cm^3)
Unthreshed ear head	1.47±0.35	101.28 ± 40.68	0.78± 0.14
Threshed ear head	0.37±0.5	64.98 ± 16.66	0.31± 0.06
Grain	0.044± 0.007	4.66±0.85	1.02± 0.20
Stalk	0.067±0.02	26.14 ±5.9	0.09± 0.02
Chaff	0.032± 0.008	7.34±1.53	0.05± 0.01

Source: Simonyan and Yiljep (2008)

Table 1 indicated that as the moisture content of a grain increases the equivalent diameter of a grain also increases. When the moisture content ranged from 8.9 to16.5% the grain equivalent diameter ranged from 3.31 to 4.18mm. From Table 2 when the mass of grain was 0.044± 0.007g the particle density was 1.02± 0.20g/cm^3.

2.6 Mechanical Threshers.

A mechanical thresher is a machine designed and constructed to separate the grains from the stalk. It has a threshing drum, which consist of a long cylindrical shape member to which a series of pegs, knives or rasp bars are attached on the surface. The threshing drum is mounted on two bearings and rotates in a perforated trough "concave". During threshing, crop is fed between the threshing drum and the concave, where it is subjected to a high degree of impact and frictional forces which detach grains from panicles (Amir, 1990). While the mechanical cleaning of grain is done by the cleaning unit which comprises shaker and blower, the former consists of fan blade, which is enclosed by a casing and attached to the mechanical thresher. This fan is connected to the shaft, power by an electric motor or I C engine which helps to rotate the fan blade to generate air current that blows the chaff out. Shakers consist of a reciprocating sieve which assist to drive the large particle and stalk out from the threshed grain (Ajayi, 1994).

2.7 Threshing of Sorghum

The threshing of sorghum is mainly by impact, rubbing and squeezing, crushing or shattering and these actions occurs simultaneously (Singh and Joshi, 1980). Amir (1990) reported that the threshing equipment performs different but concurrent operations; threshing the grain, separating the grain from panicle, sorting the grains from the straw, winnowing the chaffs from the grains.

2.8 Factors Affecting the Threshing of Sorghum

Hunt (1983), observed that factors like moisture content, concave- drum clearance, length of the threshing drum and cylinder are factors that affects the threshing of sorghum. While Ojha and Micheal (2003); noticed that the efficiency of thresher depends on the peripheral speed of the cylinder, the clearance between the cylinder and the concave, the maturity of the crop and the rate at which the crop is fed into the machine. Ali (1986) reported that the overall threshing efficiency are influenced by cylinder speed, crop ear size, feed rate and variety. While Phillip and Callaghan (1974) are of the view that the efficiency of both primary and secondary grain/straw separation are reduced with increasing moisture content, that is as the surface of straw become damp, the coefficient of straw- metal friction increases, causing transport problems. Simonyan et al. (2006) reported that increased in moisture content may lead to the increased of bidding force between the sorghum grain and other material to be separated hence affect the cleaning efficiency. They added that increase in cylinder speed result in an increase range of particles size and formation of minute particle, which aerodynamically resembles sorghum grains thereby creating challenges in cleaning operation.

Grochowicz (1980), reported that when the resident time is longer, it positively affects the efficiency of separation, as there is likelihood for lighter particles being displaced in the air stream.

2.9 Factors Affecting the Cleaning of Sorghum

Simonyan and Yiljep (2008) reported that cleaning efficiency decreases with increasing sieve oscillation frequency, feed rate and sieve length at different fan speed. Timothy (2012) also reported that there is a decrease in cleaning efficiency with increasing grain moisture content, feed rate and decreasing cylinder speed. The cleaning efficiency is not only depending on air flow/suction of air, rather it also depends on the size and types of sieve slope of the sieve, shaker speed and shaker length (Jain and Grace 2003).

2.10 Factors Affecting the Mechanical Grain Damage

Mechanical grain damage can increased as a result of one or combination of these factors, high cylinder speed, low concave cylinder clearance, feed rate, size of concave opening and moisture content (Jain and Grace 2003). Timothy (2012) stated that grain damage tend to increase with decrease in moisture content of the grains and feed rate. The authors further explained that increase in cylinder speed may led to the increase of grain damage.

2.11 Factors Affecting the Scatter Losses

Scatter losses increased with increasing sieve oscillation frequency, feed rate, high fan speed and cylinder speed Simonyan *et al*. (2006). Dalha and Dangora (2011) state that the effect of feed rate was significant to scatter loss. Timothy, (2012) reported that the scatter loss increases with decrease in moisture content and feed rate at high cylinder speed and it decreased with increase in the moisture content of the grains, and feed rate at low cylinder speed.

2.12 Efforts on the Development of Sorghum Thresher

Very recently improvement of I.A.R sorghum thresher was done by Timothy (2012). The machine consist of rectangular hopper, spike tooth beaters, straw outlet located at rear part of the machine, shaker and sieve, blower and grain outlet with 98.72 % of threshing efficiency, 93

% cleaning efficiency however, with higher mechanical grain damage (7.54 %) and scatter losses (7.91 %) and low throughput capacity (110.79 Kg/hr).

The institute for Agricultural Research (I.A.R) has developed multi crop thresher with locally available materials. The thresher consists of the hopper, threshing compartment, cleaning unit, fan, and grain outlet. It can thresh crop such as sorghum, wheat and millet by the selection of appropriate speed and sieve size. It has a threshing capacity of 80 kg/h, 70 kg/h and 60 kg/h for wheat, sorghum and millet respectively. It uses 8hp prime mover with threshing efficiency of 98 % and grain damage rate of 4 % (I.A.R, 1987).

Alonge and Adegbulugbe (2002), while developed a sorghum thresher, the machine consists of hopper, threshing unit, blower, shaker, and grain outlet. It is reported that the machine has the following performance indices: I. The threshing efficiency of the thresher varies from 71 % to 95.6 % II. The higher the speed, the higher the rate of threshing at the moisture contents level evaluated but with increased grain damage iii. The maximum grain damage occurs at the highest moisture level. IV. The highest percentage grain loss was obtained at 15% moisture content; Abiodun (2000) designed and developed a manually operated sorghum thresher which was constructed with local materials. The thresher had a drum with spirally arranged rasp bars, a concave, feed hopper and stationary screen. The threshing rate was 72 kg/h and 60 % threshing efficiency.

It can be deduced that efficient and affordable prototype sorghum thresher was not available to Nigerian farmers. Alonge and Adegbulugbe (2002) construct sorghum thresher but with high scatter grain and grain damage similarly Abiodum (2000) developed a sorghum thresher with low cleaning efficiency and operated manually. Dangora *et al.* (2006) modified IAR maize

Sheller to threshed sorghum but the machined has limitation of higher scatter loss. Timothy (2012) improved IAR sorghum thresher however, the machine associated with higher grain damage, scatter loss and low output capacity.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Design Consideration

The factors considered in developing the sorghum thresher include:

I. The prime mover of rated power and speed of 6.08kw and 1200 rpm respectively was used.

II. Threshing Cylinder diameter was chosen as 22 cm while its speed was 10 m/s for sorghum (Jain and Grace 2003 and Joshi, 1981). The pegs diameter on the cylinder and inner part of the top cylinder covers were changed from 20 mm to 12mm so as to reduce high impact force on sorghum grains which contribute to the increase in mechanical grain damage. For easy crushing of sorghum ear head, the space between pegs on cylinder was reduce from 60 to 50 mm while the space between the stationary and rotational pegs of beaters and was reduce from 30 to 10 mm respectively. The number of pegs around the cylinder was increased from 4 to 6 thereby reducing the threshing time and increase throughput capacity (FAO, 2007). 5 mm was used as concave opening to insure free passing of threshed grain to cleaning unit which aid to the increase of throughput capacity and reducing mechanical grain damage. The dimension of the hopper was chosen based on the power from the prime mover as stated by Jain and Grace (2003). The sizes of the other components were maintained from the existing machine.

III. Shaker mechanism consisting of three sieves. The upper, middle and bottom sieves was used

IV. Sieves consist of hole diameters of 6, 4.5 and 4.0 mm respectively (Timothy, 2012)

V. Pneumatic cleaning was also used with fan speed of 500 rpm and 220 mm diameter

VI. Sieve hole diameter:

3.2 Material Selection

Materials of various sizes were selected for different components of the thresher based on availability, strength and durability.

Mild steel metal sheet 18 gauge was selected for the construction of feed hopper and top cylinder cover while mild steel sheet 16 gauge was used for the threshing cylinder due to impacts from the spikes.

The shafts were made of mild steel iron (C1040). Mild steel iron rod was selected to construct spike tooth. A Square mild steel bar was used to construct the concave grate.

3.2 Determination of Size of The Components

3.3.1 Estimation of concave radius, r_c

The radius of curvature r_c, of the concave grate was determined using the following expression: as given by Dangora *et al*. (2006):

$r_c = r_d + h_p + C_c$ -- 3.0

Where:

r_c = radius of concave (mm)

r_d = radius of cylinder drum (mm)

h_p = peg height above the drum (mm)

C_c = concave clearance (mm)

$r_c = 110 + 60 + 20 = 190$ mm

Thus the concave radius of 190 mm was used as obtained from the above equation

3.3 .2 Determination of weight of fan blades

Weight of the fan blade was estimated from the following expression as given by Hannah and Stephen (1984)

$W = \rho\, v\, g$ -- 3.1

Where:

ρ = Density of fan blade i.e steel (kg/m^3)

g = Acceleration due to gravity (m/s^2)

V= Volume of the fan blades (m^3)

3.3.3 Determination of the Fan Air Flow Rate

Air discharge through the blower was estimated using the following expression as given by Joshi, (1981):

$Q = V\, D\, w$ --- 3.2

Where:

Q = Air discharged rate (m^3/s)

v = Velocity of air required for cleaning (m/s)

D = Depth of air stream over the sieve (m)

w= Width over which air is required (m)

3.3 .4 Determination of weight of the cylinder and the spike tooth

Weight of the cylinder was estimated from the following expression as given by Hannah and Stephen (1984)

$$W = \rho\, v\, g \qquad 3.3$$

Where:

ρ = Density of the cylinder material i.e steel (kg/m^3)

g = Acceleration due to gravity (m/s^2)

V= Volume of the cylinder (m^3)

$$V = \pi r^2 L \qquad 3.4$$

Where:

r = radius of the cylinder (m)

L = length of the cylinder (m)

The mild steel material for cylinder therefore, of density 7840 kg/m^3 was used (Khurmi and Gupta, 2007)

$W = 7840 \times 0.0223 \times 9.81$

W = 1.715 kN

From equation 3.3 the weight of spike tooth was obtained as 1.012 kN

The total weight of cylinder and spike = 1.715 + 1.012 = 2.727 kN

3.3.4 Determination of pulley diameter

The Pulley diameters were selected base on the speed ratio between the drive and driven pulleys as given in the expression below: (Khurmi and Gupta, 2004)

$N_1D_1 = N_2D_2$ 3.4

Where:

N_1 = Speed of drive (1200 rpm)

D_1 = diameter of drive pulley (104 mm)

N_2 = Speed of cylinder pulley (500 rpm)

D_2 = diameter of cylinder pulley (mm)

a) Estimated diameter for the cylinder pulley

$N1D1 = N_2D_2$

$D_2 = 131mm$

b) Estimated diameter for fan pulley

$N_2D_2 = N_3D_3$

Where:

N_2 and D_2 as previously define and obtained

N_3 = Speed of fan pulley (650 rpm)

D_3 = diameter of fan pulley (mm)

$D_3 = 125mm$

c) Estimated diameter for shaker pulley

$N_3D_3 = N_4D_4$

Where:

N_2 and D_3 as previously define and obtained

N_4 = Speed of shaker pulley (350 rpm)

D_4 = diameter of shaker pulley (mm)

$D_4 = 357$mm

3.3.5 Determination of centre distance (C)

The centre distance was estimated as given by (Khurmi and Gupta, 2007) below

$$D < C < 3(D + d) \quad \text{.......} \quad 3.6$$

Where:

C = centre distance between prime mover pulley and the driven pulley (mm)

D = diameter of the driven pulley (mm)

d = diameter of pulley on prime mover (mm)

Let $D = d_2$ or d_3 or d_4 = Diameter of driven pulley

D_1 = Diameter of the drive (mm)

For d_2 $\quad 131 < C < 3\,(131 + 104)$

$$131 < C < 705$$

For d_3 $\quad 125 < C < 3\,(125 + 131)$

$$125 < C < 768$$

For d_4 $\quad 357 < C < 3\,(357 + 125)$

$$357 < C < 1464$$

The value of C fall between 705 mm and 1464 mm

Let the design center distance (C) between the prime mover and the driven pulley be 900 mm

3.3.6 Estimation of belt length

The belt length was estimated using the relation given by (khurmi and Gupta, 2007): as given below

$$L = 2c + 1.57\,(D-d) + \frac{(D-d)^2}{4c} \quad \text{.......} \quad 3.7$$

Where: L = effective length of belt (mm)

C = centre distance from drive to driven pulley (mm)

D = diameter of driven pulley (mm)

d = diameter of drive pulley (mm)

I. Estimated belt length from prime mover to the fan pulley

L_1= 643mm

II. Estimated belt length from the fan pulley to the thresher pulley

L_2 =591mm

III. Estimated belt length for the cylinder pulley to the shaker pulley

L_3 = 997mm

3.3.7 Determination of angle of contact

The angle of contact was determined from the relation below

$$\theta = 180 - 2\mathrm{Sin}^{-1}\,(D-d)/C \quad \text{.......} \quad 3.8$$

Where:

θ = angle of contact

D = diameter of driven pulley (cm)

d = diameter of drive pulley (cm)

I. Estimated angle of contact for thresher pulley $\theta_1 = 170°$
II. Estimated angle of contact for fan pulley $\theta_2 = 178°$
III. Estimated angle of contact for shaker pulley $\theta_3 = 82°$

3.3.8 Estimation of belt speed

Belt speed was estimated from the expression as given by (Khurmi and Gupta, 2007):

$$V = \frac{\pi DN}{60} \quad \text{.......................} \quad 3.9$$

Where:

V = belt speed (m/s)

N = drive speed (rpm)

D = diameter of drive pulley (cm)

For N_2 = 500 rpm, d_2 = 131mm then v_1 = 6.55m/s

For N_3 = 650 rpm, d_3 = 125mm then v_2 = 6.545m/s

For N_4 = 350 rpm, d_4 = 357mm then v_3 = 6.543m/s

I. Estimated belt speed from prime mover to thresher v_1 = 6.55m/s

II. Estimated belt speed from thresher to fan $v_2 = 6.545$m/s

III. Estimated belt speed from fan to shaker $v_3 = 6.543$m/s

3.3.9 Calculating torque on the shaft

The torque required to thresh the sorghum was obtained as

$T = Fr$…………………………………………………………………………………………………….. 3.10

Where:

T = torque on the shaft (kNm)

F = Estimated force required to detach the sorghum grain and turn the cylinder (kN)

r = turning radius (m)

(Oluka *et al*, 2013) obtained the force required to detach the sorghum grain and turn the cylinder as 0.00853 KN

Total force acting on cylinder = 0.0085X17 = 0.145 kN

Assuming 75% of sorghum head was filled in the cylinder thus F = 0.1088 kN

Thus Total torque = 0.1088X0.7 = 0.076 kN

The power required for threshing sorghum was determined by:

$P = Tw$ ……………………………………………………………………………………………………3.12

Where:

P = power consumed by the shaft (kw)

T = torque on the shaft (0.076 kNm)

w = angular velocity (52.36 rad/s)

P = 0.076X 52.36

P = 3.986 kW

3.3.10 Estimation of belt tension

The belt tension was determined by the following relation:

$T = (S_1 - S_2)\, r$ 3.13

Where:

S_1 = tension on tight side (KN)

S_2 = tension on slide side (KN)

r = radius of pulley (m)

T = torque on shaft (kNm)

Similarly,

$$\frac{S_1}{S_2} = e^{\mu\theta Cos\, ec\beta} \qquad \text{3.14}$$

Where:

μ = coefficient of friction between the pulley and the belt

θ = angle of contact between of the belt on pulley

β = ½ (angle of V- groove of the pulley)

When the $\mu = 0.25$, $2\beta = 34°$, and $\theta = 170°$

Therefore,

$$\frac{S_1}{S_2} = 3.77$$

Substitute this in eq. 3.14

$$s_2 = \frac{T}{2.77r}$$

$S_2 = 0.2351$ KN

$S_1 = 0.8862$ KN

Total belt tension $S_1 + S_2 = 0.8862 + 0.2351 = 1.1213$ KN (for cylinder)

Total weight of belt and pulley = 1.1213 + 0.0207= 1.142 kN

3.4 Determination of the Shaft Diameter

3.4.1 The allowable shear stress

The maximum allowable shear stress using the ASME code (1948) can be obtained as the lower value of 18% ultimate tensile stress (S_t) and 30% yield stress (S_y). The code further stated that the allowable shear stress is reduced by 25% when there is a keyway in the shaft. Considering the above factors chosen mild steel (C1040) with ultimate tensile stress (St) 668.8MN/m^2 and yield stress (S_y) 568.7MN/m^2. Therefore,

$0.18St = 0.18X668.8 = 120.38MN/m^2$

$0.3Sy = 0.30X568.7 = 170.61MN/m^2$

The lower value of the allowable stress is 120.38MN/m^2. The shaft is provided with keyway therefore, the allowable shear stress (S_a) would be reduce by 25% to take care of the stress concentration.

