MODIFICATION AND PERFORMANCE EVALUATION OF AN IMPROVED SOYABEAN THRESHER

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By

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APPROVAL PAGE

I, Hassan Abdullahi Saeed hereby declare that this dissertation titled "MODIFICATION AND PERFORMANCE EVALUATION OF AN IMPROVED SOYBEAN THRESHER" has been entirely written by me. It is a product of my research work and has never been presented, accepted or defended anywhere for the award of a higher degree. All the sources of information which are not my own originals were duly acknowledged by means of references.

HASSAN ABDULLAHI SAEED

DATE----------

CERTIFICATION PAGE

This dissertation titled "MODIFICATION AND PERFORMANCE EVALUATION OF AN IMPROVED SOYBEAN THRESHER" by Abdullahi Saeed HASSAN, meets the regulations governing the award of Master of Science degree in Agricultural Engineering of Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my parents Hajiya Aisha Sulaiman and Shiekh Saeed Hassan Jengre and to my wife Khadija, my children Muhammad Bashir, Ahmad and Abdurrahman. I sincerely appreciate their patience while conducting this M.Sc. Programme.

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ABSTRACT

The study was conducted to investigate some physical properties of soybean at three moisture levels (10, 12 and 14%) and also to modify an existing soyabean thresher developed by Amadu, (2012) which has a low output capacity (25.5 kg/hr) and a major problem of chocking during threshing operations. The average length, width and thickness of soybean grains ranged from 6.57 to 6.75 mm, 5.54 to 5.66 mm and 4.54 to 4.66 mm respectively as the moisture content increased from 10.0 to 14.0 % (db), respectively. The geometric mean diameter increased from 5.42 to 5.53 mm. The one thousand grain mass increased from 103.55 to 108.97 g and the sphericity increased from 0.8332 to 0.8417 with the increase in moisture content from 10.0 to 14.0 % (db). The bulk density decreased from 749.7 to 643.4 kg m^{-3}, whereas the true density decreased from 1251 to 1121.12 kg m^{-3}. While porosity increased from 40.07% to 42.60 % with the increase in moisture content from 10.0 to 14.0 % (db). The angle of repose increased linearly from 26.55 to 31.02 degrees with the increase in moisture content. The static coefficient of friction increased for both surfaces, namely, glass (0.54 to 0.58) and wood (0.71 to 0.79). The performance of the modified machine was evaluated using TGX 1448-2E soyabean variety as the test crop. The results were analysed statistically using a completely randomized design (CRD). Least significant difference (LSD) was used to assess the effect of parameter level. The optimum performance of the developed thresher was obtained at a speed of 700 rpm at a feed rate level of 4 kg/min and a concave clearance of 13 mm. The threshing efficiency, cleaning efficiency, scatter loss, grain damage and the output capacity were found to be 99.97, 97.64, 0.86, 1.0 % and 86.96 kg/hr respectively. The analysis of variance carried out showed that all the independable variables - cylinder speed, feed rate, and concave clearance have a significant effects on the dependable variables - Threshing efficiency, cleaning efficiency, scatter loss, mechanical grain damage and throughput capacity. In comparison between the existing machine and the modified one using student t-test, the results indicated that the modified machine is better in terms of threshing efficiency, cleaning efficiency, scatter loss and output capacity but were found to be statistically similar in terms of mechanical grain damage.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Soybean (Glycine max[L.] Merrill) is an important oriental crop whose agronomic characteristics were apparently well known in China before 2200 BC. It is a legume that grows in tropical, subtropical and temperate climates. Originally domesticated in China around 1700-1000 BC, soybean is now cultivated throughout East and South East Asia where people depend on it for food, animal feed and medicine. Soybean reached North America in 1765 via London, and Africa through missionaries in the early 19thcentury (CGIAR, 2005).

The fact that soybean is fastly becoming the 'toast' of many countries beside China is not in doubt. However, this cannot be rightly said of African countries as a whole. According to FAO data of 2005 as reported by Kolapo, (2011), 95.2 million ha of land were used for soybean cultivation worldwide and total production was 212.6 million tones. The three major soybean-producing countries were USA (29 million ha), Brazil (23 million ha) and Argentina (14 million ha). Seed production from the cultivated hectares of land were 83, 51 and 38 million tones for USA, Brazil and Argentina respectively. In a strong contrast, the same source revealed that in the whole of Africa, soybean was grown on an average of 1.16 million ha with an average production of 1.26 million tones.

Considering both Africa's climatic and edaphic factors, tropical soybean varieties can be cultivated in about half of Africa's land. In addition, there is a greater possibility with the introduction of newly developed IITA genetically modified drought tolerant soyabean. On the understanding of the well-established soybean's medicinal and food values,

incorporation of soybean into Africans' diet is a sure way of stemming the tide of malnutrition in Africa Kolapo (2011).

1.1.1 Production in Nigeria

Soybean was first introduced to Ibadan, Oyo State, Nigeria in 1908 with little or no success in the rainforest ecology of the State (Fennel, 1966). In 1928, it was introduced to the savanna area of Northern Nigeria where the soil and climatic conditions supported its production. The crop was successfully cultivated in 1937 for multiplication and commercial production in Benue State (Nyiakura, 1982). Since then, many small-scale farmers in the south central part of the country have continuously incorporated propagation into their cropping systems.

According to a survey report by IITA in 1989, Benue State is the major producer of soybean in Nigeria. The current expansion in the production of soybeans in Nigeria has been attributed tomany years of research from the mid-1960s through the 1980s when Scientists adopted anationally-coordinated approach to Soybean research. In the 1970's, new attempts were made to cultivate the crop in southwestern Nigeria through collaborative research initiated between Institute of Agricultural Research and Training (IAR&T) and IITA, Ibadan on soybean variety production trials. Varieties that had those characteristics that made them productive in the moist savanna and forest areas were developed.