S_a = 120.38 X 0.75

90.3MN/m^2

3.4.2 The shaft diameter

The determination of the shaft diameter was obtained from the ASME code relation:

$d^3 = \frac{16}{\pi S_s}\sqrt{(k_b M_b)^2 + (K_t M_t)^2}$ 3. 15

Where:

M_b = bending moment, (Nm)

M_t = torsional moment, (Nm)

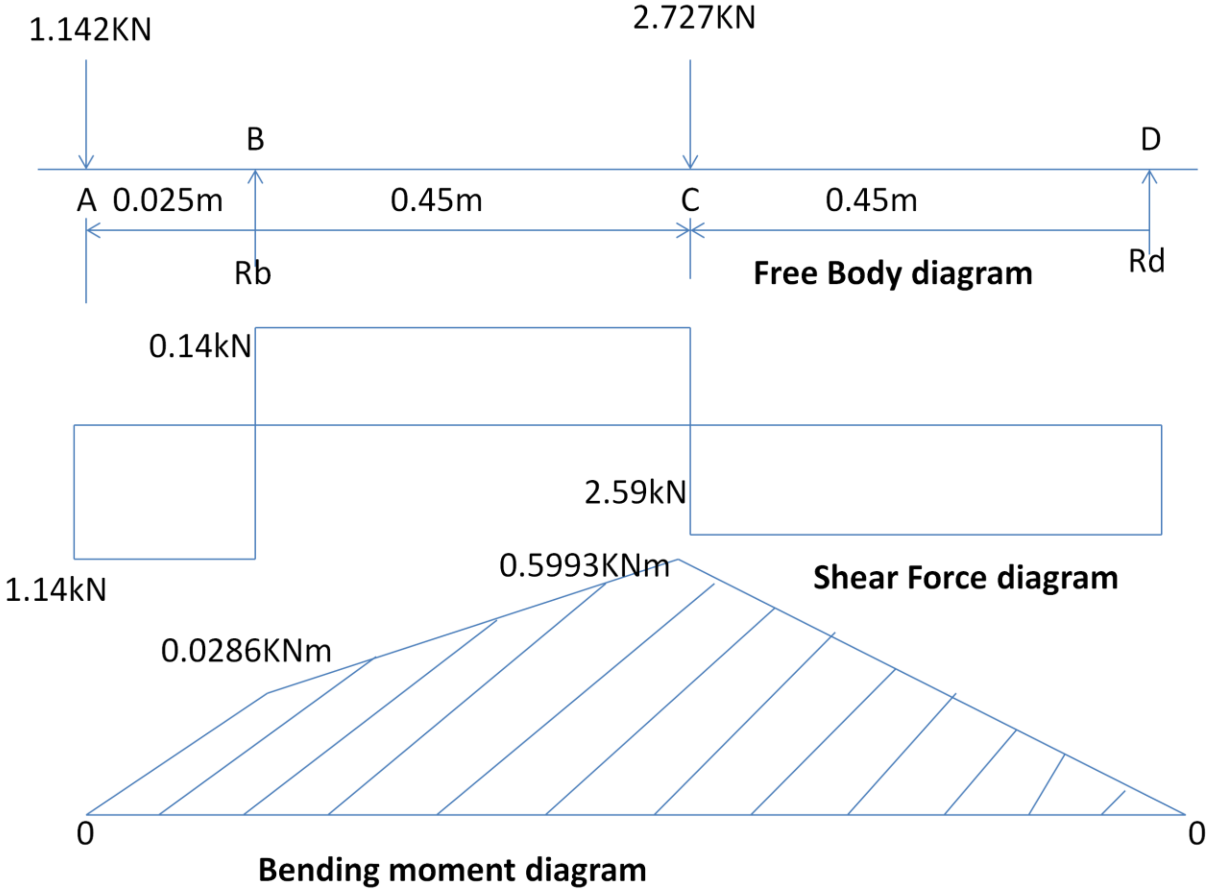
K_b = combined shock and fatigue factor applied to bending moment = 1.5

K_t = combined shock and fatigue factor applied for torsional moment = 1.0

S_s = allowable shear stress for shaft with keyway = 90.3 MN/m^2

d = shaft diameter, m

3.4.2.1 The Maximum Bending Moment and Shear Force Diagram



Maximum bending and torsional moment were determined as:

$M_b = 0.3584$ kNm

$M_t = 0.0853$ kNm

$K_b = 1.5$

$K_t = 1.0$

$S_s = 90.3$ MN/m^2

The shaft diameter is:

$$d^3 = \frac{16}{3.142 \times 90.3 \times 10^6} \sqrt{(1.5 \times 85.3)^2 + (1 \times 358.4)^2}$$

d = 27.79 mm and approximated as 28 mm

The fan and shaker shaft diameter were determined as

$$d = \sqrt{\frac{16T_f}{\pi Sa}} \qquad 3.16$$

Assuming the bending moment is zero

$$T_f = \frac{9550 \times Power}{RPM}$$

Where:

T_f = torque transmit

P_f = Power delivered

d = 22 mm for fan while that for shaker is d = 20 mm

3.5 Description of the Machine

The modified machine mainly consists of the hopper, threshing unit, fan unit and shaker unit

3.5.1 The hopper

The hopper was made from a mild steel sheet and protrudes from the top cylinder, cut to size and welded to form the required shape and tilted to achieve easy feeding of sorghum ear heads to the threshing unit. The hopper is trapezoidal in shape and has the following dimensions front base width 400mm, rear base width 480mm, front and rear height 190mm and 60mm respectively upper and base length 450mm and 900mm respectively.

3.5.2 The threshing Unit

The threshing of sorghum is mainly by, impact, rubbing and squeezing, crushing or shattering and these actions of the beater force the grain to be detached from the ear head. The grains and chaff passes onto the shaker through the concave opening. Threshing unit it consists of the beater assembly and concave drum.

3.5.3 Beater and its assembly

The threshing cylinder consists of galvanized cylindrical metal pipe 71cm long through which the shaft passes. A series of pegs are attached on this galvanize pipe which is mounted on two bearing and rotate. The spacing between the pegs is 50mm and the peg height is 60mm.The pegs was arrange in spiral form

3.5.4 The blower

The axial flow centrifugal fan was made. It has the impeller which carries four blades through the metal flat bar. The height of the blade is 135mm, with the base welded to the shaft. It was made from metal sheet gauge 18. The fan is cover and housing with two end sides opened for air suction. The housing was made with mild steel sheet gauge 16.

3.5.5 The shaker and sieve

The thresher has a shaker which is fastened on the frame through the “I” shape fasteners and it was made from mild steel gauge 16. The shaker makes reciprocating by a crank shaft connected to it through a connecting rod and act as a grain collecting point which conveys grain to the grain delivery unit. The shaker carries three different sieves with holes diameter 5mm, 4.5mm and 4mm respectively.

3.5.6 Pulleys

At the end of the cylinder shaft a double V belt pulley is mounted on the shaft which receives power from the engine and drives the blower and shaker pulley. All the pulleys were made from cast iron. The pulleys have the following estimated dimension: 131mm, 125mm and 357mm for cylinder, blower, and shaker respectively.

3.5.7The shaft

There are three shafts on the thresher, the shaft for the cylinder, fan and that of shaker respectively. All the shafts are made from mild steel. Their individual length and diameter are: 1120 mm, 1200 mm, 660 mm and 28 mm, 22 mm, 20 mm for cylinder, fan and shaker respectively.

3.6. Performance Evaluation

The machine was evaluated using the following performance indices while the expressions used were as given by (NSAE/NCAM/SON, 1995) and (Ndrika, 1994) shown in equations 4.0, 4.1, 4.2, 4.3, and 4.4:

a) Threshing efficiency (%)

b) Cleaning efficiency (%)

c) Mechanical grain damage (%)

d) grain losses (%) and

e) Throughput capacity (Kg/hr)

3.6.1 Threshing efficiency, Te (%)

This parameter was used to determine the threshing ability of the developed sorghum thresher.

$$T_e = 100 - \frac{Q_u}{Q_t} \times 100 \quad \text{.......... 3.17}$$

Where:

Q_u = quantity of unthreshed grains in sample (kg)

Q_t = Total quantity of grain in sample (kg)

a. **Cleaning efficiency Ce (%)**

$$C_e = \frac{(W_t - W_c)}{W_t} \times 100 \quad \text{.......... 3.18}$$

Where:

W_t = Weight of total mixture of grain and chaff received at the grain outlet (kg)

W_c = Weight of chaff at the main outlet of the thresher (kg)

b. Mechanical (visible) grain damage M_D (%).

This parameter was used to determine the quantity of grains damaged during threshing.

$$M_D = \frac{Q_b}{Q_t} \times 100 \quad \text{.......... 3.19}$$

Where:

Q_b = quantity of broken grains in sample (kg)

Q_t = Total quantity of grain in sample (kg)

c. Scatter Loss, SL (%)

During the threshing operation some grains were lost due to scattering. The percentage of such grains was determined using the formula below;

$$S_L = \frac{Q_l}{Q_t} \times 100 \quad \text{.......... 3.20}$$

Where:

Q_l = Quantity of grains scattered around the thresher after threshing operation (kg)

Q_t = Total quantity of grain in sample (kg)

d. Grain throughput capacity, Te (kg/hr)

This is the capacity of the thresher in terms of the total quantity of threshed materials in sample per unit time.

$$T_c = \frac{Q_s}{T} \quad \text{.......... 3.21}$$

Where:

Q_s = Quantity of threshed grain collected after a threshing operation (kg)

T = Time taken for a complete threshing operation (hr)

The moisture content of the grain was determine using oven drying in which the sample was dried at 130°C for 18 hours and moisture content on wet basis was being obtained from the equation below ASAE (1972):

$$Mc = \frac{W_{i-}W_d}{W_i} \times 100\% \quad \text{.......... 3.22}$$

Where:

M_c = moisture contain (%)

W_i = initial weight of sample (kg)

W_d = dried weight of sample (kg)

3.7 Instrumentation

The following instrument were used: Stop watch was used to determine the time taken for threshing, while tachometer was used for taking the cylinder shaft speed. Mechanical and electronic weighing scale was used to measure the weight of the crop fed into the machine per unit time and measure the quantity of mechanical grain damage.

3.8 Experimental Procedure

The operation started by putting on the prime mover. A batch of a weighed sorghum heads were fed into the machine through the hopper. After each operation, samples were collected at the grain outlet and non-grain outlets. Grains and non-grain materials were separated for all the samples and weight separately in order to calculate the performance indices as given earlier.

3.9 Experimental design

A completely randomized design experiments (CRD) was used. A layout of 5 levels of cylinder speed (700 rpm, 800 rpm, 900 rpm 1000rpm and 1100 rpm) by 2 levels of feed rates (3kg/hr and 5kg/hr) and five levels of moisture contents (11%, 12%, 13%, 14% and 15%) in three replications was used. Total of 50 treatments was used.

3.10 Analysis of Result

The results obtained from the experiments were subjected to some statistical package using SAS software 9.0 for the analysis of variance in respect to the various performance indices were given in Tables (4.4, 4.5, 4.6, 4.7, and 4.8)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Performance of Developed IAR Sorghum Thresher

4.1.1 Effect of Moisture content on threshing efficiency and Grain Damage at different feed rate

The mean threshing efficiencies at different moisture contents and feed rate is illustrated in Fig.4.1 below. The highest threshing efficiency of 99.98 % was obtained at the least moisture content of 11 % (wet basis) and feed rate of 3 kg/min. This is in agrerment with the result of Timothy, 2012 which obtained the highest threshing efficiency of 99.6% at lowest moisture content and feed rate of 9 % and 1 kg/min respectively. Similarly the lowest threshing efficiency of 91.87 % was recorded at highest moisture content (15 %) and feed rate of 5k g/min. This also agreed with the Timothy, 2012 result and Abiodun, 2000 result. The authors both reported that the lowest threshing efficiency was obtained at higher moisture content. The threshing efficiency increased with decrease in moisture content and feed rate which is associated with the bidding force between the sorghum grain and the straw of the sorghum ear head. At low moisture content the bidding force between the grain and ear head decreased hence he grains require very little force for detachment and vice visa. Similarly from Fig. 4.1 it can be seen that the threshing efficiency is also higher at 3 kg than at 5 kg feed rate, as reported by Agunsaye, 2007 and Kebede and Mishra 1990. The authors both stated that the threshing efficiency increased with decrease in feed rate. This is due to the fact that higher feed rate may result in overloading the drum thereby reducing the impact on material hence, reducing the threshing efficiency. The R^2 values of 0.93 and 0.99 show the good relation between the moisture content and threshing efficiency.

Fig.4.2 presented the effect of moisture content on mechanical grain damage at different feed rate. The maximum grain damage of 3.81 % was obtained at highest moisture content and lowest feed rate of 15 % and 3 kg/min respectively. While the minimum value of 1.98 % was found at the lowest moisture content and second feed rate of 11 % and 5 kg/min respectively. This indicates that the more dampness of the sorghum heads the more grain damage obtained. It could be due to the decrease in hardness and shear force of the grain at higher moisture contents. Decrease in moisture content of the grains increase the resistance of the grain to shear. This is in agreemen with the findings of Matouk *et al*. (2006). The author state that the hardness, shear force and shear stress decreases with increase in moisture content. However result obtained is not inline with Timothy, 2012 result who recorded a maximum grain damage of 7.09 % at lowest moisture content level of (9%) and1 kg/min feed rate and Abiodun (2000) obtained the highest grain damage of 7 % at lower moisture content (7.22 %) and 2 kg/min feed rate. Similarly Fig 4.2 indicated that the mechanical grain damage increased with decreased in feed rate which may be due to the fact that at lower feed rate the sorghum head received higher impact force which contributed to the more grain damage. However this study recorded a decrease in mechanical grain damage which could be attributed to the change of the spike tooth sizes which reduce the impact force on the material thereby, reducing the grain damage. The R^2 values of 0.941 and 0.941 show the good linear correlation between the moisture content and mechanical grain damage.

From Fig.4.1 and Fig.4.2 it can be understood that threshing efficiency and grain damage have a perfect linear relation with moisture contents. As moisture contents decreased the threshing efficiency increased while the reverse is the cases for grain damage. Therefore the best moisture content for threshing can be determined by considering the two graphs. 13 % was obtained. This may be due to the fact that at that level the grain damage are within the acceptable level and the threshing efficiency was above 97 %.

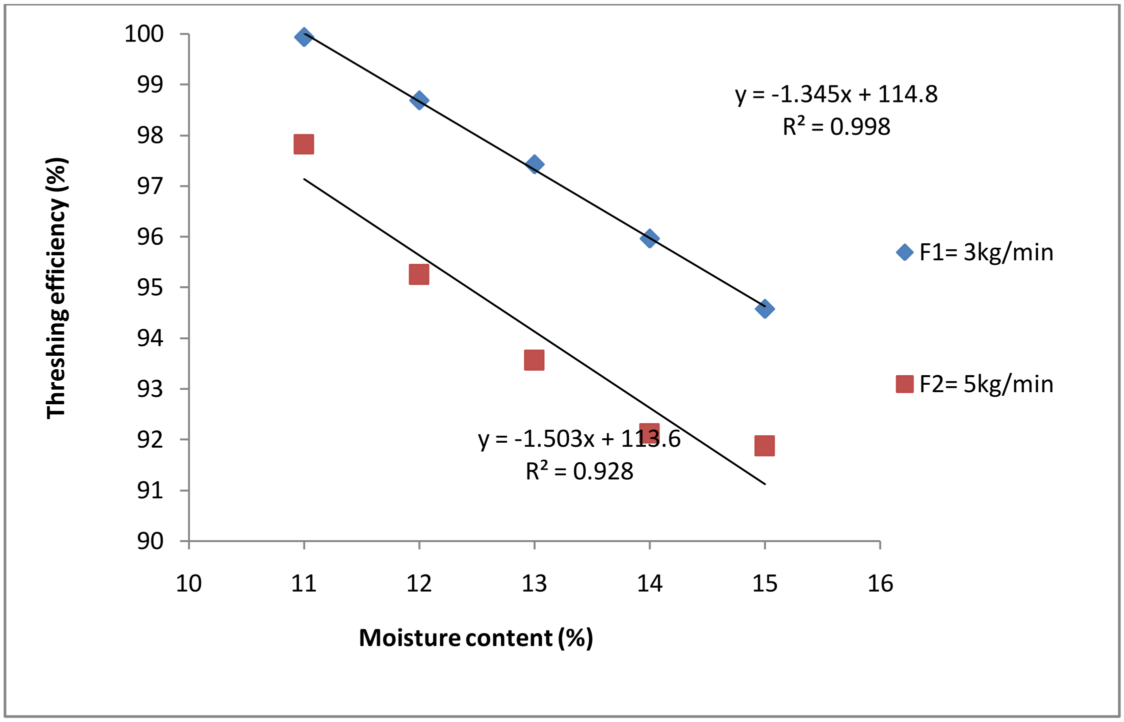


Fig.4.1 Effect of Moisture content on threshing efficiency at different feed rate

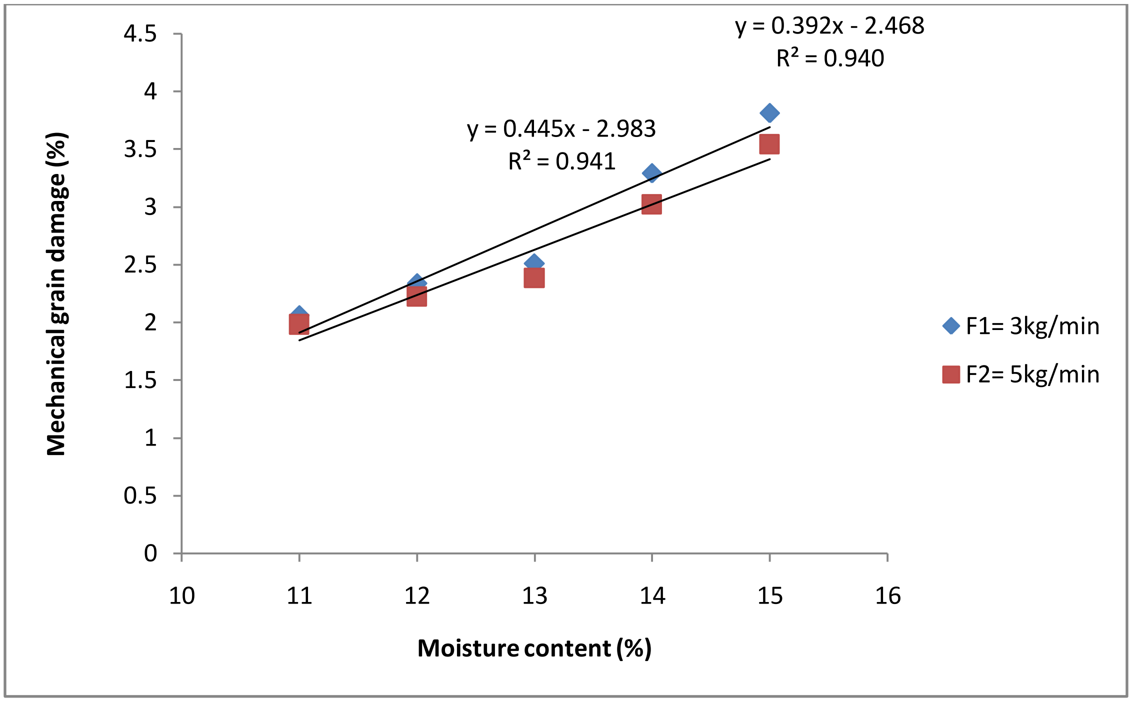


Fig.4.2 Effect of moisture content on mechanical grain damage at different feed rate

4.1.2. Effect of Moisture content on cleaning efficiency and Scatter loss at different feed rate

Fig. 4.3 presented the graphical information of the Effect of moisture content on cleaning efficiency and scatter loss at different feed rate. From the graph, the cleaning efficiency increased with decreased in moisture content and the maximum cleaning efficiency of 99.91% was obtained at lowest moisture level and feed rate of (11 %) and 3 kg/min respectively. Yavini, 2002 and Timothy, 2012 reported similar results indicating that the cleaning efficiency increased with decreased in moisture content and obtained a maximum cleaning efficiency of 99.6 % at 9 % moisture content However a minimum of 84.87% cleaning efficiency was recorded at highest moisture content level of (15 %) and feed rate of 5 kg/min. This could be due to the increased of coefficient of static friction between the grains and other constituent material. The cleaning efficiency is decreased with increase in feed rate. It could be due to the fact that at higher feed rate the threshed material matting on the sieves which result in blocking the sieve hole. The R^2 values of 0.9765 and 0.9523 show the perfect linear relation between the moisture content and cleaning efficiency.

The highest scatter losses of 5.25% was recorded at 11 % moisture content and 5 kg/min feed rate while the lowest value of 2.59% was obtained at 15% moisture content and 3kg/min feed rate. Fig 4.4 indicates that the scatter loss increase with decrease in moisture content and increase in feed rate. This may be link with decrease in moisture content decrease the terminal velocity of the grain thus the fan can be easily blown both grains and chaff. Similarly increase in feed rate results to increase in scatter loss. This could be due to increase in quantity of the threshed material that causes the grains to bounces over the sieve Fig.4.4 illustrated. The R^2 values of 0.9688 and 0.9156 show strong linear relation between the moisture content and scatter losses. However, from this work a decrease in scatter loses was recorded as compared with the existing IAR sorghum thresher which could be due to the redesign of hopper and shaker.

This indicated that the best moisture content for cleaning can be chosen by considering the two graphs (Fig 4.3 and 4.4). At 13 % the scatter losses are within acceptable limit (not more than 5 %) while cleaning efficiency are more than 90 %.

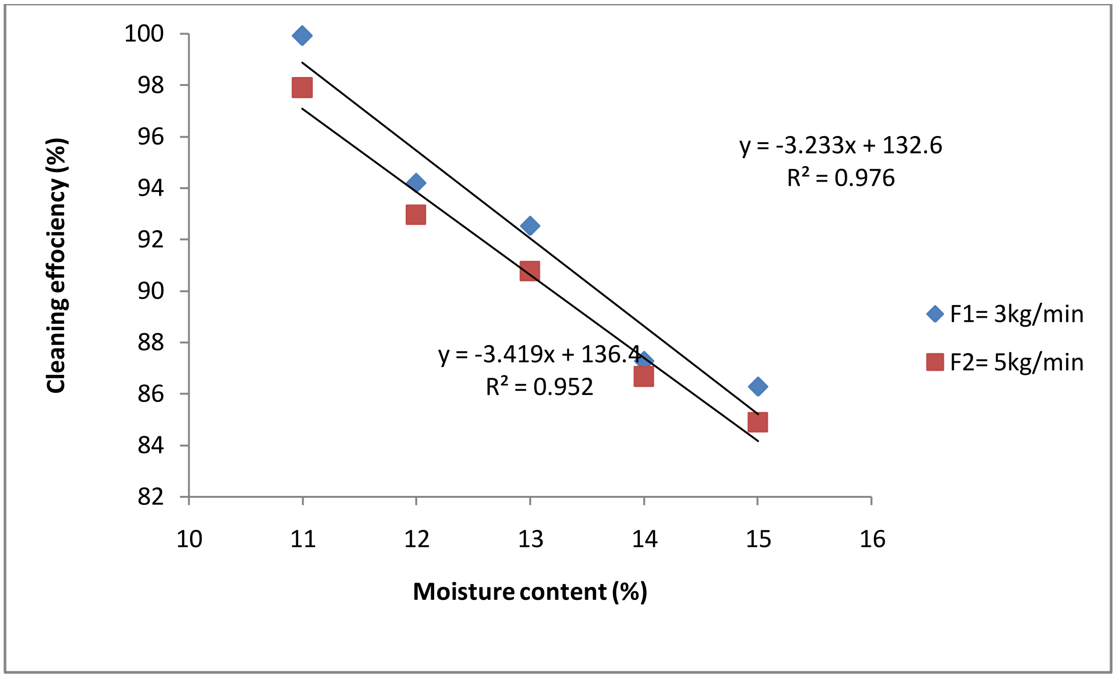


Fig.4.3 Effect of Moisture content on cleaning efficiency at different feed rate

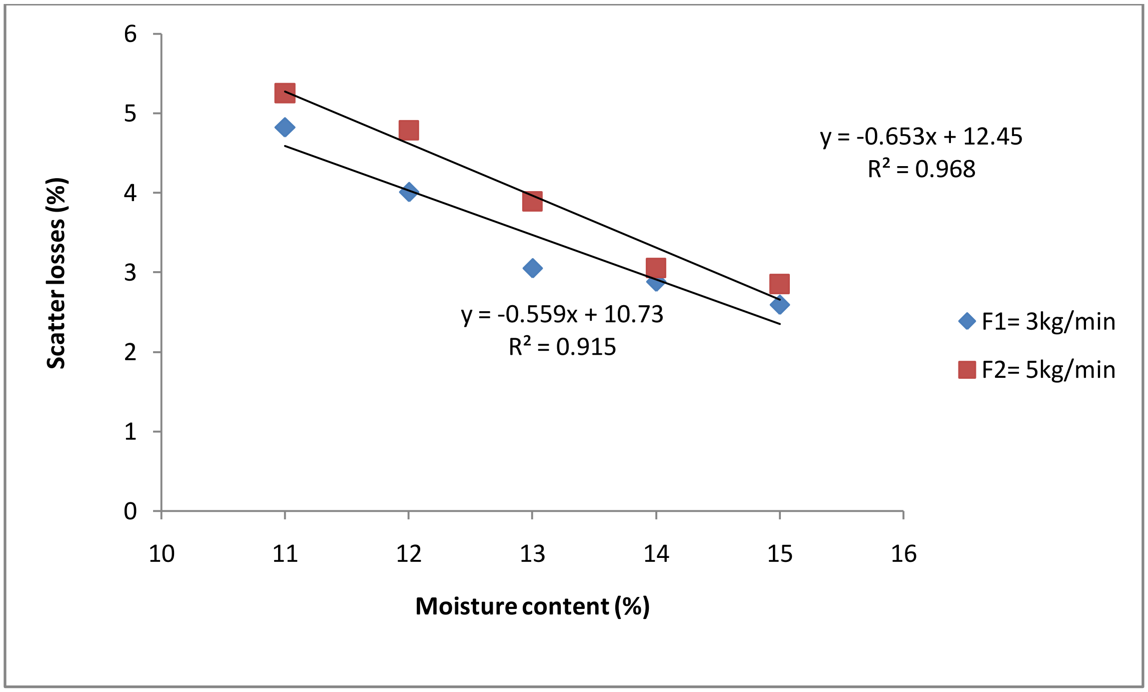


Fig.4.4 Effect of Moisture content on Scatter losses at different feed rate

4.1.3. Effect of Moisture content on throughput capacity at different feed rate

Fig.4.5 shows the effect of moisture content and feed rate on throughput capacity. The throughput capacity increases with decrease in moisture content. The maximum throughput capacity of 250kg/hr was recorded at 11% moisture content levels and 5kg/min feed rate while the lowest value of 148.95kg/hr at 3kg/min and 15% moisture content level. This shows that the capacity increase with decrease in moisture content which could be due to the decrease of bidding force between ear head and grain. Timothy, 2012 reported similar results and obtained the highest throughput capacity of 110kh/h at the lowest moisture content of (9%) and the minimum throughput capacity of 43.kg/h at the highest moisture content of (16%). However, this research observed an increased of throughput capacity from 110kg/h to 250Kg/hr which may be connected to redesign of cylinder, spike tooth arrangement and concave opening. Fig.4.5 also illustrated that the throughput capacity increase with an increase of feed rate and it agreed with Abiodun, 2000 that state throughput capacity decrease with decrease in feed rate and found the highest throughput capacity of 66kg/h at the highest feed rate level (4kg/min). The R^2 values indicate that a good relation between the moisture content and throughput capacity

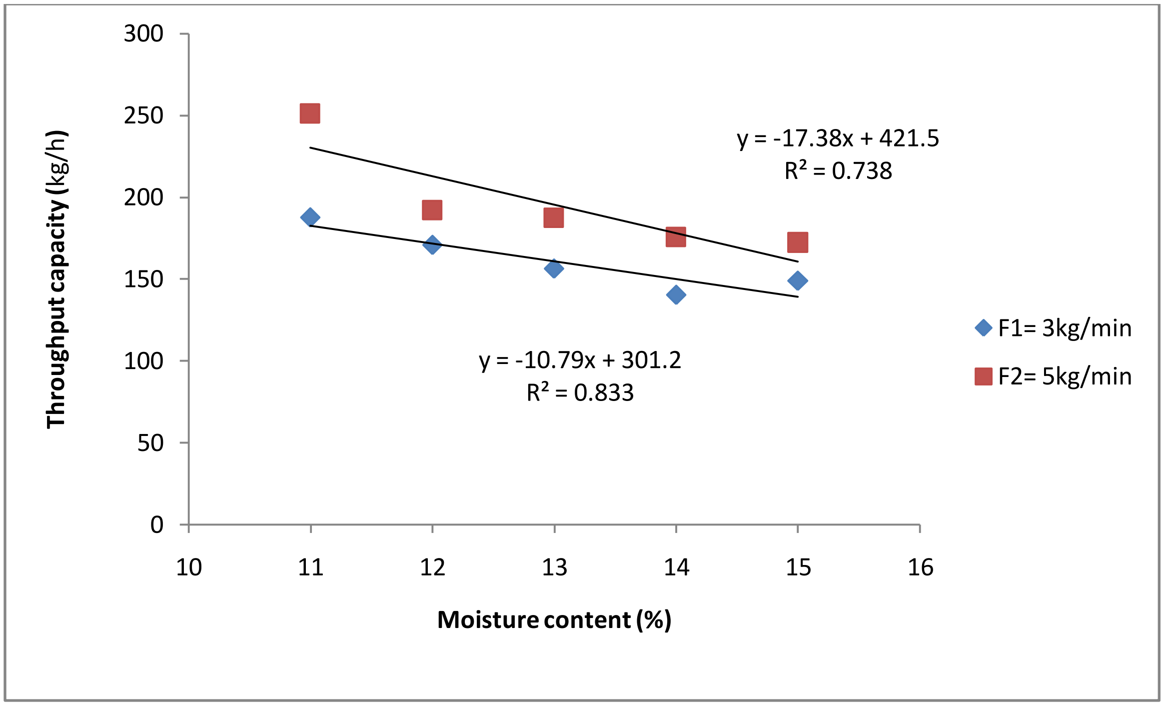


Fig.4.5 Effect of moisture content on Throughput capacity at different feed rate

4.2.1 Effect of cylinder speed on threshing efficiency and Grain Damage at different feed rate

Fig 4.6 shows the effect of cylinder speed on threshing efficiency at different feed rate. The threshing efficiency increased with increased in cylinder speed. The highest threshing efficiency of 99.96 % was obtained at 1100 rpm cylinder speed and feed rate of 3 kg/min while the lowest value of 90.39 % was recorded at a cylinder speed of 700 rpm and feed rate of 5kg/min. This result is in agreement with the result of Timothy (2012). The author stated that the threshing efficiency increased with increased in cylinder speed and obtained the highest threshing efficiency of 99.8 % at highest speed level of 700 rpm and 9 % moisture content. A slight increase of threshing efficiency was recorded which may be due to the increased of the number and arrangement of spike tooth and higher energy imparted on the sorghum ear head. The R^2

values of 0.9904 and 0.9916 indicate a strong relation between threshing efficiency and cylinder speed.

Fig 4.7 illustrated the effect of cylinder speed on mechanical grain damage. From the Figure the mechanical grain damage increased with increased in cylinder speed which is due to the high impact force from the spike and concave cylinder clearance. The highest grain damage of 3.76% was obtained at the speed level of 1100 rpm and lowest feed rate of 3 kg/min while the lowest grain damage value of 2.11% was recorded at speed level of 700 rpm and feed rate of 5 kg/min. Timothy, 2012 reported similar results with the maximum grain damage of 5.09 %.at the speed level of 700 rpm and obtained a minimum grain damage value at 300 rpm cylinder speed. R^2 value of 0.9653 and 0.9776 illustrated very close relation between the cylinder speed and mechanical grain damage. However, by considering the two graphs (Fig. 4.6 and 4.7) the best cylinder speed for threshing can be chosen. 1100 rpm was consider

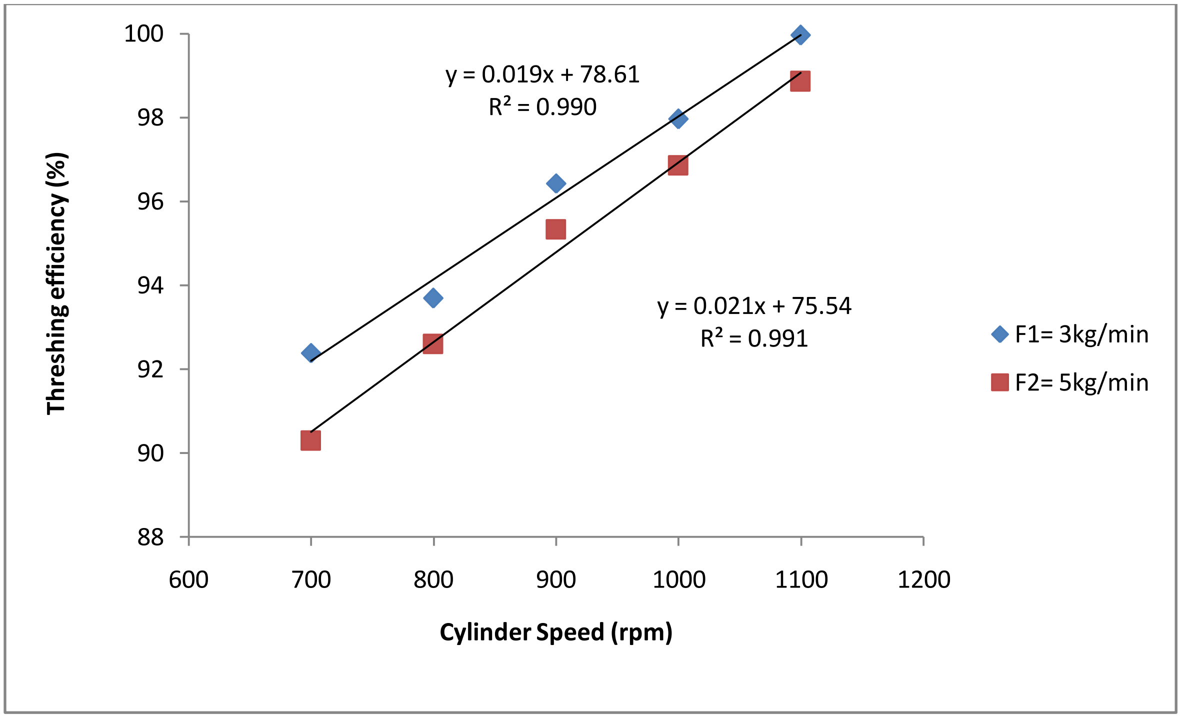


Fig4.6 Effect of speed on threshing efficiency at different feed rate

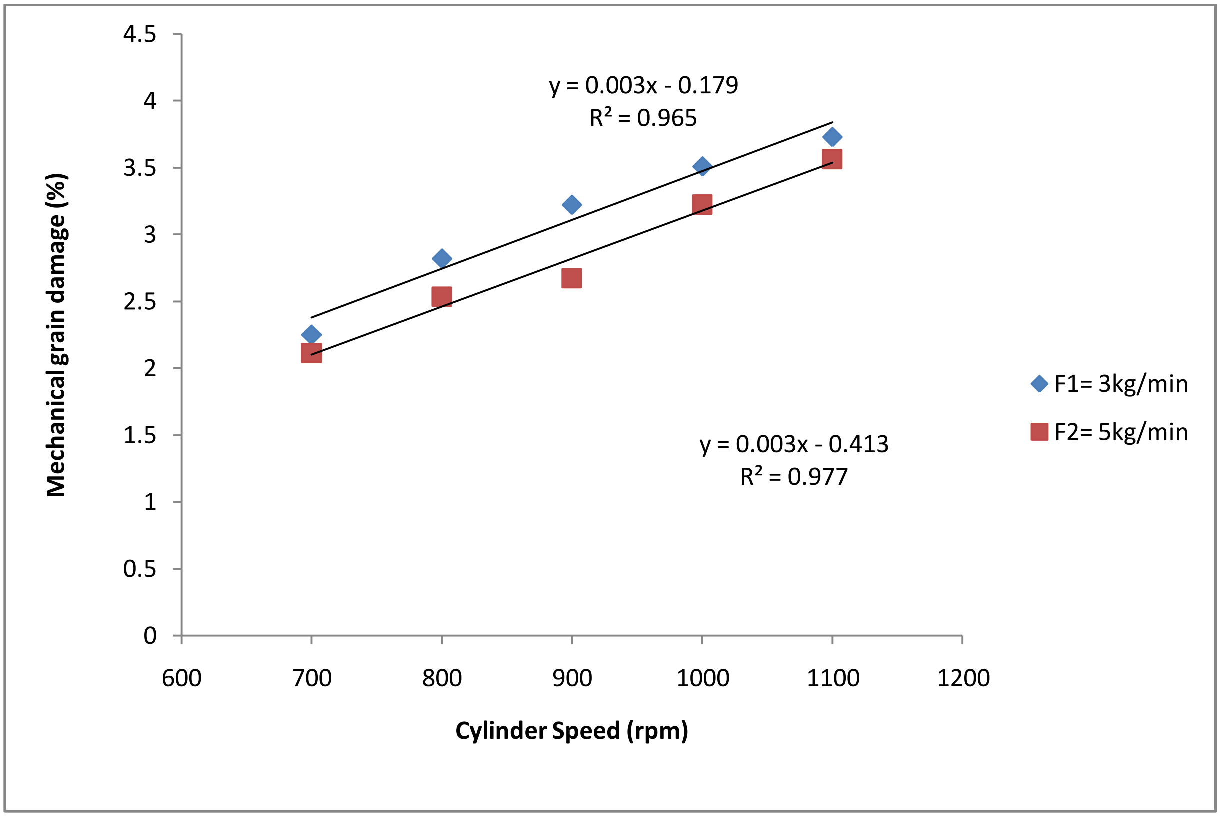


Fig4.7 Effect of speed on Mechanical grain damage at different feed rate

4.2.2 Effect of cylinder speed on cleaning efficiency and Scatter losses at different feed rate

Fig.4.8 shows the effect of cylinder speed on cleaning efficiency at different feed rate. The maximum cleaning efficiency of 99.83 % was obtained at 1100 rpm cylinder speed and 3 kg/min feed rate while the lowest cleaning efficiency of 91.53 % was recorded at the lower speed level of 700 rpm and second feed rate 5 kg/min. The result obtained is higher than that of Timothy, 2012 that obtained a maximum cleaning efficiency of 99.3% at 700 rpm and 9 % moisture content level and 1kg/min feed rate. This could be associated with the increase in the number of sieves from one sieve to three different sizes of sieves. The result is similar to the

Abiodun, 2000 that obtained the highest cleaning efficiency of 98.77% at the highest speed level of 800 rpm. The R^2 values of 0.9927 and 0.9906 show a good linear relation between cleaning efficiency and cylinder speed.