Nigeria is the largest producer of the crop for human and livestock feeds in West and Central Africa and has great potentials for substituting soy oil for some imported vegetable Oils. The current domestic demand and home consumption have made the crop a versatile

and multipurpose agricultural product that could be processed in almost 365 ways for human, livestock and industrial purposes (Kolapo, 2011). With the current ban on the importation of vegetable oils, some of the hitherto idle mills across the country are now looking inwards, producing edible oils from soybeans, preventing inefficiency of vegetable oil processing facilities as well as preventing inadequate supply of the oils.

According to a report by Omotayo *et al.,* (2007), the major soybean producing states in the country are Benue, Kaduna, Taraba, Plateau and Niger. Other growing areas include, Nasarawa, Kebbi, Kwara, Oyo, Jigawa, Borno, Bauchi, Lagos, Sokoto, Zamfara and FCT. The yield of soybean of 1,700 kg per hectare on research plots in Nigeria compared favourably with the United States (US) yields of 2000 kg/ha and Brazil yields of 1,800 kg/ha (Omotayo *et al.,* 2007).

1.1.2 Cultivation, harvesting and threshing

Land preparation for soyabean is similar to that for maize, the land is ploughed and harrowed. Seeds are sown at a seed rate of 50-75 kg/ha depending on the plant population required (Amadu, 2012). The sowing depth for soyabeans ranges from 2.5-5.0 cm. When soyabeans are grown for seed, harvesting is done before the pods shatter. The best stage is when the pods are fully mature with the seeds in the hand-dough state. The seeds should have moisture content of less than 15%. In non-shattering cultivars, harvesting is delayed until the crop is fully dried.The plants are either cut at ground level or pulled out of the ground. In the developed countries, most soyabean crops are harvested with combines. They are dried for some days and then threshed. The seeds should be stored at a moisture content of 10-20% or less.

1.1.3 Varieties of soyabean

Soyabean is of so many varieties worldwide. Among the varieties found in the United States of America includes Amsay, Corsoy, Harosoy, Lee and Clark. All these varieties are of similar botanical characteristics and are adaptable to only the climatic conditions around the United States of America. In 1984 due to lack of adaptable soyabean varieties in Nigeria and also due to the poor agronomic attributes of the only popular variety "Malayan". In the limited era where it is adapted, the Nigerian scientist developed high yielding varieties through National Coordinated Research Project on Soyabean. (NCRPS, 1988). Among the varieties developed includes samsoy-I samsoy- 2, TGX 536-020, TGM 344, TGX 814-270 and TGX 855-610 (NCRPS,1988). These varieties were found to be very adaptable in most of the northern states such as Kaduna, Kano, Niger, Plateau and Taraba (NCRPS,1988). The recommended soyabean variety for guinea savannah ecological zone in Nigeria are presented in table 1.1. Also, the recommended dates for planting soyabean in Nigeria are presented in table 1.2.





Plate 1.1**: Two Different Varieties of Soyabean Seeds**

Table 1. 1: Recommended Soyabeans Varieties for Guinea savanna ecological zones in Nigeria

Variety	Ecology	Characteristics	Striga control
TGX 1448-2E	Southern and northern guinea savannas	Medium maturing, high yield, low shattering, high oil content, excellent grain colour	Good
TGX1835-10E	Guinea savanna	Early maturing, rust resistant, pustule resistant	Not known
TGX 1485-1D	Guinea savanna	Early maturing, pustule resistant, rust susceptible	Not known

N.B: Early and extra maturing varieties are strongly recommended in the sudan savanna because of the low amount and duration of rainfall in the zone.

Source; IITA (2002)

Table 1. 2: Recommended dates for planting soyabean in Nigeria

Ecological zone	Suggested time of planting
Moist savanna/southern guinea savanna	Early June – early July
Northern guinea savanna – Sudan savanna	Mid-June – early July
Sudan savanna	July, weeks 1 – 2

Source: IITA (2002)

1.1.4 Nutritional and economic values of soyabean

Soyabean is among the major industrial and food crops grown in every continent. The crop can be successfully grown in many states in Nigeria using low agricultural input. Soyabean cultivation in Nigeria has expanded as a result of its nutritive and economic importance and diverse domestic usage. It is also a prime source of vegetable oil in the international market. Soyabean has an average protein content of 40% and is more protein-rich than any

of the common vegetable or animal food sources found in Nigeria. Soyabean seeds also contain about 20% oil on a dry matter basis, and this is 85% unsaturated and cholesterol-free. The rapid growth in the poultry sector in the past five years has also increased demand for soyabean meal in Nigeria. It is believed that soyabean production will increase as more farmers become aware of the potential of the crop, not only for cash/food but also for soil fertility improvement and Striga control. The market for soyabean in Nigeria is growing very fast with opportunities for improving the income of farmers.

Currently, SALMA Oil Mills in Kano, Grand Cereals in Jos, ECWA Feeds in Jos, AFCOT Oil Seed Processors, Ngurore, Adamawa State, and PS Mandrides in Kano all process soyabean.

1.2 Statement of the Problem

According to Sanusi,(2016) some of the problems encountered by farmers in crop production in Nigeria have been the method of threshing of the seeds. Most threshers in the country still operate at subsistence level. Soyabean threshing is accomplished by striking the grain with sticks or bamboo flails on the bare ground. This method is high time consuming, high energy demanding and drudgery. Amalendu *et al* (2003) reported that, the maximum output in manual threshing was 12 – 18 kg/hr while it was 80 – 110 kg/hr in threshing of grain by treading under the hooves of animals. Choudhury and Kaul (1979) noted that 6-8 % of grains being manually winnowed is lost in the chaff. Odigboh (2004) gave post harvest losses estimate in Nigeria to be up to 25%.This and many more make traditional method of threshing slow, laborious, high potential of contamination with debris and stones, susceptible to internal and external damage and give very low output (Asota, 1996). Plate 1.1 shows a manual method of threshing soyabean.