Fig.4.9 shows the effect of cylinder speed on scatter losses at different feed rate. The result shows that an increase in cylinder speed and feed rate results in increase of scatter grain which may be connected to the fact that at higher speed large percentage of the threshed grains are waiting on the sieve and pile up thereby causing grain losses. The highest scatter grain loss of 5.38 % was recorded at 1100 rpm cylinder speed and 5 kg/min feed rate while the lower value of 2.02 % was obtained at 700 rpm cylinder speed and 3 kg/min feed rate. A decreased of scatter grain loss was record as compared with the Timothy, 2012 result tha recorded the maximum of 11.8 % scatter loss at cylinder speed of 700 rpm. These decreased of scatter grains loss may be due to redesigning of the hopper and shaker. The R^2 values of 0.9532 and 0.9906 show a strong linear relation between the scatter grain and cylinder speed.

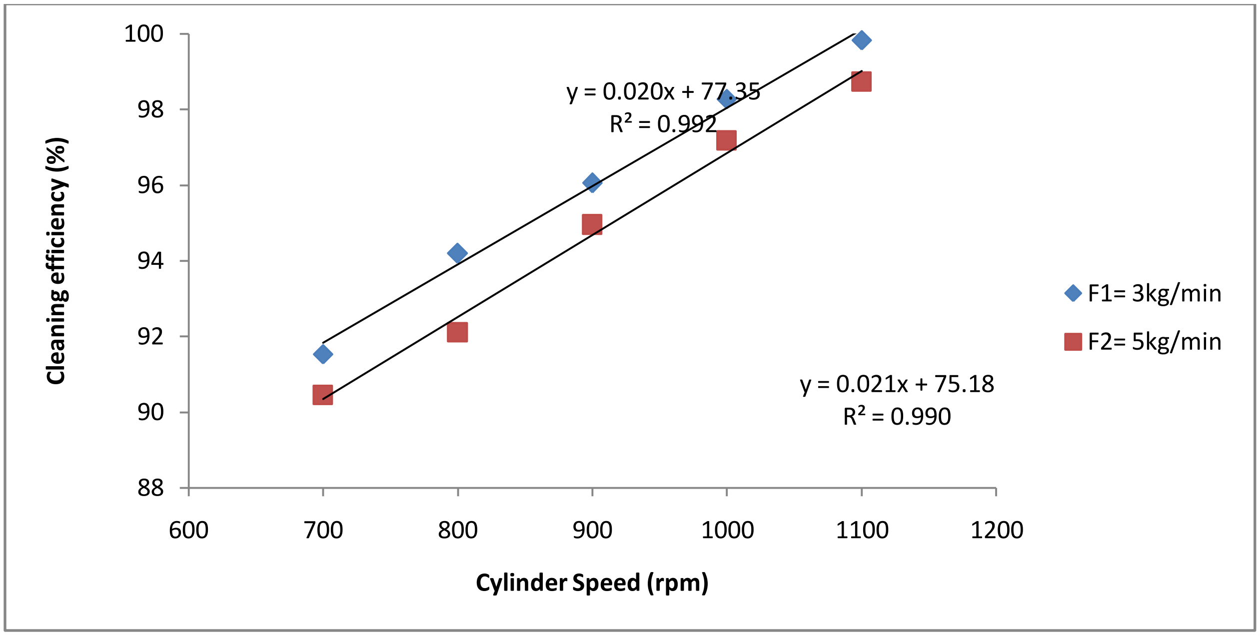


Fig4.8 Effect of speed on cleaning efficiency at different feed rate

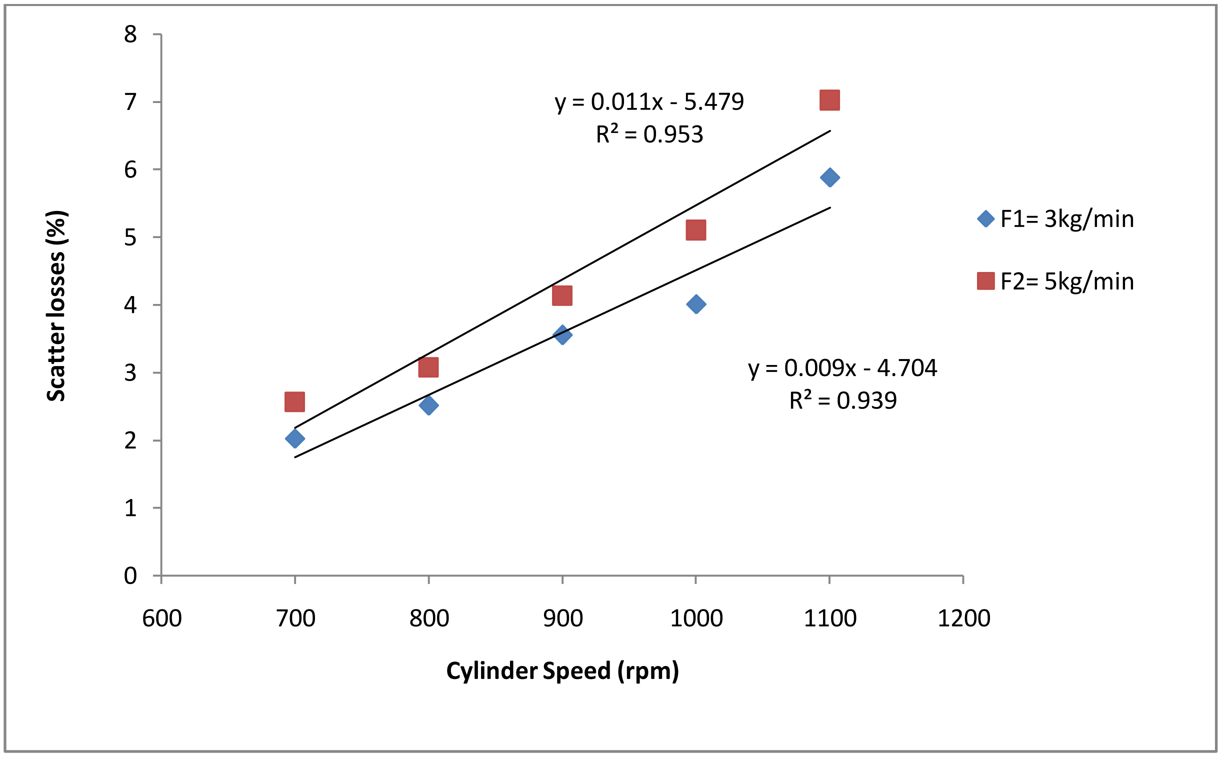


Fig4.9 Effect of Speed on Scatter losses at different feed rate

4.2.3 Effect of cylinder speed on throughput capacity at different feed rate

Fig.4.11 presented the effect of cylinder speed on throughput capacity from the graph the throughput capacity increased with increase in cylinder speed which could be due to the fast rotation of the drum and high impact on the sorghum ear head. The maximum capacity of 235.96 kg/hr was obtained at the cylinder speed of1100 rpm and feed rate of 5 kg/min while the minimum throughput capacity of 96.50 kg/hr was observed at the speed level of 700 rpm and feed rate of 3 kg/min. The results show an increase of throughput capacity from 110 kg/hr to 2305.96 kg/hr when compared with the previous IAR sorghum thresher. This may be associated with the redesign spike tooth arrangement which increase the rate of crushing and shattering of sorghum head. The R^2 values of 0.9362 and 0.8848 show a strong correlation between throughput capacity and cylinder speed.

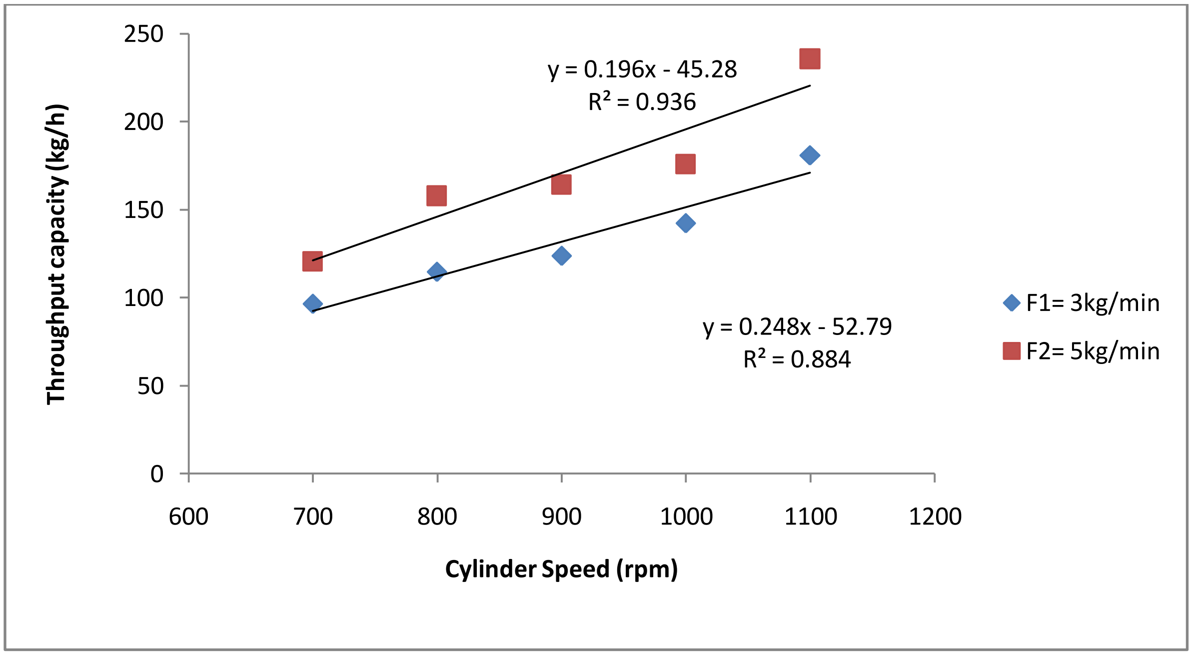


Fig4.11 Effect of speed on throughput capacity at different feed rate

4.4 Results of the Analysis of Variance and Duncan Multiple range test

4.4.1 ANOVA for Threshing Efficiency

Table 4.4 shows the analysis of variance of an independent variable on threshing efficiency. From the table moisture content and replication are highly significance on the threshing efficiency while feed rate and speed are not significance at 5%. However the interaction between the factors such as moisture content and feed rate, moisture content and speed, feed rate and speed are not significance at 5%. The same for interaction of the three factors moisture content, feed rate and speed are not significance at 5%. When the mean was subjected to Duncan range test for moisture content m_1 has the highest effect on the threshing efficiency while m_2 has the least.m_3, m_5, m_4 and m_2 are not significance. When the mean of feed rate was compared it was found that f_1 and f_2 they are statistically the same i.e having the same effect on the threshing efficiency. Similarly for speed no significance differences between their mean (Table 4.9, 4.11 and 4.12)

Table 4.4 ANOVA of the Independent Variables on Threshing Efficiency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	56604.64	28302.32	291.47	0001**
Moisture	4	10263.19	2565.80	26.42	0001**
Feed rate	1	138.36	138.36	1.42	0.2355^{NS}
Speed	4	222.87	55.72	0.57	0.6823^{NS}
Moisture*Feed rate	4	210.96	52.74	0.54	0.7044^{NS}
Moisture*Speed	16	561.95	35.12	0.36	0.9879^{NS}
Feed rate*Speed	4	110.40	27.60	0.28	0.8876^{NS}
Moisture*Feed rate*Speed	16	562.77	35.17	0.36	0.9878^{NS}
Error	98	9516.14	97.10		
Total	149	78191.30			

4.4.2 ANOVA for Cleaning Efficiency

Table 4.5 shows ANOVA of independent variable on cleaning efficiency. It can be understand that replication and moisture content are highly significance on the cleaning efficiency. The other factors feed rate and speed are not significance on the cleaning efficiency although their interaction shows similar scenario. The interaction between the two factors and three factors indicated that are not significance at 5% for different combination between the factors When the means was subjected to Duncan test the result show that m_1 are statistically significance with m_5, m_3, m_4 and m_2. For Speed and feed rate no significance different between their means.

Table 4.5 ANOVA of the Independent Variables on Cleaning Efficiency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	57005.40	28502.69	342.99	0001**
Moisture	4	6286.48	1571.62	18.91	0001**
Feed rate	1	12.32	12.32	0.15	0.7010NS
Speed	4	80.59	20.15	0.24	0.9136 NS
Moisture*Feed rate	4	58.30	14.58	0.18	0.9506 NS
Moisture*Speed	16	582.38	36.40	0.44	0.9683 NS
Feed rate*Speed	4	178.95	44.74	0.54	0.7079 NS
Moisture*Feed rate*Speed	16	808.72	50.55	0.61	0.8704 NS
Error	98	8143.75	83.09		
Total	149	73156.89			

4.4.3 ANOVA for Throughput capacity

Table 4.6 presented the ANOVA result of moisture content, speed and feed rate on throughput capacity. The results indicated that there is highly significance difference for replication, moisture content, feed rate and speed at 5%. Similarly the interaction between the factors moisture content and feed rate, feed rate and speed are highly significance at 5% while moisture content and speed are significance at 5%. The interaction between the three factors shows highly significance at 5% on throughput capacity. When the Duncan range test was carried out the result shows that m_1, m_3, and m_5 there is no significance different between their means thus, have the same effect while m_4 and m_2 are also the same. F_1 and F_2 are statistically significance. For the speed s_5 and s_4 are the same s_3 and s_2 are also the same similarly $s_3$and s_1 are the same Illustrated in Table 4.9, 4.11 and 4.12.

Table 4.6 ANOVA of the Independent Variables on Throughput capacity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	115070.85	57535.43	43.36	0001**
Moisture	4	83979.32	20994.83	15.82	0001**
Feed rate	1	13160.73	13160.73	9.92	0.0022**
Speed	4	78707.09	19676.78	14.83	0001**
Moisture*Feed rate	4	35366.06	8841.51	6.66	0001**
Moisture*Speed	16	43407.54	2712.97	2.04	0.0172*
Feed rate*Speed	4	22926.37	5731.59	4.32	0.0029**
Moisture*Feed rate*Speed	16	58778.40	3673.65	2.77	0.0011**
Error	98	130042.44	1326.96		
Total	149	581438.79			

4.4.4 ANOVA for Scatter losses

Table 4.7 presented the effect of independent variables on scatter losses. From the Table it can be understood that replication, moisture content and speed are highly significance while feed is not significance at 5%. Similarly the interaction between the two factors such as moisture content and feed rate, moisture content and speed are highly significance at 5% while feed rate and speed are not significance at the same probability level. However, the interaction between the three factors shows highly significance at 5%. Table 4.9, 4.11 and 4.12 shows the Duncan range test the results shows that m_3, m_2 m_4 and m_5 have no significance difference between their means while m_1 and m_3, m_2, m4, m_5 are statistically significance. F_1 and F_2 are not significance while s_5 and s_4, are the same likewise $s_{3,}$ s_5, s_2 and s_4 are not significance with s_1.

Table 4.7 ANOVA of the Independent Variables on Scatter losses

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	211.20	105.60	19.91	0001^{**}
Moisture	4	389.20	97.30	18.34	0001^{**}
Feed rate	1	8.61	8.61	1.62	0.2057^{NS}
Speed	4	220.66	55.17	10.40	0001^{**}
Moisture*Feed rate	4	179.25	44.81	8.45	0001^{**}
Moisture*Speed	16	292.63	18.29	3.45	0001^{**}
Feed rate*Speed	4	36.65	9.16	1.73	0.1500^{NS}
Moisture*Feed rate*Speed	16	202.24	12.64	2.38	0.0048^{**}
Error	98	519.89	5.31		
Total	149	2060.35			

4.4.5 ANOVA for Mechanical Grain Damage

Table 4.8 presented the ANOVA of independent variable on mechanical grain damage. The Table indicated that all the three factors (moisture content, speed and feed rate) including the replication are highly significance at 5%. The same with their interaction are also highly significance at 5%. A Duncan range test is further evaluated (Table 4.9, 4.11 and 4.12) and the result shows that m_4 and m_2 are not significance with m_3 and m_5 but m_1 are statistically significance with each. s_5, s_4 and s_1 are not significance; s_4, s_1 and s_2 are also not significance while s_3 is significance with each. F_1 and F_2 are statistically significance indicating that have different effect on mechanical grain damage.

Table 4.8 ANOVA of the Independent Variables on Mechanical Grain Damage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	97.19	48.59	8.13	0.0005**
Moisture	4	262.86	65.71	10.99	0001**
Feed rate	1	106.75	106.74	17.85	0001**
Speed	4	157.72	39.42	6.59	0001**
Moisture*Feed rate	4	252.77	63.19	10.57	0001**
Moisture*Speed	16	643.74	40.23	6.73	0001**
Feed rate*Speed	4	321.39	80.35	13.44	0001**
Moisture*Feed rate*Speed	16	524.34	32.77	5.48	0001**
Error	98	586.00	5.98		
Corrected Total	149	2952.75			

Table 4.9 Duncan Multiple Range Test of Moisture Content on independent Variables

Moisture Content (%)	11	12	13	14	15
TE	99.94^a	98.69^b	97.43^b	95.96^b	94.58^b
CE	99.91^a	94.19^b	94.53^b	87.28^b	86.27^b
TC	250.98^a	192.06^b	187.29^a	175.54^b	172.34^a
SL	5.25^a	4.01^b	3.05^b	2.88^b	2.59^b
MD	2.06^a	2.34^b	2.51^c	3.29^b	3.81^c

Table 4.11 Duncan Multiple Range Test of Speed on independent Variables

Speed (rpm)	700	800	900	1000	1100
TE	90.39^a	92.69^a	96.43^a	97.96^a	99.96^a
CE	91.53^a	94.19^a	96.05^a	98.28^a	99.83^a
TC	120.43^c	157.79b^c	164.08^b	175.89^a	235.57^a
SL	2.02^c	2.51^c	3.55^{cb}	4.01^{ba}	5.28^a
MD	2.25b^a	2.82^b	3.22^c	3.51^{ba}	3.73^a

Table 4.12 Duncan Multiple Range Test of Feed rate on independent Variables

Feed rate (Kg/min)	3	5
TE	99.98^a	96.43^a
CE	96.05^a	91.53^a
TC	123.86^b	248.23^a
SL	2.56^a	5.38^a
MD	2.11^b	3.33^a

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.4 Summary

An improved IAR sorghum thresher was developed at the Agricultural Engineering Workshop of the Department of Agricultural engineering, Ahmadu Bello University Zaria. The performance evaluation carried out on the thresher indicate that

1. Threshing efficiency increased with decrease in feed rate and moisture content at an increase speed
2. Cleaning efficiency was observed to increase with a decreasing feed rate and moisture content and increase in the cylinder speed.
3. Mechanical (visible) grain damage increased with an increase in cylinder speed, moisture content and decrease in feed rate.
4. Scatter loss increased with an increase in cylinder speed and feed rate and lower moisture content. The highest losses were recorded at a cylinder speed of 1100 rpm.
5. Throughput capacity also increased with an increase in cylinder speed and feed rate and lower moisture content.

Based on the analysis of variance, it was discovered that the independent variables i.e. feed rate, moisture content and speed are highly significance on the depended variables i.e. threshing efficiency, cleaning efficiency, scatter loss, grain damage and throughput capacity at 5%.

5.2 Conclusion

An improved prototype sorghum thresher was developed and evaluated. The performance achieved were 99.98 %, 99.95%, 5.45%, 3.70% and 250 kg/h for threshing efficiency, cleaning efficiency, scatter loss, grain damage and throughput capacity respectively. However, as compared the results of the existing IAR sorghum thresher a decrease in scatter losses and mechanical grained damage from 11.6% to 5.45% and 5.08% to 3.70% respectively were obtained. Similarly the throughput capacity increase from 110kg/h to 250kg/h. A slice increase of threshing and cleaning efficiency was achieved from 99.8 to 99.98% and 99.3 to 99.95% respectively. The best combination of the independent variables for optimum operation was observed at 13% moisture content 1100rpm cylinder speed and 5 kg/min feed rate.

5.3 Recommendation

From the analysis and discussions on the performance of the Developed IAR sorghum thresher the following recommendations were made.

1. The shaker orientation should be changed to further reduce the scatter losses
2. The length of the drum and straw outlet should be increased thereby improving the threshing efficiency and reducing the scatter losses
3. A smaller capacity sorghum thresher should be constructed so that small scale farmer could afford to buy and owned
4. The technology should be extended to farmers in order to reduce drudgery and fatigue involved in sorghum threshing

REFERENCES

Abiodun, A. (2000). Design and Construction of Manually operated sorghum thresher. Unpublished HND. project. Department of Agricultural Engineering Samaru, College of Agriculture, Zaria, Nigeria. Pp23-52

Ajayi, (1994). Evaluation of locally built soybean thresher. Unpublished B.Eng. Project Department of Agricultural Engineering. Ahmadu Bello University, Zaria, Nigeria. Pp25-33

Agunsoye A .M (2007). Design and Construction of modified cowpea thresher. Unpublished, Undergraduate Project. Department of Agric Engineering Ahmadu Bello University, Zaria, Nigeria.Pp37- 45

Akinsoye, V. O (1993). Tropical agriculture for senior secondary school Published: Macmillan Nigeria Ltd. Pp15

Ali M. A.(1999). Maize Dehusker sheller Development and Women use participation. Samaru journal of Agricultural mechanization. Vo1.1 Pp 43-51

Ali, M. A. 1986 Comparative Ergonomics Studies of Male and Female Operations on Selected Farm Task. Unpublished M.sc. Thesis. Ahmadu Bello University, Zaria, Nigeria.Pp 42-45

Alonge, A. F and Adegbugbe. T. A, (2002). Performance Evaluation of locally developed grain thresher. *Journal of Agricultural mechanization in Asia, Latin America and Africa (AMA)* 3(2): Pp52-54

ASME. (1948). American Society of Mechanical Engineers; ASME Standard S.417. Pp21

ASAE. (1972). American Society of Agricultural Engineers; ASAE Standard S.352-1 and S

401-1. Yearbook, 2950 n Taylor, Niles Road, St Joseph, Michigan 49085.Pp 25

Amir, u. k, (1990). Dual model all crop thresher for Egyptian condition. *Journal of Agricultural mechanization in Asia, Latin America and Africa (AMA)* 2(21): Pp11- 14

Bashir, I. M. and Dauda J.O (2003). Problem associated with maintenance of fully imported technology Proceeding of agricultural engineering Vol.1: Pp59-62

Dalha, I. B. and Dangora N. D (2011). Performance Evaluation of RF450 sorghum thresher Proceeding of agricultural engineering Vol.32: Pp139-140

Dangora, N.D. Sulaiman, M.L. and Yusuf D.D. (2006): Modification of IAR Maize Dehusker Sheller for Sorghum Threshing “Proceeding of the Seven International Conference of Institute For Agricultural Engineers” Vol. 28:Pp106-109.

FAO (1979). Processing and storage of food grain by rural famers. Agricultural Service bulletin. UN Rome.Pp33

FAO, 2007.Agricultural Engineering in Development Post-Harvest Operations.(Threshing and Shelling). http://www.fao.org/docep/19/1/07. Pp23

FAO, 2003 Statistical Reports on Food losses due to Improper Storage Facilities. FAO x 00 76, Rome Italy. Pp11

Grochowicz, J. (1980). Machine for cleaning and sorting of seed (translated from polish). Published US Department of agriculture and national science foundation Washington DC.Pp33- 40

Hunt, D. (1983). *Farm power and machinery management* 8th edition Iowa state University press USA. Pp30

Hannah J. and R. C Stephens (1984) *mechanics of machines* Published. Edward Arnold London. Pp103-120

Lawan I. (2008), A Survey of Available Rice and Sorghum Threshers in Kano,State. Unpublished, B. Eng. Project. Department of Agric Engineering Bayero University, Kano, Nigeria.Pp45

Institute for Agricultural Research (1974). Agricultural mechanization Research programmed. Ahmadu Bello University, Zaria. Report No. DAE/AM/87. Pp20

Institute of Agricultural Research (1987); A Report on Agricultural Engineering Prototypes Agricultural Mechanization Research Programme. Ahmadu Bello University, Zaria. Nigeria.Pp19

Jain, S. C and Grace P. (2003). *Farm machinery an approach*. Centre for farm machinery training & testing institute of Tractor Nager, BUDN. Published Standard publishers Distributors. 1st edition.Pp203-250

Joshi, H. C (1981). Design and selection of thresher parameters and components. *Journal of Agricultural mechanization in Asia, Latin America and Africa (AMA)* 12(2): Pp61-68

Joshi, H. C and Singh K. N (1980). Axial flow thresher with multi crop potential. IRRI newsletter, Feb-Mar, 1980.Pp11

Kebede. D and T. N Mishral. (1990). Development and performance evaluation of a sorghum thresher. Department of farm machinery and power engineering college of Technology Pantangal, India.Pp30-39

Khumir, R.S and Gupta, J.K (2004). *A textbook of machine design*. 14 Edition, Eurasian Ltd. Ran Nagar New Delhi, Pp.1230

Matouk, A. M. El-kholy M. M. Radwan S. M and Owies T. R. (2000). Effect of moisture content on mechanical properties of some cereal Grain. *Misr. Journal of Agricultural Engineering* 23(1): Pp217-231

Mishra, T. N and Desta (1990). Development and performance evaluation of sorghum thresher. *Journal of agricultural mechanization in Asia, Latin America and Africa* 7(3): Pp31-34

Mohsenin, N. N (1980) *Physical properties of plant and animal materials*, 2nd edition. Gordon and Breach science, New York USA. Pp31-33.

Mustapha, M. Bello (2008): Rice And Sorghum Threshing: A Study Towards Upgrading the Current Practice in Kano State. Unpublished B. Eng. Project, Department of Agric. Engineering, Bayero University, Kano.Pp45-50

NAERLS (2012) Agricultural performance survey of wet season in Nigeria executive summary.Pp23

Ndirika, V. I. O (1994). Modeling the performance selected of stationary grain thresher. Unpublished PhD thesis. Department of Agricultural Engineering Ahmadu Bello University, Zaria.Pp78-90

NSAE/NCAM/SON, (1995). Nigeria standard Test code for Grain and seed cleaners. Grain Harvesters, and maize Sheller, Nigeria Agricultural Engineering standards for the Nigerian society of Agricultural Engineers. Sponsored by National centre for Agricultural mechanization and standards organization of Nigeria.Pp34

Odigboh, E. U, (2004). Mechanization for enhanced gricultural productivity in Nigeria, proceeding of valedictory seminar. Department of Agricultural and Bioresource Engineering. University of Nigeria, Nsuka.Pp56-60

Ojha D.A and Micheal A. (2003); Performance Evaluation of Foot Operated Thresher. *AMA Journal* Vol. 33. No 3. Pp140-141

Oluka S.I., O. Oduma and P.C. Eze (2013) “Physical and Mechanical Properties of Grains” *Journal of Experimental Research*. Vol 1.Pp23

Phillip, P.R and Callaghan J. R. O, (1977). Mathematical model of cereal harvesting. *Journal of Agricultural engineering research.* Vol.19: Pp415-417

Simonyan, K. J., Yiljep Y D. and O.J Mudiare 2006. Modeling cleaning Process of a stationary sorghum thresher. “Proceeding of the Seven International Conference of Institute For Agricultural Engineers” Vol. 28:Pp106-109

Simonyan, K. J. and Yiljep Y D, 2008. Investigation of Grain separation and cleaning efficiency distribution of conventional stationary raspbar sorghum thresher. *Agricultural engineering international Journal* (ICGR) volume X,Pp45

Singh, K. L and H. C Joshi (1977). Design and Development of rice culture machinery for different power sources, Progress report for AD-Hoc I.C.A.R research project. Agric Engineering Department GB Pant University of Agric and Technology Pantnager.Pp46-47

Taylor, J.R.N. (2002). Overview of an importance of sorghum in Africa. *Journal of the institute of Brewery* Vol.21.Pp2

Timothy, Y. J, (2012). Design, Construction and Performance Evaluation of an improve Sorghum thresher. Unpublished MSc. thesis. Department of Agricultural Engineering Ahmadu Bello University, Zaria, Nigeria.Pp40-50

USAID, 2006.Trip Report: Northern Nigeria Joint Food Supply Assessment Mission.http://www.fews.net/nigeria..pdf. Pp22

Yavini S. (2002). Development of improved IAR multicrop thresher. Unpublished B.Eng. Project Department of Agric Engineering Ahmadu Bello University, Zaria.Pp45

Yisa, M. G (1997). Agricultural mechanization. How far and what next, Paper presented at NSE quarterly Dinner minna, Niger State, Nigeria.Pp48

Yusuf, D.D (2011). Role and challenges of Agricultural mechanization in meeting the needs of Tomorrow`s Agriculture in Nigeria. Lead paper presented at 11th international conference and 32nd annual general meeting of *Nigerian institute of agricultural engineers* 11th – 20th October,2011 Ilorin, Kwara state Nigeria. Pp13-42

Appendix A: Experimental Layout

The field layout of the experiment in a completely Randomize design with the cylinder speed at 5 levels (S_1, S_2, S_3, S_4, S_5), feed rate at 2 levels (F_1, and F_2) and moisture content at 5 levels (M_1, M_2, M_3, M_4 & M_5). In three replications are shown below

RI

M1S1F1	M1S1F2	M2S1F1	M2S1F2	M3S1F1	M3S1F2	M4S1F1	M4S1F2	M5S1F1	M5S1F2
M1S2F1	M1S2F2	M2S2F1	M2S2F2	M3S2F1	M3S2F2	M4S2F1	M4S2F2	M5S2F1	M5S2F2
M1S3F1	M1S3F2	M2S3F1	M2S3F2	M3S3F1	M3S3F2	M4S3F1	M4S3F2	M5S3F1	M5S3F2
M1S4F1	M1S4F2	M2S4F1	M2S4F2	M3S4F1	M3S4F2	M4S4F1	M4S4F2	M5S4F1	M5S4F2
M1S5F1	M1S5F2	M2S5F1	M2S5F2	M3S5F1	M3S5F2	M4S5F1	M4S5F2	M5S5F1	M5S5F2

RII

M1S1F1	M1S1F2	M2S1F1	M2S1F2	M3S1F1	M3S1F2	M4S1F1	M4S1F2	M5S1F1	M5S1F2
M1S2F1	M1S2F2	M2S2F1	M2S2F2	M3S2F1	M3S2F2	M4S2F1	M4S2F2	M5S2F1	M5S2F2
M1S3F1	M1S3F2	M2S3F1	M2S3F2	M3S3F1	M3S3F2	M4S3F1	M4S3F2	M5S3F1	M5S3F2
M1S4F1	M1S4F2	M2S4F1	M2S4F2	M3S4F1	M3S4F2	M4S4F1	M4S4F2	M5S4F1	M5S4F2
M1S5F1	M1S5F2	M2S5F1	M2S5F2	M3S5F1	M3S5F2	M4S5F1	M4S5F2	M5S5F1	M5S5F2

RIII

M1S1F1	M1S1F2	M2S1F1	M2S1F2	M3S1F1	M3S1F2	M4S1F1	M4S1F2	M5S1F1	M5S1F2
M1S2F1	M1S2F2	M2S2F1	M2S2F2	M3S2F1	M3S2F2	M4S2F1	M4S2F2	M5S2F1	M5S2F2
M1S3F1	M1S3F2	M2S3F1	M2S3F2	M3S3F1	M3S3F2	M4S3F1	M4S3F2	M5S3F1	M5S3F2
M1S4F1	M1S4F2	M2S4F1	M2S4F2	M3S4F1	M3S4F2	M4S4F1	M4S4F2	M5S4F1	M5S4F2
M1S5F1	M1S5F2	M2S5F1	M2S5F2	M3S5F1	M3S5F2	M4S5F1	M4S5F2	M5S5F1	M5S5F2

Appendix: B

ANOVA FOR THE LAYOUT

Source of variance	DF	SS	MS	F
Rep (r-1)	2			
Speed (S-1)	4			
Feed (f-1)	1			
Moisture (M-1)	4			
Speed*Feed rate (S-1)(f-1)	4			
Feed*Moisture (f-1)(M-1)	4			
Moisture*Speed (M-1)(S-1)	16			
Feed*Moisture*Speed	50			
Error (SMF)(r-1)	100			
Total array (SFMr-1)	149			

Appendix: C

Table 4.2 Effect of Moisture content on Machine Performance

Feed rate (kg/min)	Moisture content (%)	Threshing efficiency (%)	Cleaning efficiency (%)	throughput capacity (kg/h)	Scatter losses (%)	Grain damage (%)
3	11	99.94	99.91	187.7	4.82	2.06
3	12	98.69	94.19	170.86	4.01	2.34
3	13	97.43	94.53	156.56	3.05	2.51
3	14	95.96	87.28	140.44	2.88	3.29
3	15	94.58	86.27	148.95	2.59	3.81
5	11	97.82	97.89	250.98	5.25	1.98
5	12	95.25	92.95	192.06	4.78	2.22
5	13	93.56	90.75	187.29	3.89	2.38
5	14	92.12	86.66	175.54	3.05	3.02
5	15	91.87	84.87	172.34	2.85	3.54

Appendix: D

Table 4.3 Effect of cylinder Speed on Machine Performance

Feed rate (kg/min)	Speed (rpm)	Threshing efficiency (%)	Cleaning efficiency (%)	throughput capacity (kg/h)	Scatter losses (%)	Grain damage (%)
3	700	90.39	91.53	96.5	2.02	2.25
3	800	92.69	94.19	114.7	2.51	2.82
3	900	96.43	96.05	123.86	3.55	3.22
3	1000	97.96	98.28	142.44	4.01	3.51
3	1100	99.96	99.83	180.95	5.28	3.73
5	700	90.3	90.44	120.43	2.56	2.11
5	800	92.6	92.1	157.79	3.07	2.53
5	900	95.33	94.95	164.08	4.13	2.67
5	1000	96.86	97.18	175.89	5.10	3.22
5	1100	98.86	98.73	235.57	5.38	3.56

Appendix: E

Cost estimates for production of Developed sorghum thresher.

Component	Type of materials	Quantity	Unit price	Total price
Frame	Mild steel angle iron	4	3700	14800
Pulleys	Ø 131, Ø 125, and Ø 357mm	3	1200	3600
Bearings	6250	7	580	4060
Hopper and fan housing	Mild steel sheet metal gauge 18 (2.4X1.4X 3)	5	3400	17000
Shaft for cylinder, fan and shaker	Mild steel 1.5	3	2000	6000
Concave rod	10mmX10mm square bar	5	900	4500
Bearing housing	3G I pipe	5 feet	1800	1800
Belt for Cylinder, fan and shaker	Long and medium	3	450	1350
Sieve	5mm diameter	3	1300	6500
Pegs	5mm flat bar	6	850	5100
Miscellaneous				4500
				₦ 69,210

Appendix: F

Performance Data of Improved IAR Sorghum Thresher

Obs	MC	F	S	rep	Te	Ce	Tc	SL	MD
1	1	3	700	1	98.57	99.71	46.96	5.79	3.56
2	1	3	700	2	98.91	99	150	3.63	0.24
3	1	3	700	3	99.89	93.68	97.49	4.66	2.87
4	1	3	800	1	99.89	94	62.61	15.53	0.22
5	1	3	800	2	99.84	98.33	207.27	2.36	2.25
6	1	3	800	3	91.81	86.35	133.59	8.85	3.2
7	1	3	900	1	98.64	92.5	39.27	17.36	4.38
8	1	3	900	2	97.98	95.71	231.43	3.59	0.4
9	1	3	900	3	99.89	79.55	134	10.37	2.81
10	1	3	1000	1	99.99	95	52.94	21.78	3.29
11	1	3	1000	2	99.98	96.25	259.2	3.85	3.88
12	1	3	1000	3	99.08	84.56	154.51	12.69	3.98
13	1	3	1100	1	99.25	92.5	72	18.7	3.53
14	1	3	1100	2	99.67	95.91	201.18	4.45	0.59
15	1	3	1100	3	97.31	79.88	135.22	11.46	3.5
16	1	5	700	1	95.5	96.79	128.57	9.49	0.1
17	1	5	700	2	98.57	97.93	151.88	2.59	0.6
18	1	5	700	3	89.22	90.28	138.82	5.98	0.35
19	1	5	800	1	94.23	97.27	110.77	8.4	3.33
20	1	5	800	2	97.6	99	180	2.75	3.76
21	1	5	800	3	89.52	92.85	143.93	5.52	3.73
22	1	5	900	1	96.88	97.5	198	8.27	0.1
23	1	5	900	2	92.65	98.33	217.36	5.21	5
24	1	5	900	3	91.72	92.13	205.6	6.68	2.52
25	1	5	1000	1	99.39	99.12	182.77	7.38	0.1
26	1	5	1000	2	99.06	75.36	200	14.74	2.56