One of the major problems facing the farmers in this country is the issue of efficient soyabean threshing. Conventional threshers, modified to accommodate soyabean gets easily chocked up because of the stalk hardness and low grain/stalk ratio. Attempts have been made in IAR, ABU Zaria for the development of an efficient soyabean thresher but the performance values were still not satisfactory. One of such soyabean threshers that have problems of chocking and low output is the machine developed by Amadu, (2012).A preliminary study revealed that thesoyabean thresher is not functional due to the chocking up of the stalks in the threshing chamber.This and other problems brought about the idea of modifying the existing thresher developed by Amadu, (2012) by increasing the size of the threshing cylinder and introducing stationary knives that will shred the stalk and prevent the problem of chocking during the operation.



Plate 1. 2: Manual Threshing of Soyabean

1.3 Justification

The increase in demand for soyabean meal and products makes it inevitable for efficient soyabean threshing machine to be developed. The demand for soyabeans is on the increase both at local and global markets to satisfy the growing feed and food processing industries. Therefore, an attempt to improve the post-harvest operations more especially threshing aspect, which is highly laborious, would be welcome. Thus the development of a more efficient threshing machine for soyabean, which is the aim of this study, would contribute immensely to the soyabean processing activities. In addition, such works would continue to aid the process of perfecting soyabean threshers by researchers and other stake holders. Therefore, there is need to design the thresher with blades attaches to the threshing bar so that the stalk of the soyabean are easily slash to prevent chocking. Also, based on the limitations observed in some of the earlier research, this design and fabrication of soyabean threshing machine hopes to overcome those problems stated above.

1.4 Aim and Objectives

The aim of this study is to modify an existing soyabean thresher developed by Amadu, (2012).

The objectives are:

i. to determine some basic physical properties of TGX 1448-2Esoyabean variety
ii. to design and fabricate a modified soyabean threshing machine
iii. to evaluate the performance of the machine and compare the results with the existing one.

1.5 Scope of the Study

This study was centered on the construction and testing of the thresher. The performance evaluation includes feed rate, percentage threshing efficiency,cleaning efficiency, grain damaged scatter loss and output capacity. Cost implication of the machine was alsoassessed to draw suggestions and to enable targeted farmers take decisions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Soyabean is one of the world's most important food crops having superior amino acid profile compared to other sources of plant protein (Tandon and Panwar, 1989). It provide about 64% of world's oil seed meal supply and is a major source of oil, accounting for about 29 percent of total world's production(Tandon and Panwar, 1989). It is an important source of high quality but inexpensive protein and oil with dominant supply of the world's edible vegetable oil and dominant supply of high-protein feed supplements for livestock it is referred to as "meat of the world" because it is the cheapest source of protein and oil (Tandon and Panwar, 1989). It contains about 40-41% protein and 20.5-21.5% oil and is second to groundnut in terms of oil content amongst food legumes. Soyabean production represents an important source of foreign currency especially in countries like Brazil and Argentina. World-wide soyabean production amounts to about 130 million tones per year. Utilizing around 60 million hectares, with the largest producers being the USA, Brazil, China. Argentina, the E.U. and India (Tandon and Panwar, 1989).

Other products of soyabean include: Soyabean Milk. Soy-Source, Soy Flour. Soyabean Curd and Soyabean Spouts. Soyabeans are packed with important nutrients including calcium, magnesium and many B- complex vitamins. From investigation it has shown that from 100g of soyabean milk you can get 2.8-3.4g of protein. 1.5g of lipids and 12-24 mg iron. It is also comparable to cow milk for amino acid and vitamin B (Tandon and Panwar, 1989).

2.2 Physical andMechanical Properties of Soyabean

The major moisture-dependent physical properties of biological materials are shape, size, mass, bulk density, true density, porosity and static friction of coefficient against various surfaces (Mohsenin, 1980). In recent years, many researchers have investigated these properties for various agricultural crops as pistachio nut (Kashaninejad *et al.,* 2005), Shea kernel (Olajide *et al.,* 2000), apricot pit and its kernel (Gezer *et al.,* 2002), pumpkin seeds (Joshi *et al.,* 1993) and sunflower seeds (Gupta and Das, 1997). The physical and mechanical properties of soyabeans are important in the design of equipment for post harvesting technology such as; transporting, sorting, cleaning, separating, sizing, packaging, and processing. These designs result in a reduction in work efficiency and rise in product loss. Thus, the determination and consideration of these criteria play an important role (Gholami *et al.,* 2012).

Huji (2002) conducted a research on the physical and mechanical properties of soyabean using two varieties Samsoy 2 and TAS1485-ID. He found that the length, width, thickness, density, angle of repose, hardness and compressive strength for 60 samples of Samsoy-2 variety were; 6.39mm, 5.28mm, 4.69mm, 0.83 kg, 17.50^{o}, 28.06 kg, 98.65 and for TGX 1485 ID variety were 6.47mm, 5.43mm, 4.65mm, 0.21 kg, 12.85^{o}, 19.37 kg and 101.30 for those properties respectively. Polat *et al.,* (2006) evaluated some physical properties of soyabean as a function of moisture content in the range of 6.7-15.3% (db). At 6.7% (db) moisture content the average length, width, thickness, unit mass, the geometric mean

diameter, arithmetic mean diameter, sphericity, porosity, true and bulk density were 7.41 mm, 5.34 mm, 4.50 mm, 121.76g, 5.62mm, 5.75 mm, 75.0, 51.0%,1062.6 kgm^{-3} and 804.8 kgm^{-3}, respectively. Corresponding values at 15.3% (db) moisture content were 9.57 mm, 6.75 mm,5.17 mm, 223.65 g, 5.62 mm, 5.75 mm, 72.0%, 44.2%, 1086.4 kgm^{-3} and 689.3 kgm^{-3}those propertiesrespectively. The terminal velocity increased from 7.13 to 9.24 ms^{-1} and the coefficient of static friction increased linearly against all the tested surfaces as the moisture content increased.