Obs	MC	F	S	rep	Te	Ce	Tc	SL	MD
27	1	5	1000	3	99.15	56.88	189.47	10.95	2.8
28	1	5	1100	1	98.75	96.54	129.38	4.12	3.26
29	1	5	1100	2	98.24	99.12	282.86	3.01	3.71
30	1	5	1100	3	98.03	91.83	204.05	3.53	3.91
31	2	3	700	1	92.5	90.87	77.84	4.94	4
32	2	3	700	2	93.25	81.78	70.05	4.44	3.5
33	2	3	700	3	97.13	34.43	38.53	2.44	2.43
34	2	3	800	1	91.08	97.19	130.5	1.52	3.17
35	2	3	800	2	91.97	87.47	117.45	1.37	3.75
36	2	3	800	3	99.78	94.86	64.6	0.75	2.06
37	2	3	900	1	94.83	92.5	77.14	5.25	3.26
38	2	3	900	2	85.34	83.25	69.43	4.72	3.74
39	2	3	900	3	90.97	97.13	38.19	2.6	2.61
40	2	3	1000	1	99.57	97.27	114.29	4.93	3.35
41	2	3	1000	2	94.21	87.55	102.86	4.43	3.91
42	2	3	1000	3	98.89	96.05	56.57	2.44	2.15
43	2	3	1100	1	96.36	96.84	130.21	5.81	0.09
44	2	3	1100	2	96.73	87.16	117.19	5.23	0.08
45	2	3	1100	3	98.5	94.29	64.46	2.88	0.05
46	2	5	700	1	94.06	99.9	89.14	4.35	3.76
47	2	5	700	2	84.6	87.21	80.23	3.91	3.29
48	2	5	700	3	99.6	94.38	44.13	2.15	2.36
49	2	5	800	1	94.17	99.98	104.4	2.84	0.11
50	2	5	800	2	95.75	89.1	93.96	2.55	0.09
51	2	5	800	3	93.38	97.85	51.68	1.4	0.05
52	2	5	900	1	98.33	98.24	160	4.8	0.21
53	2	5	900	2	98.06	88.41	144	4.32	0.19
54	2	5	900	3	98.5	96.59	79.2	2.38	0.1

Obs	MC	F	S	rep	Te	Ce	Tc	SL	MD
55	2	5	1000	1	99.38	99.42	190.19	5.96	3.17
56	2	5	1000	2	99.85	96.77	171.17	5.36	3.75
57	2	5	1000	3	99.88	93.58	94.14	2.95	2.06
58	2	5	1100	1	95.95	97.06	135	5.86	3.53
59	2	5	1100	2	98.35	98.36	121.5	5.88	3.47
60	2	5	1100	3	92.81	98.15	66.83	4.88	3.21
61	3	3	700	1	97.86	95	154.29	6.37	3.53
62	3	3	700	2	88.07	85.5	138.86	5.73	3.47
63	3	3	700	3	95.96	91.25	76.37	3.15	3.21
64	3	3	800	1	97.27	95	145.95	5.3	0.11
65	3	3	800	2	87.55	85.5	131.35	4.77	0.09
66	3	3	800	3	95	91.25	72.24	2.62	0.05
67	3	3	900	1	95.71	99.67	135	4.62	0.22
68	3	3	900	2	86.14	87	121.5	4.16	0.2
69	3	3	900	3	92.43	94	66.83	2.29	0.11
70	3	3	1000	1	98.98	96.67	192	6.23	0.33
71	3	3	1000	2	98.2	87	172.8	5.61	0.3
72	3	3	1000	3	96.2	94	95.04	3.08	0.17
73	3	3	1100	1	97.25	99.67	144	5.25	0.4
74	3	3	1100	2	96.63	87	129.6	5.22	0.36
75	3	3	1100	3	99.31	94	71.28	5.07	0.2
76	3	5	700	1	97.5	98	82.29	5.7	3.26
77	3	5	700	2	98.75	88.2	74.06	5.83	3.74
78	3	5	700	3	95.38	96.2	40.73	4.3	2.61
79	3	5	800	1	95.5	97.19	168	4.09	3.55
80	3	5	800	2	85.95	87.47	151.2	3.68	3.09
81	3	5	800	3	92.08	94.86	83.16	2.02	2.25
82	3	5	900	1	96.79	97.27	204.71	4.97	0.17

Obs	MC	F	S	rep	Te	Ce	Tc	SL	MD
83	3	5	900	2	97.11	87.55	184.24	4.48	0.16
84	3	5	900	3	94.2	95	101.33	2.46	0.09
85	3	5	1000	1	97.93	98.24	291.89	5.32	3.56
86	3	5	1000	2	88.14	88.41	262.7	4.78	3
87	3	5	1000	3	96.09	96.59	144.49	2.63	2.75
88	3	5	1100	1	98.42	97.35	371.61	5.48	4.35
89	3	5	1100	2	98.58	87.62	334.45	6.73	3.91
90	3	5	1100	3	96.89	95.13	183.95	3.7	2.15
91	4	3	700	1	94.55	93.33	195.79	1.44	0.13
92	4	3	700	2	89.09	84	176.21	1.29	0.11
93	4	3	700	3	90.5	98.5	96.92	0.71	0.06
94	4	3	800	1	97	98.24	100.8	3.19	0.17
95	4	3	800	2	87.3	88.41	90.72	2.87	0.16
96	4	3	800	3	94.55	96.59	49.9	1.58	0.09
97	4	3	900	1	95.56	95	108.68	0.31	0.3
98	4	3	900	2	98	85.5	97.81	0.28	0.27
99	4	3	900	3	92.17	91.25	53.8	0.15	0.15
100	4	3	1000	1	98.85	96.84	132.63	4.98	5.26
101	4	3	1000	2	98.96	87.16	119.37	4.48	4.74
102	4	3	1000	3	97.6	94.29	65.65	2.47	2.61
103	4	3	1100	1	98.7	95.26	180	5.59	1.11
104	4	3	1100	2	88.83	85.74	162	5.53	1.00
105	4	3	1100	3	97.35	91.68	89.1	5.24	0.55
106	4	5	700	1	92.5	97.69	113.68	2.43	4.55
107	4	5	700	2	83.25	87.92	102.32	2.19	4.09
108	4	5	700	3	97.13	95.69	56.27	1.2	2.25
109	4	5	800	1	92.73	96.25	144	3.7	3.00
110	4	5	800	2	83.45	86.63	129.6	3.33	3.5

Obs	MC	F	S	rep	Te	Ce	Tc	SL	MD
111	4	5	800	3	97.5	93.31	71.28	1.83	2.48
112	4	5	900	1	94.09	96.25	168	3.89	0.30
113	4	5	900	2	84.6	86.63	151.2	3.5	0.27
114	4	5	900	3	99.6	93.31	83.16	1.92	0.15
115	4	5	1000	1	80.65	96.4	155.29	5.92	3.0
116	4	5	1000	2	92.58	86.76	139.76	5.13	3.5
117	4	5	1000	3	99.56	93.56	76.87	3.92	3.43
118	4	5	1100	1	97.39	96.25	109.57	5.7	3.00
119	4	5	1100	2	97.65	86.63	98.61	5.53	3.00
120	4	5	1100	3	95.2	93.31	54.23	5.79	2.9
121	5	3	700	1	94.23	98.5	175.61	0.25	0.1
122	5	3	700	2	94.81	88.65	158.05	0.22	0.09
123	5	3	700	3	99.98	97.03	86.93	0.12	0.05
124	5	3	800	1	96.25	97.86	130	5.7	0.21
125	5	3	800	2	86.63	88.07	117	5.13	0.19
126	5	3	800	3	93.31	95.96	64.35	2.82	0.1
127	5	3	900	1	95.86	96.67	192	5.79	0.3
128	5	3	900	2	86.28	87	172.8	5.11	0.27
129	5	3	900	3	92.67	94	95.04	3.36	0.15
130	5	3	1000	1	99.56	98.42	231.43	0.28	1.43
131	5	3	1000	2	99.61	88.58	208.29	0.25	1.29
132	5	3	1000	3	98.78	96.89	114.56	0.14	0.71
133	5	3	1100	1	99.55	97.27	288	0.25	2.31
134	5	3	1100	2	99.59	87.55	259.2	0.22	2.08
135	5	3	1100	3	98.75	95	142.56	0.12	1.14
136	5	5	700	1	94.19	91.43	105.88	6.4	3.76
137	5	5	700	2	84.77	82.29	95.29	5.76	3.29
138	5	5	700	3	92.92	95.36	52.41	3.17	2.36

Obs	**MC**	**F**	**S**	**rep**	**Te**	**Ce**	**Tc**	**SL**	**MD**
139	5	5	800	1	95.38	95.71	144	3.09	3
140	5	5	800	2	85.85	86.14	129.6	2.78	3.6
141	5	5	800	3	91.88	92.43	71.28	1.53	1.98
142	5	5	900	1	95.86	97.69	148.97	6.2	3.17
143	5	5	900	2	96.28	87.92	134.07	5.58	3.75
144	5	5	900	3	97.67	95.69	73.74	3.07	2.06
145	5	5	1000	1	98.84	98.33	235.38	5.46	3.35
146	5	5	1000	2	97.16	88.5	211.85	5.71	3.91
147	5	5	1000	3	99.29	96.75	116.52	3.69	2.15
148	5	5	1100	1	99.36	98	214.47	5.23	3.17
149	5	5	1100	2	98.73	88.2	193.02	5.01	3.75
150	5	5	1100	3	99.5	96.2	106.16	5.06	2.06

Appendix: G

Result of Statistical Analysis

The ANOVA Procedure

Class Level Information		
Class	**Levels**	**Values**
rep	3	1 2 3
moist	5	1 2 3 4 5
feedrt	2	3 5
Speed	5	700 800 900 1000 1100

Number of Observations Read	150
Number of Observations Used	150

The ANOVA Procedure

Dependent Variable: threshing efficiency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	51	68675.14728	1346.57152	13.87	<.0001
Error	98	9516.14813	97.10355		
Corrected Total	149	78191.29542			

R-Square	Coeff Var	Root MSE	thrshef Mean
0.878297	12.59930	9.854113	99.21160

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	2	56604.63567	28302.31783	291.47	<.0001
moist	4	10263.19388	2565.79847	26.42	<.0001
feedrt	1	138.35522	138.35522	1.42	0.2355
Speed	4	222.87323	55.71831	0.57	0.6823
moist*feedrt	4	210.96332	52.74083	0.54	0.7044
moist*Speed	16	561.95164	35.12198	0.36	0.9879

Source	DF	Anova SS	Mean Square	F Value	Pr > F
feedrt*Speed	4	110.40688	27.60172	0.28	0.8876
moist*feedrt*Speed	16	562.76744	35.17297	0.36	0.9878

The ANOVA Procedure

Dependent Variable: cleaning efficiency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	51	65013.14793	1274.76761	15.34	<.0001
Error	98	8143.75030	83.09949		
Corrected Total	149	73156.89823			

R-Square	Coeff Var	Root MSE	clneff Mean
0.888681	11.58846	9.115892	98.66353

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	2	57005.39370	28502.69685	342.99	<.0001
moist	4	6286.47894	1571.61973	18.91	<.0001
feedrt	1	12.32093	12.32093	0.15	0.7010
Speed	4	80.59118	20.14780	0.24	0.9136
moist*feedrt	4	58.30726	14.57682	0.18	0.9506
moist*Speed	16	582.38196	36.39887	0.44	0.9683
feedrt*Speed	4	178.95128	44.73782	0.54	0.7079
moist*feedrt*Speed	16	808.72267	50.54517	0.61	0.8704

The ANOVA Procedure

Dependent Variable: throughput capacity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	51	451396.3521	8850.9089	6.67	<.0001
Error	98	130042.4355	1326.9636		
Corrected Total	149	581438.7876			

R-Square	Coeff Var	Root MSE	tpcap Mean
0.776344	27.45294	36.42751	253.6907

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	2	115070.8503	57535.4251	43.36	<.0001
moist	4	83979.3157	20994.8289	15.82	<.0001
feedrt	1	13160.7287	13160.7287	9.92	0.0022
Speed	4	78707.0944	19676.7736	14.83	<.0001
moist*feedrt	4	35366.0582	8841.5145	6.66	<.0001
moist*Speed	16	43407.5365	2712.9710	2.04	0.0172
feedrt*Speed	4	22926.3732	5731.5933	4.32	0.0029
moist*feedrt*Speed	16	58778.3952	3673.6497	2.77	0.0011

The ANOVA Procedure

Dependent Variable: Scatter Grain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	51	1540.454473	30.204990	5.69	<.0001
Error	98	519.898876	5.305091		
Corrected Total	149	2060.353349			

R-Square	Coeff Var	Root MSE	scteff Mean
0.747665	45.92717	2.303278	5.015067

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	2	211.1962573	105.5981287	19.91	<.0001
moist	4	389.2019293	97.3004823	18.34	<.0001
feedrt	1	8.6112240	8.6112240	1.62	0.2057
Speed	4	220.6640293	55.1660073	10.40	<.0001
moist*feedrt	4	179.2466227	44.8116557	8.45	<.0001
moist*Speed	16	292.6388240	18.2899265	3.45	<.0001
feedrt*Speed	4	36.6546427	9.1636607	1.73	0.1500
moist*feedrt*Speed	16	202.2409440	12.6400590	2.38	0.0048

The ANOVA Procedure

Dependent Variable: Grain damage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	51	2366.743279	46.406731	7.76	<.0001
Error	98	586.004521	5.979638		
Corrected Total	149	2952.747800			

R-Square	Coeff Var	Root MSE	grndmag Mean
0.801539	66.44918	2.445330	3.680000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	2	97.1892120	48.5946060	8.13	0.0005
moist	4	262.8589133	65.7147283	10.99	<.0001
feedrt	1	106.7491440	106.7491440	17.85	<.0001
Speed	4	157.7187867	39.4296967	6.59	<.0001
moist*feedrt	4	252.7668493	63.1917123	10.57	<.0001
moist*Speed	16	643.7307667	40.2331729	6.73	<.0001
feedrt*Speed	4	321.3912027	80.3478007	13.44	<.0001
moist*feedrt*Speed	16	524.3384040	32.7711502	5.48	<.0001

The ANOVA Procedure

Duncan's Multiple Range Test for threshing efficiency

Note: This test controls the Type I comparison wise error rate, not the experiment wise error rate.

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	97.10355

Number of Means	**2**	**3**	**4**	**5**
Critical Range	5.049	5.313	5.489	5.617

Means with the same letter are not significantly different.

Duncan Grouping	**Mean**	**N**	**moist**
A	99.395	30	1
B	96.430	30	3
B			
B	95.585	30	5
B			
B	92.960	30	4
B			
B	91.689	30	2

The ANOVA Procedure

Duncan's Multiple Range Test for cleaning efficiency

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	83.09949

Number of Means	**2**	**3**	**4**	**5**
Critical Range	4.671	4.915	5.078	5.197

Means with the same letter are not significantly different.

Duncan Grouping	**Mean**	**N**	**moist**
A	99.529	30	1
B	96.270	30	5
B			
B	96.053	30	3
B			
B	95.279	30	4
B			
B	94.187	30	2

The ANOVA Procedure

Duncan's Multiple Range Test for throughput capacity

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	1326.964

Number of Means	**2**	**3**	**4**	**5**
Critical Range	18.66	19.64	20.29	20.77

Means with the same letter are not significantly different.

Duncan Grouping	**Mean**	**N**	**moist**
A	254.704	30	1
A			
A	190.864	30	3
A			
A	188.949	30	5
B	129.441	30	4
B			
B	116.496	30	2

The ANOVA Procedure

Duncan's Multiple Range Test for scatter grain

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	5.305091

Number of Means	**2**	**3**	**4**	**5**
Critical Range	1.180	1.242	1.283	1.313

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**moist**
A	5.1230	30	1
B	5.0547	30	3
B			
B	4.0113	30	2
B			
B	4.0030	30	4
B			
B	3.8833	30	5

The ANOVA Procedure

Duncan's Multiple Range Test for Grain damage

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	5.979638

Number of Means	**2**	**3**	**4**	**5**
Critical Range	1.253	1.319	1.362	1.394

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**moist**
A	3.8067	30	1
B	3.1377	30	4
B			
B	3.8833	30	2
C	2.5130	30	3
C			
C	2.0593	30	5

The ANOVA Procedure

Duncan's Multiple Range Test for threshing efficiency

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	97.10355

Number of Means	**2**
Critical Range	3.193

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**feedrt**
A	99.172	75	3
A			
A	97.251	75	5

The ANOVA Procedure

Duncan's Multiple Range Test for cleaning efficiency

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	83.09949

Number of Means	**2**
Critical Range	2.954

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**feedrt**
A	99.950	75	5
A			
A	98.377	75	3

The ANOVA Procedure

Duncan's Multiple Range Test for throughput capacity

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	1326.964

Number of Means	**2**
Critical Range	11.80

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**feedrt**
A	250.058	75	5
B	123.324	75	3

The ANOVA Procedure

Duncan's Multiple Range Test for scatter Grain

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	5.305091

Number of Means	**2**
Critical Range	.7464

Means with the same letter are not significantly different.

Duncan Grouping	**Mean**	**N**	**feedrt**
A	5.2547	75	5
A			
A	4.7755	75	3

The ANOVA Procedure

Duncan's Multiple Range Test for Grain damage

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	5.979638

Number of Means	**2**
Critical Range	.7924

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**feedrt**
A	3.5236	75	5
B	2.8364	75	3

The ANOVA Procedure

Duncan's Multiple Range Test for threshing efficiency

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	97.10355

Number of Means	**2**	**3**	**4**	**5**
Critical Range	5.049	5.313	5.489	5.617

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**Speed**
A	99.421	30	1100
A			
A	98.208	30	1000
A			
A	97.986	30	900
A			
A	97.739	30	700
A			
A	96.704	30	800

The ANOVA Procedure

Duncan's Multiple Range Test for cleaning efficiency

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	83.09949

Number of Means	**2**	**3**	**4**	**5**
Critical Range	4.671	4.915	5.078	5.197

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**Speed**
A	98.005	30	800
A			
A	98.875	30	900
A			
A	98.238	30	1000
A			
A	98.217	30	1100
A			
A	97.983	30	700

The ANOVA Procedure

Duncan's Multiple Range Test for throughput capacity

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	1326.964

Number of Means	**2**	**3**	**4**	**5**
Critical Range	18.66	19.64	20.29	20.77

Means with the same letter are not significantly different.				
Duncan Grouping		**Mean**	**N**	**Speed**
	A	253.723	30	1100
	A			
	A	187.821	30	1000
	B	179.550	30	900
	B			
C	B	113.173	30	800
C				
C		103.187	30	700

The ANOVA Procedure

Duncan's Multiple Range Test for scatter Grain

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	5.305091

Number of Means	**2**	**3**	**4**	**5**
Critical Range	1.180	1.242	1.283	1.313

Means with the same letter are not significantly different.

Duncan Grouping		**Mean**	**N**	**Speed**
	A	5.9510	30	1100
	A			
B	A	5.8180	30	1000
B				
B	C	4.6563	30	900
	C			
	C	3.8543	30	700
	C			
	C	3.7957	30	800

The ANOVA Procedure

Duncan's Multiple Range Test for Grain damage

Note: This test controls the Type I comparison wise error rate, not the experiment wise error rate.

Alpha	0.05
Error Degrees of Freedom	98
Error Mean Square	5.979638

Number of Means	**2**	**3**	**4**	**5**
Critical Range	1.253	1.319	1.362	1.394

Means with the same letter are not significantly different.

Duncan Grouping		**Mean**	**N**	**Speed**
	A	3.7790	30	1100
	A			
B	A	3.5163	30	1000
B	A			
B	A	3.9240	30	700
B				
B		3.2670	30	800
	C	1.9137	30	900

Appendix: H

Result of the Interaction of Two factors (MXF)

L/MC	**L/F**	**No**	**Te**		**Ce**		**Tc**		**SL**		**MD**	
			Mean	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
1	**3**	**15**	99.62	4.12	91.00	6.36	131.84	70.23	5.67	6.34	3.91	4.94
1	**5**	**15**	98.17	5.14	92.06	11.47	177.56	44.51	5.57	3.41	3.70	6.83
2	**3**	**15**	92.34	24.79	93.84	24.51	184.62	31.57	3.58	1.65	3.61	4.43
2	**5**	**15**	91.04	25.64	94.53	24.70	108.37	43.88	4.44	2.39	3.16	3.39
3	**3**	**15**	96.31	23.61	95.10	23.94	123.14	38.79	5.23	2.24	1.85	3.56
3	**5**	**15**	86.55	23.55	87.01	23.39	255.59	99.47	4.88	2.01	3.18	1.90
4	**3**	**15**	96.20	23.71	84.79	24.10	114.63	45.96	3.27	3.23	1.11	1.71
4	**5**	**15**	99.72	26.42	95.77	23.74	110.26	36.89	4.73	3.23	7.16	6.60
5	**3**	**15**	96.39	23.71	97.16	23.36	162.39	64.83	2.12	2.60	0.69	0.77
5	**5**	**15**	94.78	24.03	95.38	24.06	135.51	56.19	5.65	3.00	3.42	1.00

Appendix: I

Result of the Interaction of Two factors

Level of	**Level of**	**No.**	**Te**		**Ce**		**Tc**		**SL**		**MD**	
Feed rate	**Speed**		**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
3	**700**	**15**	97.89	23.61	96.88	23.47	115.99	50.65	3.01	2.24	3.69	5.34
3	**800**	**15**	98.68	23.54	99.67	22.32	107.89	41.84	4.29	3.77	1.39	2.01
3	**900**	**15**	98.76	23.32	97.18	22.82	108.86	56.70	4.80	4.41	2.54	4.29
3	**1000**	**15**	90.15	22.30	99.70	22.09	138.14	63.49	5.18	5.54	3.83	3.95
3	**1100**	**15**	90.39	22.10	98.45	22.23	145.73	65.39	6.60	5.09	1.73	2.81
5	**700**	**15**	97.59	23.65	99.08	23.17	190.38	34.00	4.70	2.57	3.16	1.76
5	**800**	**15**	94.73	25.05	90.34	22.74	118.46	38.29	3.30	1.77	3.15	6.51
5	**900**	**15**	97.21	22.98	90.57	22.51	150.24	48.17	4.52	1.74	1.28	1.75
5	**1000**	**15**	96.26	25.99	96.78	22.49	254.50	59.49	5.46	3.16	3.21	4.08
5	**1100**	**15**	90.46	22.81	97.98	24.23	173.71	94.94	5.30	3.19	3.83	5.42

Appendix: J

Result of the Interaction of Three factors

Level of MC	Level of Feed	Level of Speed	No.	Te		Ce		Tc		SL		MD	
				Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1	**3**	**700**	**3**	94.79	4.45	91.46	6.75	98.15	51.52	4.69	1.08	2.89	2.66
1	**3**	**800**	**3**	95.82	3.61	92.89	6.07	134.49	72.33	5.91	6.59	3.22	3.02
1	**3**	**900**	**3**	95.81	3.57	99.25	8.56	134.90	96.08	5.44	6.89	3.86	7.49
1	**3**	**1000**	**3**	93.28	6.01	91.94	6.42	155.55	103.13	5.77	8.97	3.05	4.21
1	**3**	**1100**	**3**	93.41	5.29	99.43	8.44	136.13	64.59	5.54	7.13	3.54	4.97
1	**5**	**700**	**3**	94.43	4.77	95.00	4.13	139.76	11.68	6.02	3.45	0.35	0.25
1	**5**	**800**	**3**	92.45	6.23	96.37	3.17	144.90	34.63	5.56	2.83	4.83	10.12
1	**5**	**900**	**3**	90.42	7.82	95.99	3.37	206.99	9.75	6.72	1.53	2.54	2.45
1	**5**	**1000**	**3**	98.53	3.05	97.12	21.17	190.75	8.69	6.02	3.68	2.82	2.73
1	**5**	**1100**	**3**	99.71	2.59	95.83	3.70	205.43	76.75	3.55	0.56	4.96	2.73
2	**3**	**700**	**3**	90.96	29.66	96.03	30.30	103.14	20.81	3.94	1.32	4.98	4.01
2	**3**	**800**	**3**	99.28	30.22	96.51	27.83	104.18	34.90	1.21	0.41	3.33	1.12
2	**3**	**900**	**3**	93.71	28.75	90.96	29.66	101.59	20.63	4.19	1.40	4.20	1.40
2	**3**	**1000**	**3**	92.22	29.24	96.61	27.80	191.24	30.56	3.93	1.32	3.47	1.16
2	**3**	**1100**	**3**	95.53	28.15	96.10	27.97	103.95	34.82	4.64	1.55	0.07	0.02

2	**5**	**700**	**3**	92.73	29.08	96.16	27.95	107.17	23.83	3.47	1.16	3.80	1.27
2	**5**	**800**	**3**	91.10	32.94	98.65	27.13	183.35	27.92	2.26	0.76	0.08	0.03
2	**5**	**900**	**3**	97.94	29.34	97.75	27.43	127.73	42.79	3.83	1.28	0.17	0.06
2	**5**	**1000**	**3**	97.37	28.54	95.59	28.14	151.83	50.86	4.76	1.59	3.33	1.12
2	**5**	**1100**	**3**	99.04	28.32	94.52	31.80	107.78	36.10	5.87	2.64	3.40	2.82
3	**3**	**700**	**3**	97.30	27.58	93.92	28.69	123.17	41.26	5.08	1.70	3.40	2.82
3	**3**	**800**	**3**	96.61	27.80	93.92	28.69	116.51	39.03	4.23	1.42	0.08	0.03
3	**3**	**900**	**3**	98.76	28.40	97.89	28.04	107.78	36.10	3.69	1.23	0.18	0.06
3	**3**	**1000**	**3**	99.47	27.52	95.89	28.04	153.28	51.34	4.97	1.67	0.27	0.09
3	**3**	**1100**	**3**	99.70	28.20	97.89	28.04	114.96	38.51	5.18	2.74	0.32	0.11
3	**5**	**700**	**3**	96.88	27.71	97.47	27.52	105.69	22.01	6.94	2.33	4.20	1.40
3	**5**	**800**	**3**	97.51	28.49	90.51	27.83	134.12	44.92	3.26	1.10	3.63	1.22
3	**5**	**900**	**3**	97.03	27.99	97.61	27.80	163.43	54.74	3.97	1.33	0.14	0.04
3	**5**	**1000**	**3**	99.39	27.54	97.75	27.43	233.03	78.05	4.24	1.42	4.44	1.49
3	**5**	**1100**	**3**	99.96	27.36	97.70	27.77	296.67	99.37	5.97	2.00	3.47	1.16
4	**3**	**700**	**3**	97.38	28.87	91.94	29.34	156.31	52.35	1.15	0.39	0.10	0.04
4	**3**	**800**	**3**	96.28	27.91	97.75	27.43	108.47	26.95	2.55	0.85	0.14	0.04
4	**3**	**900**	**3**	94.58	28.47	97.92	28.69	108.76	29.06	0.25	0.09	0.24	0.08
4	**3**	**1000**	**3**	98.47	27.19	97.10	27.97	115.88	35.47	3.98	1.33	4.20	1.40

4	**3**	**1100**	**3**	98.29	27.25	97.23	28.59	143.70	48.13	5.45	2.83	0.89	0.30
4	**5**	**700**	**3**	90.96	29.66	97.10	27.64	100.76	30.40	1.94	0.65	3.63	1.22
4	**5**	**800**	**3**	97.23	29.57	95.40	28.20	114.96	38.51	2.95	0.99	3.99	1.33
4	**5**	**900**	**3**	97.73	29.08	97.40	28.20	134.12	44.92	3.10	1.04	0.24	0.08
4	**5**	**1000**	**3**	98.93	34.33	97.57	28.14	123.97	41.53	6.32	2.12	3.98	4.01
4	**5**	**1100**	**3**	99.75	27.75	97.40	28.20	108.47	29.30	5.34	3.13	3.97	5.35
5	**3**	**700**	**3**	97.01	28.99	90.06	27.32	140.20	46.96	0.20	0.07	0.08	0.03
5	**3**	**800**	**3**	97.40	28.20	97.30	27.58	103.78	34.76	4.55	1.53	0.17	0.06
5	**3**	**900**	**3**	98.94	28.35	97.89	28.04	153.28	51.34	5.42	1.82	0.24	0.08
5	**3**	**1000**	**3**	99.32	26.91	97.96	27.36	184.76	61.89	0.22	0.07	1.14	0.38
5	**3**	**1100**	**3**	99.90	26.92	96.61	27.80	229.92	77.01	0.20	0.07	1.84	0.62
5	**5**	**700**	**3**	97.96	29.00	96.69	30.08	104.53	28.31	5.11	1.71	3.80	1.27
5	**5**	**800**	**3**	97.37	28.54	94.76	28.40	114.96	38.51	2.47	0.83	3.19	1.07
5	**5**	**900**	**3**	97.94	28.35	97.10	27.64	118.93	39.84	4.95	1.66	3.33	1.12
5	**5**	**1000**	**3**	99.10	27.97	97.86	27.39	187.92	62.94	5.95	2.00	3.47	1.16
5	**5**	**1100**	**3**	99.93	28.15	97.47	27.52	171.22	57.35	5.77	3.27	3.33	1.12

`

Appendix K

Plate 1: left side view thresher

Plate 2: front View of the thresher

Plate 3: Right side view of the thresher

Plate 4: Rear View of the thresher

Plate 5: Threshing operation

Appendix: L

Experimental Row Data

First Experimental Trial

Treatment	F (kg)	S (rpm)	T (sec)	Wt	Qu	Wc	Qt	QL	Qu	Qb	Qs
M1S1F1	3	700	46	0.7	0.6	0.03	0.09	0.035	0.005	0.005	0.035
M1S2F1	3	800	46	1	0.8	0.06	0.09	0.125	0.005	0.0002	0.125
M1S3F1	3	900	55	0.8	0.6	0.06	0.065	0.105	0.005	0.01	0.105
M1S4F1	3	1000	34	0.6	0.5	0.03	0.07	0.11	0.005	0.01	0.11
M1S5F1	3	1100	30	0.8	0.6	0.06	0.095	0.115	0.015	0.01	0.115
M1S1F2	5	700	70	2.8	2.5	0.09	0.1	0.24	0.03	0.0001	0.24
M1S2F2	5	800	65	2.2	2	0.06	0.08	0.17	0.025	0.02	0.17
M1S3F2	5	900	60	3.6	3.3	0.09	0.1	0.275	0.025	0.0001	0.275
M1S4F2	5	1000	65	3.4	3.3	0.03	0.2	0.245	0.02	0.0002	0.245
M1S5F2	5	1100	64	2.6	2.3	0.09	0.095	0.095	0.005	0.005	0.095
M2S1F1	3	700	74	2.3	1.6	0.21	0.1	0.08	0.02	0.015	0.08
M2S2F1	3	800	80	3.2	2.9	0.09	0.12	0.045	0.055	0.005	0.045
M2S3F1	3	900	70	2	1.5	0.15	0.095	0.08	0.025	0.005	0.08
M2S4F1	3	1000	63	2.2	2	0.06	0.115	0.1	0.03	0.005	0.1
M2S5F1	3	1100	47	1.9	1.7	0.06	0.11	0.1	0.02	0.0001	0.1
M2S1F2	5	700	105	2.9	2.6	0.09	0.105	0.115	0.045	0.005	0.115
M2S2F2	5	800	100	3	2.9	0.03	0.095	0.085	0.095	0.0001	0.085
M2S3F2	5	900	72	3.4	3.2	0.06	0.095	0.155	0.03	0.0002	0.155
M2S4F2	5	1000	53	3.18	2.8	0.114	0.12	0.168	0.02	0.005	0.168
M2S5F2	5	1100	48	3.2	1.8	0.414	0.095	0.18	0.025	0.01	0.18
M3S1F1	3	700	42	1.8	1.8	0.09	0.095	0.115	0.005	0.01	0.115
M3S2F1	3	800	37	1.8	1.5	0.09	0.095	0.08	0.01	0.0001	0.08
M3S3F1	3	900	40	1.8	1.5	0.06	0.09	0.07	0.015	0.0002	0.07
M3S4F1	3	1000	30	1.8	1.6	0.06	0.09	0.1	0.005	0.0003	0.1
M3S5F1	3	1100	40	1.8	1.6	0.06	0.1	0.165	0.01	0.0004	0.165
M3S1F2	5	700	70	3	1.6	0.06	0.095	0.14	0.01	0.005	0.14
M3S2F2	5	800	60	3.2	2.8	0.09	0.11	0.115	0.015	0.005	0.115
M3S3F2	5	900	51	3.3	2.9	0.09	0.115	0.145	0.015	0.0002	0.145
M3S4F2	5	1000	37	3.4	3	0.06	0.09	0.16	0.01	0.005	0.16
M3S5F2	5	1100	31	3.4	3.2	0.09	0.115	0.24	0.01	0.005	0.24
M4S1F1	3	700	57	1.8	3.1	0.12	0.08	0.045	0.03	0.0001	0.045
M4S2F1	3	800	50	1.7	1.4	0.03	0.115	0.045	0.01	0.0002	0.045

M4S3F1	3	900	53	1.2	1.6	0.06	0.1	0.005	0.02	0.0003	0.005
M4S4F1	3	1000	38	1.9	1.4	0.06	0.095	0.07	0.005	0.005	0.07
M4S5F1	3	1100	32	1.9	1.6	0.09	0.09	0.17	0.005	0.001	0.17
M4S1F2	5	700	76	2.6	2.4	0.06	0.11	0.06	0.07	0.005	0.06
M4S2F2	5	800	70	3.2	2.8	0.12	0.1	0.105	0.04	0.005	0.105
M4S3F2	5	900	60	3.2	2.8	0.12	0.1	0.11	0.03	0.0003	0.11
M4S4F2	5	1000	51	2.5	2.2	0.09	0.1	0.19	0.2	0.015	0.19
M4S5F2	5	1100	46	1.6	1.4	0.06	0.1	0.165	0.01	0.02	0.165
M5S1F1	3	700	41	2	2	0.03	0.1	0.005	0.025	0.0001	0.005
M5S2F1	3	800	36	1.4	1.3	0.03	0.095	0.075	0.015	0.0002	0.075
M5S3F1	3	900	30	1.8	1.6	0.06	0.1	0.11	0.02	0.0003	0.11
M5S4F1	3	1000	28	1.9	1.8	0.03	0.14	0.005	0.002	0.002	0.005
M5S5F1	3	1100	25	2.2	2	0.06	0.13	0.005	0.002	0.003	0.005
M5S1F2	5	700	68	2.8	2	0.24	0.105	0.13	0.03	0.005	0.13
M5S2F2	5	800	60	2.8	2.4	0.12	0.1	0.075	0.03	0.004	0.075
M5S3F2	5	900	58	2.6	2.4	0.06	0.12	0.15	0.02	0.005	0.15
M5S4F2	5	1000	52	3.6	3.4	0.06	0.115	0.255	0.02	0.005	0.255
M5S5F2	5	1100	47	3	2.8	0.06	0.12	0.345	0.02	0.005	0.345

Second Experimental Trial

Treatment	F (kg)	S (rpm)	T (sec)	Wt	Qu	Wc	Qt	QL	Qu	Qb	Qs
M1S1F1	3	700	46	0.693	0.594	0.030	0.089	0.035	0.005	0.005	0.035
M1S2F1	3	800	46	0.990	0.792	0.059	0.089	0.124	0.005	0.000	0.124
M1S3F1	3	900	54	0.792	0.594	0.059	0.064	0.104	0.005	0.010	0.104
M1S4F1	3	1000	34	0.594	0.495	0.030	0.069	0.109	0.005	0.010	0.109
M1S5F1	3	1100	30	0.792	0.594	0.059	0.094	0.114	0.015	0.010	0.114
M1S1F2	5	700	69	2.772	2.475	0.089	0.099	0.238	0.030	0.000	0.238
M1S2F2	5	800	64	2.178	1.980	0.059	0.079	0.168	0.025	0.020	0.168
M1S3F2	5	900	59	3.564	3.267	0.089	0.099	0.272	0.025	0.000	0.272
M1S4F2	5	1000	64	3.366	3.267	0.030	0.198	0.243	0.020	0.000	0.243

M1S5F2	5	1100	63	2.574	2.277	0.089	0.094	0.094	0.005	0.005	0.094
M2S1F1	3	700	73	2.277	1.584	0.208	0.099	0.079	0.020	0.015	0.079
M2S2F1	3	800	79	3.168	2.871	0.089	0.119	0.045	0.054	0.005	0.045
M2S3F1	3	900	69	1.980	1.485	0.149	0.094	0.079	0.025	0.005	0.079
M2S4F1	3	1000	62	2.178	1.980	0.059	0.114	0.099	0.030	0.005	0.099
M2S5F1	3	1100	47	1.881	1.683	0.059	0.109	0.099	0.020	0.000	0.099
M2S1F2	5	700	104	2.871	2.574	0.089	0.104	0.114	0.045	0.005	0.114
M2S2F2	5	800	99	2.970	2.871	0.030	0.094	0.084	0.094	0.000	0.084
M2S3F2	5	900	71	3.366	3.168	0.059	0.094	0.153	0.030	0.000	0.153
M2S4F2	5	1000	52	3.148	2.772	0.113	0.119	0.166	0.020	0.005	0.166
M2S5F2	5	1100	48	3.168	1.782	0.410	0.094	0.178	0.025	0.010	0.178
M3S1F1	3	700	42	1.782	1.782	0.089	0.094	0.114	0.005	0.010	0.114
M3S2F1	3	800	37	1.782	1.485	0.089	0.094	0.079	0.010	0.000	0.079
M3S3F1	3	900	40	1.782	1.485	0.059	0.089	0.069	0.015	0.000	0.069
M3S4F1	3	1000	30	1.782	1.584	0.059	0.089	0.099	0.005	0.000	0.099
M3S5F1	3	1100	40	1.782	1.584	0.059	0.099	0.163	0.010	0.000	0.163
M3S1F2	5	700	69	2.970	1.584	0.059	0.094	0.139	0.010	0.005	0.139
M3S2F2	5	800	59	3.168	2.772	0.089	0.109	0.114	0.015	0.005	0.114
M3S3F2	5	900	50	3.267	2.871	0.089	0.114	0.144	0.015	0.000	0.144
M3S4F2	5	1000	37	3.366	2.970	0.059	0.089	0.158	0.010	0.005	0.158
M3S5F2	5	1100	31	3.366	3.168	0.089	0.114	0.238	0.010	0.005	0.238
M4S1F1	3	700	56	1.782	3.069	0.119	0.079	0.045	0.030	0.000	0.045
M4S2F1	3	800	50	1.683	1.386	0.030	0.114	0.045	0.010	0.000	0.045