Esref (2007) conducted a study on some engineering properties of Soyabean at different Moisture content. His findings were; average length, width and thickness to be 7.795, 7.123 and 4.189 mm, at a moisture content of 10.62% d.b., respectively. In the above moisture range, the arithmetic and geometric mean diameters increased from 6.36 to 8.048mm and from 6.149 to 7.933 mm, respectively, while the sphericity increased from 0.788 to 0.835. In the moisture range from 10.62-27.06% d.b., studies on rewetted soyabean grains showed that the thousand grain mass increased from 200 to 255 g, the projected area from 37.69 to 53.39 mm^2, the true density from 1090 to 1200 kgm^{-3}, the porosity from 40.36 to 54.16% and the terminal velocity from 8.01 to 9.1 ms^{-1}. The bulk density decreased from 650 to 550 kgm^{-3} with an increase in the moisture content range of 10.62-27.06% d.b. The static coefficient of friction of soyabean grains increased linearly against surfaces of six structural materials, namely, rubber (0.3443-0.3919), aluminum (0.2867-0.3115), stainless steel (0.2905-0.3443), galvanized iron (0.2962-0.3482), glass (0.2309-0.2773) and medium density fiber board (0.2126- 0.2679) as the moisture content increased from 10.62-27.06%.

According to (Shirkole*et al.,* 2011), the physical properties of soyabean grains showed

linear regression equations as a function of moisture content with high correlation except sphericity. The grain size, thousand grain weight, terminal velocity and angle of repose were found to linearly increase. The bulk density, true density, porosity and sphericity were found linearly decreased. The values of static coefficient of friction were found in the range of 0.390 to 1.428 against various surfaces for both the soyabean varieties tested in the specified level of moisture contents.

In a recent study (Mustapha, 2012) the length, width, thickness, equivalent diameter, sphericity, roundness, solid density, bulk density, porosity, one thousand seed weight, surface area, moisture content, angle of repose, coefficient of friction on wood and coefficient of friction on steel of soyabean (Soy sam 1 variety) were found tobe 7.04mm, 5.88mm, 4.87mm, 5.85mm, 0.84, 72%, 1136 kg/m^3, 743.19 kg/m^3, 34.5%, 118.82g, 3.78cm^2, 10.49% wet basis, 19.5^0, 0.21 and 0.25, respectively. Wandkar *et al.* (2012) also conducted a study to investigate some physical properties of soyabean at various moisture levels. The average length, width, thickness and thousand mass found were 6.55 mm, 5.56 mm, 4.53 mm and 103.57 g, respectively, at moisture content of 7.37% (dry basis). 6.66mm, 5.60mm, 4.56mm, 5.53mm 104.87g respectively at moisture content of 10.92% (dry basis). At moisture content of 15.80% (dry basis) the average length, width, thickness and thousand mass were 6.73mm, 5.64mm, 4.64mm, 5.57mm and 109.67g. In the same moisture range, the bulk and true densities decreased from 749.1 kgm^{-3}, 700 kgm^{-3} to 644.4 kgm^{-3} and 1250 kgm^{-3}, 1176.47 kgm^{-3} to 1111.11 kgm^{-3} respectively, whereas the corresponding porosity increased from 40.07%, 40.49% to 41.9%. As the moisture content increased from 7.37% to 15.80% (db) angle of repose was found to increase from 27.89 to 30.96^o. The static coefficient of friction of soyabean increased linearly against the surfaces

of two structural materials, namely glass and wood as the moisture content increased from 7.37% to 15.80% (db). Abubakar (2013) also conducted a study on the physical properties of soyabean TGX 1448-2E variety at 14.18% moisture content. The results obtained for the length, width, thickness, equivalent diameter, sphericity, surface area, roundness, bulk density, true density, porosity and angle of repose were 9.42mm, 5.89mm, 6.02mm, 7.02mm, 70%, 147.26mm^2, 83.66%, 600.94 kg/m^3, 1002.53 kgm^{-3}, 40.03%, and 26.4^o, respectively.

2.3 Research and Development Efforts on Soyabean Threshing

Singh (1969) designed a soyabean thresher and observed that feed rate, concave clearance and type of concave have direct effect on the loss of grains with chaff. At cylinder speed of 2000 rpm, concave clearance of 10.3 mm, moisture content of 9.5 % and feed rate of 115 kg/hr, minimum seed damage of 3.6 % was reported.

Kanafojski and Karwowski (1976) reported that soyabean threshing cylinder required about 40 % of the engine's power. This is due to the fact that the threshing cylinder requires high power to thresh the whole soyabean plant instead of only the pods. Sharma and Devnani (1978) developed variable speed thresher and evaluated the performance using soyabean and cowpea at the sun dried moisture content of 6.10 % and 6.5 % respectively and found that energy consumption in threshing to be directly proportional to the feed rate and cylinder tip speed, irrespective of the concave clearance. At the same rate of material flow and cylinder tip speed, the energy consumption for cowpea was higher than for soyabean and the cleaning and separating units consumed 0.625 kW-hr /g for cowpea as against 0.50 kW-hr /g for soyabeans. This higher energy consumption at same speed and feed rate was associated with the more vegetative nature of the crop. It was also

noted that the peripheral speed of the cylinder and concave clearance were the most important factors that cause grain damage. For the same cylinder speed and concave clearance, the visible grain damage was greater for soyabean whereas the internal grain damage was greater for the cowpea. It was also noticed that, although at higher speeds, the visible grain damage was below 5%, the internal damage to grain was very high as determined by germination test. Mesquita and Hoag (1989) found out that soyabean pods require only a small amount of energy to shatter them. To reduce mechanical damage while increasing the threshing capacity, efforts have been made to develop rotary threshing equipment. Amir (1990) stated that one major improvement in threshing mechanism was the axial flow cylinder threshing system which when compared to the conventional transverse cylinder had higher capacity and lower seed damage. Transverse threshing cylinders usually have high peripheral speeds. To maintain that speed when threshing entire soyabean plants, it requires a considerable amount of energy. Vejasit (1991) compared the performance of the raspbar and peg-tooth threshing drums of an axial flow thresher for soyabean crop. The results indicated that amount of grain retained on threshing unit for both cylinder at all cylinder speeds and feed rates were not significantly different. The results obtained for CIAE (1985) high capacity multicrop thresher Cylinder speed 8 m/s, Broken grain 0.91%, Total grain losses 1.55%, Threshing efficiency 99.9%, Cleaning efficiency 98%, Output capacity 780 kg/hr, power consumption 8.4 kW and also the results obtained for CIAE (1985) Multi crop thresher were found to be Cylinder speed 7.8 m/s, Broken grain 2.2%, Total grain losses 4.0%, Threshing efficiency 98.8%, Cleaning efficiency 93%, Output capacity 200 kg/h, power consumption 2.8 Kw.

Dauda (2001) evaluated a manually operated cowpea thresher for small scale farmers in northern Nigeria. The threshing efficiency was 84.1 to 85.9% and seed damage was 1.8 to 2.3%. Rani *et al.* (2001) studied the plot combine to thresh seed crop of chickpea and stated that maximum threshing efficiency was 97.2% at 8.9% (w.b.) seed moisture content and at 10.1 m/s cylinder speed. Vejasit and Salokhe (2004) fabricated a threshing unit to study the effect of machine-crop variables on the performance of an axial flow thresher for threshing soyabeans. Test results indicated that the threshing efficiency varied from 98 to100%. The grain damage and grain loss were less than 1 and 1.5% respectively at drum speeds of 600 to 700 rpm, feed rates of 540 to 720 kg/hr and at 14.34 to 22.77% (w.b.) seed moisture contents.Oforka (2004) also modify the existing I.A.R soyabean thresher and obtained the best performance combination at a cylinder speed of 850 rpm, feed rate of 30 kg/hr with Samsoy- 2 variety at 10 % moisture content of the grain. His performance results of the modified thresher gave 96 % threshing efficiency, 2.86 % mechanical grain damage, 97 % cleaning efficiency and 2.86 % scatter loss.

Anurson and Vilas (2006) developed and evaluated an axial flow soyabean thresher. Machine crop parameters affecting the performance of the soyabean thresher were evaluated. The threshing mechanism consists of a threshing drum rotating inside a two section concave. During the test, he uses four drum speeds 400, 500, 600 and 700rpm, and three feed rates 360, 540, and 720 kg/hr, and three average moisture contents of 32.88, 22.77 and 14.34% (w.b). The most common soyabean variety KKU-35 grown in Thailand was used for the test. The performance evaluation shows that at grain moisture content of 14.34% (w.b), feed rate of 720 kg/hr and a drum speed of 700rpm with an average power

of 1.85kW, the output capacity, threshing efficiency and grain damage were found to be 214kg/hr, 99.49% and 0.80%.

Hyetson (2003) also worked on an existing I.A.R soyabean thresher, where some missing components of the thresher were identified and replaced then the thresher was evaluated based on the performance using some parameters. After the evaluation, the best performance with TAS1485-ID variety at cylinder speed of 850 rpm and feed rate of 20 kg/hr was obtained. This combination has 98 % threshing efficiency, 2.99 % mechanical grain damage, 75 % cleaning efficiency, 2.99 % scatter loss and 22 kg/ hr throughput capacity. Also the result showed that threshing efficiency increases with increase in cylinder speed for both varieties. The mechanical grain damage also increases with feed rate and cylinder speed for both varieties but Samsoy-2 has higher grain damage than TAS1485-ID variety. The cleaning efficiency decreases with an increase in feed rate in both varieties but with an increase in speed. The throughput capacity also increases with increase in cylinder speed and feed rate for both varieties. Oforka (2004) modified the existing I.A.R soyabean thresher and obtained the best performance combination at a cylinder speed of 850 rpm, feed rate of 30 kg/hr with samsoy- 2 variety at 10 % moisture content of the grain. Also from his results the values of the parameter obtained are 96 % threshing efficiency, 2.86 % mechanical grain damage, 97 % cleaning efficiency, 2.86 % scatter loss and 33 kg/hr throughput capacity.

I.A.R (2006) evaluated an existing prototype soyabean thresher for performance and reported that the threshing efficiency, cleaning efficiency, grain damage, scatter loss and output capacity obtained with Samsoy-2 variety are 80 %, 70 %, 2 %, 1.94 % and 23 kg/hr, respectively, while the values obtained with TAS 1485-ID variety were 86%, 64%, 1.6 %,

2.2 % and 21 kg/hr, respectively. It was then concluded that the best combinations of cylinder speed and feed rate that gave the highest threshing efficiency were 900 rpm and 20 kg/hr with both varieties.

Amadu (2012) also worked on an ImprovedI.A.R soyabean thresher with the following findings: The Threshing efficiency, Cleaning efficiency, Mechanical grain damage, Scatter loss and Output capacity were found to be 99%, 95%, 1.01%, 2.7% 2.7%and 25.5kg/hr respectively, but the thresher had a problem of consistent chocking during the threshing operations.

2.4 Methods of Threshing Soyabean

2.4.1 Manual threshing

Threshing is done manually by beating the grain using a flail on a threshing floor. Another traditional method is to make donkeys or oxen walk in circles on the grain on a hard surface. A modern version of this in some areas is to spread the grain on the surface of a country road so the grain may be threshed by the wheels of passing vehicles.