M4S3F1	3	900	52	1.188	1.584	0.059	0.099	0.005	0.020	0.000	0.005
M4S4F1	3	1000	38	1.881	1.386	0.059	0.094	0.069	0.005	0.005	0.069
M4S5F1	3	1100	32	1.881	1.584	0.089	0.089	0.168	0.005	0.001	0.168
M4S1F2	5	700	75	2.574	2.376	0.059	0.109	0.059	0.069	0.005	0.059
M4S2F2	5	800	69	3.168	2.772	0.119	0.099	0.104	0.040	0.005	0.104
M4S3F2	5	900	59	3.168	2.772	0.119	0.099	0.109	0.030	0.000	0.109
M4S4F2	5	1000	50	2.475	2.178	0.089	0.099	0.188	0.198	0.015	0.188
M4S5F2	5	1100	46	1.584	1.386	0.059	0.099	0.163	0.010	0.020	0.163
M5S1F1	3	700	41	1.980	1.980	0.030	0.099	0.005	0.025	0.000	0.005
M5S2F1	3	800	36	1.386	1.287	0.030	0.094	0.074	0.015	0.000	0.074
M5S3F1	3	900	30	1.782	1.584	0.059	0.099	0.109	0.020	0.000	0.109
M5S4F1	3	1000	28	1.881	1.782	0.030	0.139	0.005	0.002	0.002	0.005
M5S5F1	3	1100	25	2.178	1.980	0.059	0.129	0.005	0.002	0.003	0.005
M5S1F2	5	700	67	2.772	1.980	0.238	0.104	0.129	0.030	0.005	0.129
M5S2F2	5	800	59	2.772	2.376	0.119	0.099	0.074	0.030	0.004	0.074
M5S3F2	5	900	57	2.574	2.376	0.059	0.119	0.149	0.020	0.005	0.149
M5S4F2	5	1000	51	3.564	3.366	0.059	0.114	0.252	0.020	0.005	0.252

Third Experimental Trial

Treatment	F (kg)	S (rpm)	T (sec)	Wt	Qu	Wc	Qt	QL	Qu	Qb	Qs
M1S1F1	3	700	46	0.697	0.597	0.030	0.090	0.035	0.005	0.005	0.035
M1S2F1	3	800	46	0.995	0.796	0.060	0.090	0.124	0.005	0.000	0.124
M1S3F1	3	900	55	0.796	0.597	0.060	0.065	0.104	0.005	0.010	0.104
M1S4F1	3	1000	34	0.597	0.498	0.030	0.070	0.109	0.005	0.010	0.109
M1S5F1	3	1100	30	0.796	0.597	0.060	0.095	0.114	0.015	0.010	0.114
M1S1F2	5	700	70	2.786	2.488	0.090	0.100	0.239	0.030	0.000	0.239
M1S2F2	5	800	65	2.189	1.990	0.060	0.080	0.169	0.025	0.020	0.169
M1S3F2	5	900	60	3.582	3.284	0.090	0.100	0.274	0.025	0.000	0.274
M1S4F2	5	1000	65	3.383	3.284	0.030	0.199	0.244	0.020	0.000	0.244
M1S5F2	5	1100	64	2.587	2.289	0.090	0.095	0.095	0.005	0.005	0.095
M2S1F1	3	700	74	2.289	1.592	0.209	0.100	0.080	0.020	0.015	0.080
M2S2F1	3	800	80	3.184	2.886	0.090	0.119	0.045	0.055	0.005	0.045
M2S3F1	3	900	70	1.990	1.493	0.149	0.095	0.080	0.025	0.005	0.080
M2S4F1	3	1000	63	2.189	1.990	0.060	0.114	0.100	0.030	0.005	0.100
M2S5F1	3	1100	47	1.891	1.692	0.060	0.109	0.100	0.020	0.000	0.100
M2S1F2	5	700	104	2.886	2.587	0.090	0.104	0.114	0.045	0.005	0.114
M2S2F2	5	800	100	2.985	2.886	0.030	0.095	0.085	0.095	0.000	0.085
M2S3F2	5	900	72	3.383	3.184	0.060	0.095	0.154	0.030	0.000	0.154
M2S4F2	5	1000	53	3.164	2.786	0.113	0.119	0.167	0.020	0.005	0.167
M2S5F2	5	1100	48	3.184	1.791	0.412	0.095	0.179	0.025	0.010	0.179
M3S1F1	3	700	42	1.791	1.791	0.090	0.095	0.114	0.005	0.010	0.114
M3S2F1	3	800	37	1.791	1.493	0.090	0.095	0.080	0.010	0.000	0.080
M3S3F1	3	900	40	1.791	1.493	0.060	0.090	0.070	0.015	0.000	0.070
M3S4F1	3	1000	30	1.791	1.592	0.060	0.090	0.100	0.005	0.000	0.100
M3S5F1	3	1100	40	1.791	1.592	0.060	0.100	0.164	0.010	0.000	0.164
M3S1F2	5	700	70	2.985	1.592	0.060	0.095	0.139	0.010	0.005	0.139
M3S2F2	5	800	60	3.184	2.786	0.090	0.109	0.114	0.015	0.005	0.114

M3S3F2	5	900	51	3.284	2.886	0.090	0.114	0.144	0.015	0.000	0.144
M3S4F2	5	1000	37	3.383	2.985	0.060	0.090	0.159	0.010	0.005	0.159
M3S5F2	5	1100	31	3.383	3.184	0.090	0.114	0.239	0.010	0.005	0.239
M4S1F1	3	700	57	1.791	3.085	0.119	0.080	0.045	0.030	0.000	0.045
M4S2F1	3	800	50	1.692	1.393	0.030	0.114	0.045	0.010	0.000	0.045
M4S3F1	3	900	53	1.194	1.592	0.060	0.100	0.005	0.020	0.000	0.005
M4S4F1	3	1000	38	1.891	1.393	0.060	0.095	0.070	0.005	0.005	0.070
M4S5F1	3	1100	32	1.891	1.592	0.090	0.090	0.169	0.005	0.001	0.169
M4S1F2	5	700	76	2.587	2.388	0.060	0.109	0.060	0.070	0.005	0.060
M4S2F2	5	800	70	3.184	2.786	0.119	0.100	0.104	0.040	0.005	0.104
M4S3F2	5	900	60	3.184	2.786	0.119	0.100	0.109	0.030	0.000	0.109
M4S4F2	5	1000	51	2.488	2.189	0.090	0.100	0.189	0.199	0.015	0.189
M4S5F2	5	1100	46	1.592	1.393	0.060	0.100	0.164	0.010	0.020	0.164
M5S1F1	3	700	41	1.990	1.990	0.030	0.100	0.005	0.025	0.000	0.005
M5S2F1	3	800	36	1.393	1.294	0.030	0.095	0.075	0.015	0.000	0.075
M5S3F1	3	900	30	1.791	1.592	0.060	0.100	0.109	0.020	0.000	0.109
M5S4F1	3	1000	28	1.891	1.791	0.030	0.139	0.005	0.002	0.002	0.005
M5S5F1	3	1100	25	2.189	1.990	0.060	0.129	0.005	0.002	0.003	0.005
M5S1F2	5	700	68	2.786	1.990	0.239	0.104	0.129	0.030	0.005	0.129
M5S2F2	5	800	60	2.786	2.388	0.119	0.100	0.075	0.030	0.004	0.075
M5S3F2	5	900	58	2.587	2.388	0.060	0.119	0.149	0.020	0.005	0.149
M5S4F2	5	1000	52	3.582	3.383	0.060	0.114	0.254	0.020	0.005	0.254
M5S5F3	5	100	47	2.985	2.786	0.060	0.119	0.343	0.020	0.005	0.343

Appendix M

Design Calculations

Weight of fan blade

$W = \rho\ v\ g$

Where:

ρ = Density of fan blade i.e steel = 7.83 x10^3 kg/m^3

g = Acceleration due to gravity = 9.8m/s2

v = Volume of Fan blades = 16 gauge = 0.1304m^3

v = Length x width x thickness (gauge 18 of 0.00156m) x 4 blades

:. $W = 7.83 X 10^3 X 9.81 X 0.435 X 0.105 X 0.00156 X 4$

$W = 21.89N$

Theoretical weight of 12 mm iron rod from the manufacturers was stated to be 39.3 kg/m^2

Air discharge through the blower

$Q = V D W$

Where

v = Velocity of air required for cleaning (m/s)

Speed of fan blade (N) is 650rpm, the

Velocity 6.545 m/s

W = width over which air is to blow = 0. 6m

D = depth of air stream over the sieve = 0.13m

:. Q = 6.45 x 0.6 x 0.13

Q = 0.0.5031 m^3/s

Pulley Dimensions

i. For threshing pulley

$N1D1 = N2D2$

$N1$= speed of Prime mover pulley = 1200 rpm

$N2$ = speed of thresher pulley = 500 rpm

$D1$ = Diameter of prime mover pulley = 104 mm

$D2$ = Diameter of thresher pulley

$D2 = N1D1/N2$

$D2 = (1200 \times 104)/500 = 131\ \text{mm}$

ii. For blower Pulley

$N2D2=N3D3$

$N2 = 500$ rpm, $N3 = 650$ rpm and $D2 = 131$mm

$D3 = (500 \times 131)/650 = 125\text{mm}$

iii. For Shaker Pulley

$N3D3 = N4D4$

Where

$N3$ = 650 rpm, $N4$ = 350 rpm, $D3$= 163 mm

$D4 = (650 \times 125) = 357$ mm

(iv) Belt Lengths

Length of belt from prime mover to thresher pulley:

Where

d = diameter of drive pulley = 14 cm

D= diameter of thresher pulley = 22 cm

C= centre to centre distance between drive pulley and driven pulley = 90cm

$$L1 = 2 \times 90 + 1.57\,(14-13.1) + \frac{(14 - 13.1)^2}{4 \times 90}$$

$L1 = 643$mm

Length of belt from thresher pulley to fan pulley

D = 12.5cm

D = 13 cm

C = 90 cm

$$L2 = 2 \times 90 + 1.57\,(12.5 - 130) + \frac{(12.5 - 130)^2}{4 \times 90}$$

$L2 = 591$mm

Length of belt from thresher pulley to shaker pulley

$$L3 = 2 \times 90 + 1.57\,(35.7 - 12.5) + \frac{(35.7 - 12.5)^2}{4 \text{ X } 90}$$

$L3 = 997$mm

Calculation of Belt Speed

But $V = \frac{N\pi D}{60}$

Where

N = drive speed = 1200rpm

D = diameter of drive pulley = 104mm

$V1 = (\frac{500 \times 3.142 \times 0.131}{60}) = 6.55m/s$

$V1$ = 6.55m/s (speed of belt from prime mover to thresher)

Speed of belt from thresher to fan pulley

$V2 = (\frac{650 \times 3.142 \times 0.125}{60}) = 6.545m/s$

Speed of belt from thresher to shaker pulley

$V3 = (\frac{350 \times 3.142 \times 0.357}{60}) = 6.543m/s$

Calculation of Belt Tension

The tension on each of the belts involved in the thresher was calculated using the following expression. Hannah and Stephen (1984)

$T = (S_1 - S_2)\, r$ 3.11

Where:

S_1 = tension on tight side (KN)

S_2 = tension on slide side (KN)

r = radius of pulley (m)

T = torque on shaft (kNm)

T= 0.372kN

Similarly,

Where:

$\frac{S_1}{S_2} = e^{\mu\theta Cosec\beta}$ ……………………………3.12

μ = coefficient of friction between the pulley and the belt

θ = angle of contact between of the belt on pulley

β = ½ (angle of V- groove of the pulley)

When the μ = 0.25, 2β = 34°, and θ = 170°

Therefore,

$\frac{S_1}{S_2} = 3.77$

Substitute this in eq. 3.12

$$s_2 = \frac{T}{2.77r}$$

$S_2 = 0.2351$ KN

$S_1 = 0.8862$ KN

Total belt tension $S_1 + S_2 = 0.8862 + 0.2351 = 1.1213$ KN (for cylinder)

Total weight of belt and pulley = 1.1213 + 0.0207= 1.142 kN

Power required to threshed the sorghum

P = Tw 3.12

Where:

P = power consumed by the shaft (kw)

T = torque on the shaft (kNm)

w = angular velocity (rad/s)

But

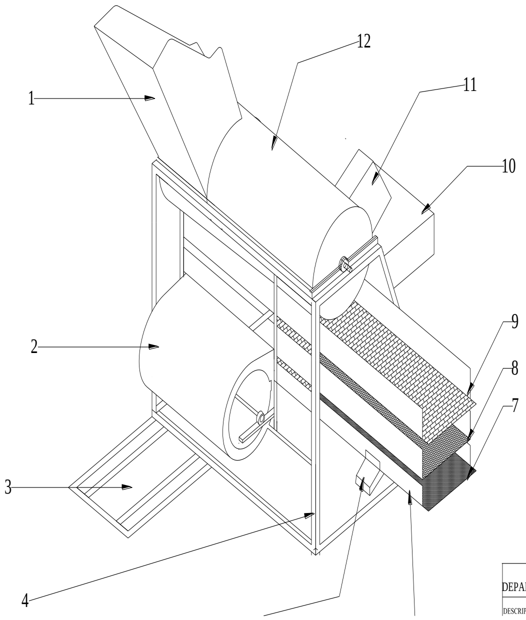
$$w = \frac{2\pi N}{60}$$

Where: N = Cylinder speed (rpm)

w = 52.367 (rad/s)

P = 0.076X 52.36

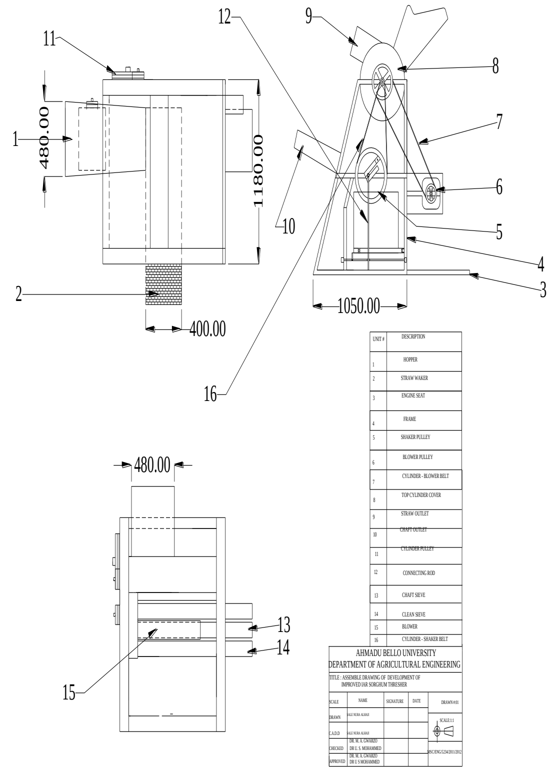
P = 3.986 kW



UNIT #	DESCRIPTION
1	HOPPER
2	Blower
3	Engine seat
4	FRAME
5	GRAIN OUTLET
6	SHAKER
7	CLEAN SIEVE
8	CHAFT SIEVE
9	STRAW WAKER
10	CHAFT OUTLET
11	STRAW OUTLET
12	TOP CYLINDER COVER

AHMADU BELLO UNIVERSITY
DEPARTMENT OF AGRICULTURAL ENGINEERING

DESCRIPTION: DEVELOPMENT OF IMPROVED IAR SORGHUM THRESHER

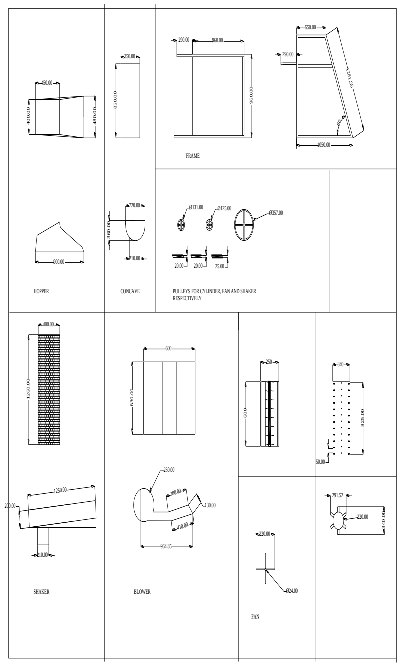


UNIT #	DESCRIPTION
1	HOPPER
2	STRAW WAKER
3	ENGINE SEAT
4	FRAME
5	SHAKER PULLEY
6	BLOWER PULLEY
7	CYLINDER - BLOWER BELT
8	TOP CYLINDER COVER
9	STRAW OUTLET
10	CHAFT OUTLET
11	CYLINDER PULLEY
12	CONNECTING ROD
13	CHAFT SIEVE
14	CLEAN SIEVE
15	BLOWER
16	CYLINDER - SHAKER BELT

AHMADU BELLO UNIVERSITY
DEPARTMENT OF AGRICULTURAL ENGINEERING

TITLE : ASSEMBLE DRAWING OF DEVELOPMENT OF
IMPROVED IAR SORGHUM THRESHER

SCALE	NAME	SIGNATURE	DATE	DRAWN #:01
DRAWN	SALE NURA ALHAJI			SCALE:1:1
C.A.D.D	SALE NURA ALHAJI			
CHECKED	DR. M. A. GWARZO DR U. S. MOHAMMED			MSC/ENG/5234/2011/2012
APPROVED	DR. M. A. GWARZO DR U S MOHAMMED			



AHMADU BELLO UNIVERSITY
DEPARTMENT OF AGRICULTURAL ENGINEERING

TITLE: DEVELOPMENT OF SORGHUM THRESHER

SCALE	NAME	SIGNATURE	DATE	DRAWN #:03
DRAWN	SALE NURA ALHAJI			SCALE:1:1
C.A.D.D	SALE NURA ALHAJI			
CHECKED	DR. M. A. GWARZO DR U. S. MOHAMMED			MSC/ENG/5234/2011/2012
APPROVED	DR. M. A. GWARZO DR U S MOHAMMED			