2.4.2 Mechanical threshing

A mechanical thresher has a threshing drum, which consist of a long cylindrical shaped member to which a series of pegs, knives or rasp bars are attached on its surface. The drum is mounted on two bearings and rotates in a perforated trough like member called the "concave". During threshing, the 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 the grains from the panicles (Amir, 1990). Two types of mechanical threshers were identified- the beater types and the axial flow type. According to him the beater thresher

have a threshing cylinder which rotates in an enclosed chamber with lower part of the chamber forming the concave. The concave contains some perforations and there are no separate outlets in the machine for ejection of straw. The beating knives shred the straw into smaller pieces until it is small enough to pass with the grains through the small perforations in the concave for several complete turns. The continuous rotation of the pegs with an impact force over a period of time results in threshing the crop and the grain is separated from the chaff through the concave. Finally the straw is collected at a large straw outlet at the end of the concave. These types of threshers however cannot be used for threshing crops with tougher straw such as sorghum, soyabean etc. The axial flow type thresher is constructed with steel metal and is a general purpose thresher suitable for crops like paddy, wheat, sorghum, soyabean and other grain crops. It has a capacity ranging from 300 kg/hr for wheat to 600 kg/hr for sorghum and a prime mover of about 5-7 hp (either petrol or diesel engine) (Amir, 1990). In the axial flow machines, crops moves spirally between the threshing drum and the circular concave for several complete turns.

2.5 Threshing Parameters

Sharma and Devnani (1978) developed a specially designed variable speed thresher used for determining threshing parameters like feed rate, grain output, threshing efficiency, energy consumption, and grain damage for soyabean and cowpea at the sun dried moisture content of 6.1 % and 6.5 % respectively. They found that energy consumption in threshing was found to be directly proportional and highly correlated with feed rate and cylinder tip speed, irrespective, of the concave clearance. At the same rate of material flow and cylinder tip speed the energy consumption for cowpea was higher than for soyabean. Also

the cleaning and separating units consumed 0.625 kW hr/g for cowpea and 0.5 kW hr/g for soyabeans.

This higher energy consumption at some speed and feed rate was associated with high non-grain material of the crop. Sharma and Devnani (1978) also reported that the peripheral speed of the cylinder and concave clearance were the most important factors that causes grain damage. For the same cylinder speed and concave clearance, the visible grain damage was grater for soyabean whereas the internal grain damage was greater for cowpea. It was also noticed that, although at higher speeds the visible grain damage was below 5 %, the internal damage to grain was very high as determined by germination test.

2.6 Factors Affecting Soyabean Threshing

Threshing of soyabean and other similar grain crops can be done with a squeezing action, a rubbing action or a combination of the two, and is a function of crop and machine variables. The crop variables are related to the type, variety, maturity, and moisture content. The machine variables include the feed rate, type of cylinder and concave, cylinder tip speed and concave clearance (Sharma and Devnani, 1978).

2.7 Factors Affecting Soyabean Cleaning

Grains cleaning can be considered a stochastic process with particular changing orientation in a random manner both in time and space. The physical parameters affecting the cleaning process are grouped into:

i. Machine factors which include : frequency of sieve oscillation, amplitude of oscillation, sieve slope, length of sieve, width of sieve, sieve hole diameter, threshing pressure, air density and terminal velocity,

ii. Crop factors which include: crop varieties, maturity stage, grain moisture content, straw moisture content, bulk density of grain, bulk density of straw, grain diameter and angle of repose.

2.8 Research Gap

It was observed from the reviewed literature that threshing operations is an extensive field work that requires research and development. With regard to the existing soyabean thresher developed by Amadu, (2012) there is a need to modify it for improved performances especially output capacity and also to proffer solution to its problem of chocking. This work will modify the thresher by introducing stationary knives to the threshing chamber and also increase the size of the hopper in order to improve the feeding rate. The existing configuration of the thresher will be maintained.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Determination of Physical Properties of Soyabean

3.1.1 Test sample

The soyabean grain sample of varieties TGX 1448 -2E was procured from the Agricultural Engineering department, Faculty of Engineering, Ahmadu Bello University, Zaria. The variety was selected because of its characteristics (high yielding, early maturity and low shattering) and it is the most commonly used by farmers in north part of Nigeria (Ahmad, 2015).

The following instruments were used in conducting the experiments:

- Stop watch (Precista max 60, d =15) was used in recording time taken for threshing
- Tachometer (Smith Industrial Division, London HW2, max 50,000 rpm, d=1 rpm) was used for measuring the speed of threshing cylinder shaft.
- Electronic weighing balance (Optima scale, OPH-T300, Max 30000 g, d = 0.1 g) was used to measure the weight of the crop fed into the machine, weight of chaffs, broken and scatter grains.
- Drying oven (Agrisearch equipment, UN30, Min 5°C, Max 300°C) was used in the determination of grain moisture content.
- Other instrument used were tilt table, ruler and sheet metal and glass sheet for the determination of the angle of repose and grains coefficient of friction.

3.1.2 Preparation of the sample

Broken, split, spoiled and deformed seeds were discarded before the samples were prepared for the experiment. Sample selection was randomized all through the tests and care was taken to ensure that only good seeds were used. For the variety, three levels of moisture content were taken (10, 12 and 14 %). Values of 10-14 % were selected based on the range of moisture content values in literature. These values are the normal values at which post-harvest threshing operations are carried out. The moisture content of the sample was determined by using oven drying (103±2 ^{o}C) method until constant weight was reached. The average moisture content of the soyabeans was calculated based on dry basis (Kashaninejad *et al.*, 2003). The soyabean was conditioned by adding a calculated quantity of water (equation 1), which was mixed thoroughly in the samples and sealed in separate polyethylene bags. The samples were kept in a refrigerator for fifteen days in order to have uniform distribution of moisture throughout. (Karababa, 2005).

$$q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \qquad (3.1)$$

Where: q = additional quantity of moisture (g)

W_i = initial weight of sample, (g)

M_f = final moisture content (db) (which is to be attained after adding water)

M_i = initial moisture content (db)

3.1.3 Dimensions

In order to determine the linear dimensions of the soyabean seeds, one hundred soyabeans were randomly selected. For each soyabean, the three principle dimensions, namely length

(major diameter), width (minor diameter) and thickness (intermediate diameter) were measured using a vernier caliper having the least count of 0.001 mm at each moisture level. The length (L) was defined as the distance from the tip cap to kernel crown. Width (W) was defined as the widest point to point measurement taken parallel to the face of the kernel. Thickness (T) was defined as the measured distance between the two kernels faces as described by Pordesimo *et al*. (1990). The geometric mean diameter of the soyabean was calculated by using equation (3.2) (Mohsenin, 1980). The linear dimension of the soyabean seed is shown in Figure 3.1.

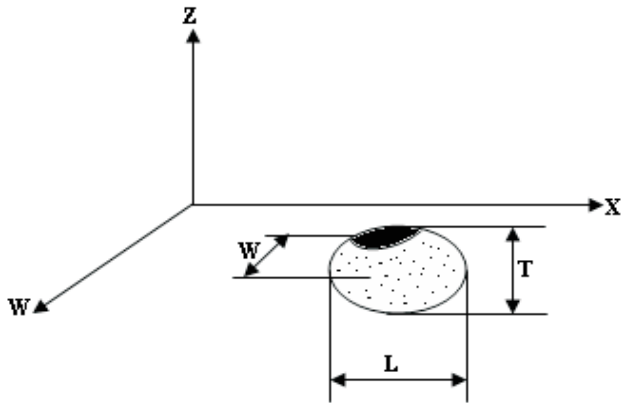


Fig. 3. 1: Characteristic Dimensions of Soyabean

The geometric mean diameter of the Soyabean was calculated using the following relationship (Mohsenin, 1980):

$$D_g = (LWT)^{1/3} \qquad (3.2)$$

Where: D_g = geometric mean diameter

L = major diameter (mm)

W = minor (mm)

T = intermediate diameter (mm)

The sphericity was computed using the formula given by (Mohsenin, 1980):

$$\emptyset = \frac{(LWT)^{1/3}}{L} \quad (3.3)$$

Where: $\emptyset$ = sphericity

3.1.4 One thousand grains mass

The thousand grain mass was determined using an electronic weighing scale having an accuracy of 0.1g.

3.1.5 Bulk density

The bulk density is the ratio of the sample mass of soyabeans to its total volume. It was determined by filling a 1000 mL container with kernels from a height of about 150 mm, striking the top level and then weighing the content (Deshpande *et al.*, 1993; Gupta and Das; 1997; Konak *et al.*, 2002).

$$P_b = \frac{\boldsymbol{M}}{\boldsymbol{V}} \quad (3.4)$$

Where: P_b = bulk density, (kg/m^3)

M = mass of seeds (kg)

V = volume of seeds (m^3)

3.1.6 True density

The true density was determined using liquid displacement method. (Mohsenin, 1980) Grain sample of 5g was submerged in kerosene in a measuring cylinder having an accuracy of 0.1 mL, the increased in volume due to sample was noted as true volume of sample which was used to determine the true density of the sample.

$$P_s = \frac{(M_s + M_w)}{(V_s + V_w)} \quad (3.5)$$

Where: P_s = true density (kg/m^3)

M_s = weight of liquid (kg)

M_w = weight of air dry sample (kg)

V_s = volume of liquid (m^3),

V_w = volume of sample (m^3).

3.1.7 Porosity

Porosity is the ratio of volume of internal pores in the particle to its bulk volume. It was expressed using Mohsenin (1980) relationship:

$$\acute{\varepsilon} = \frac{P_{s-P_b}}{P_s} \times 100 \quad (3.6)$$

Where: P_s = true density (kg/m^3)

P_b = the bulk density (kg/m^3)

3.1.8 Angle of repose

The angle of repose is the characteristics of the bulk material which indicates the cohesion among the individual grains (Wandkar *et al.*, 2012). The higher the cohesion, the higher

the angle of repose. The angle of repose is the angle from the horizontal at which the material will rest in a pile. This was determined by using an open-ended cylinder of 15 cm diameter and 30 cm height. The cylinder was placed at the center of circular plate having a diameter of 70 cm and was filled with soyabean grains. The cylinder was raised slowly until it formed a cone on the circular plate. The height of the cone was recorded. The angle of repose, was calculated by using the following formula:

$$\theta = \tan^{-1}(\frac{2h}{d_c}) \quad (3.7)$$

Where: θ = angle of repose

h = hieght of pile

d_c = diameter of cone

3.1.9 Static coefficient of friction

The coefficient of friction of the seeds were determined on plywood, glass and galvanized steel surfaces using a tilting table. The angle of inclination of the table to the horizontal at which samples started sliding were measured with the protractor attached beside the inclined plane apparatus (Maduako and Hannan, 2004). Measurements were replicated five times for each sample and the coefficient of friction was calculated from the relation;

$$\mu = \tan \alpha \quad (3.8)$$

Where: μ = the static coefficient of friction

α = the angle of tilt in degrees.

3.2 Material Selection

Materials selected for the construction of the machine were based on strength, durability, low cost, and availability. Gauge 16 (low carbon steel) mild steel sheet metal was selected for the production of the machine components such as fan blades, cylinder, sides and top covers of cylinder housing while Gauge 18 was selected for blower casing, chaffs outlet, feed hopper, grain delivery chute among others. Medium carbon steel (C1040) round bar with yield stress of 568.7 MN/m^2 and ultimate tensile strength of 668.8 MN/m^2 was selected for the shafts. A 15 mm diameter round bar made up of cast iron was used for the cylinder beaters. The cost estimate (bill of quantity) for the production of the machine is presented in Table 3.2.

3.3 Design

3.3.1Results of existing thresher

Table 3.1 shows the performance of the existing thresher developed by Amadu, (2012) at 12 % moisture content. The existing thresher was developed at a total cost of one hundred and twenty six thousand naira (#126,000) as at year 2012.

Table 3.1: **Average Values of Performance Parameters of the Existing Thresher Developed by Amadu, (2012)**

MC	SPD (rpm)	Te (%)	CE (%)	SL (%)	GD (%)	Cp (kg/hr)
12%	300	97.0	82	0.15	0.97	16
	400	97.7	89	0.56	0.56	17
	500	98.0	90	1.1	0.87	18
	600	98.5	91	2.0	0.98	24
	700	94.0	92	3.4	0.93	16

SPD = speed, Te = threshing efficiency, CE = cleaning efficiency, SL = scatter loss, GD = grain damage and Cp = throughput capacity

3.3.2 Design consideration

Various factors were considered in the design and construction of the improved soybean thresher.

i) The thresher was operated using a 6 hp diesel engine. This was chosen based on the power requirement of the machine and the diesel engine was available and can also be operated at different desirable speeds.

ii) The speed of 700 rpm was chosen as the optimum speed for the operation of the machine as used by Amadu, (2012) in evaluating his machine.

iii) The size of the sieve openings (oblong openings of 8 mm wide and 10 mm long) was used taking into consideration the average size of the soybean grain that was determined to be 5.66 mm wide, 6.75 mm long and 4.66 mm thick.

iv) The angle of repose of 31.02 ^{o} was determined and was used for the determination of the size of the feed hopper. Slope of the hopper base was maintained at 46^{o} as used by Amadu (2012).

v) The method of material feeding into the machine is by reliance on gravitational flow and manual aid through pushing. The machine is to be of low cost affordable to a small scale farmer.

vi) Terminal velocity of 9.24 m/s was used as reported by Vijasit and Salokhe, (2010).

3.3.3 Design calculations

3.3.3.1 Determination of weight of fan blades

The weight of fan blades (W) was determined using the expression outlined by (Mohammed, 2009);

$$W = \delta g v \quad (3.9)$$

Where: W= weight of fan blade (N)

δ = density of fan galvanized steel blade (kg/m^3)

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

v = volume of the fan blades (length x width x thickness) (m^3)

3.3.3.2 Determination of air discharge by the blower

The air discharge through the blower (Q) was determined using the expression established by Joshi (1981) thus:

$$Q = V \times D \times W \quad (3.10)$$

Where: V = velocity of air required for cleaning, $V = \frac{2\pi rN}{60}$, m/s

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

W= width of fan blade (m)

Q = air discharge (m^3/s)

3.3.3.3 Determination of pulleys diameters

The pulleys diameter was determined using the expression established by Sanjay (2010) as;

Thus:

$$N_1D_2 = N_2D_2 \quad (3.11)$$

Where: N_1= speed of driving pulley (rpm)

D_1 =diameter of driving Pulley (m)

N_2 =speed of driven pulley (rpm)

D_2 = diameter of driven pulley (m)

i. The diameter of thresher pulley *(D)* was determined thus;

$$D_2 = \frac{N_1 \times D_1}{N_2} \quad (3.12)$$

ii. The diameter of fan pulley *(D_2)* was determined thus:

$$D_3 = \frac{N_1 D_1}{N_3} \quad (3.13)$$

Where: N_3 = speed of fan (rpm)

D_3 = diameter of fan pulley (m)

3.3.3.4 Determination of belt length

The length of each belt (L) was determined using the expression established by Hannah and Stephen (1984) thus:

$$L = \frac{\pi}{2}(d + D) + 2C + \frac{(D-d)^2}{4C} \quad (3.14)$$

Where: L = effective length of belt (m)

c = center distance from drive to driven pulley

d = outside diameter of drive pulley

D = diameter of driven pulley (m)

3.3.3.5 Determination of Toque

Hall and Hallowenko, (1982) gave torsional moment as;

$$M_t = \frac{60P}{2\pi N} \quad (3.15)$$

Where: P = *power requirement (kW)*

N = speed of the cylinder drum (rpm)

3.3.3.6 *Determination of belt speed*

The speed of each belt *(L)* was determined using the expression established by Hannah and Stephen (1984) thus:

$$V_b = \frac{\pi ND}{60} \quad (3.16)$$

Where: N= drive speed (rpm)

D = diameter of drive pulley (m)

V_b = belt speed (m/s)

3.3.3.7 *Determination of belt tension*

The following expressions were used to determine the belt tension (Sharma and Kamlesh 2006; Sanjay 2010);

$$M_t = (T_t - T_s)R \quad (3.17)$$

$$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta}$$

Where: T_t and T_s = tension in tight and slack side of belt respectively (N)

R = radius of the shaft pulley (m)

μ = coefficient of friction between the pulley and belt

θ = angle of contact between the pulley and belt (^{o})

β= one half angle of groove of the pulley (^{o})

3.3.3.8 *Determination of angle of contact of the belt*

The angle of contact of the belt with the smaller pulley was determined using the expression outlined by Sanjay (2010) as;

$$\theta = 180 - 2sin^{-1}\frac{(r_1 - r_2)}{x} \quad (3.18)$$

Where: r_1= radius of driver pulley (cm)

r_2= radius of driven pulley (cm)

3.3.3.9 *Determination of power requirement*

i. The power transmitted by the belt was determined as expressed by Sanjay (2010) as follows;

$$P_b = (T_t - T_s)V_b \quad (3.19)$$

Where: P_b = power transmitted by the belt (W)

V_b = velocity of the belt (m/s)

T_t = tension on the tight side (N)

T_s = tension on the slack side (N)

ii. The power required by the thresher includes:

- Power required to thresh crop
- Power required to turn the unloaded cylinder

- Power required by the blower

The total power required by the machine was determined and was found to be $3.623\ kW\ (appendix\ E)$.

This was used in selecting the appropriate prime mover that can conveniently power the machine. A prime mover of 4.472 kW (6 hp) was selected to power the machine.

3.3.3.10 *Determination of shafts diameters*

The shafts sizes were selected using the relationship given by Hall and Hollowenko, (1982) (equation 3.20). This is because the loadings of the shaft are due to bending and torsion only.

The allowable stress is determined based on the ASME code of 1948 which stipulated that the allowable stress of shaft under loadings is determined as the least value of 30 % of yield stress and 18 % of ultimate stress. The least value is further reduced by 25 % to account for stress concentration due to presence of keyway.

$$d_s{}^3 = \frac{16}{\pi\tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (3.20)$$

Where: d_s = shaft diameter (m)

τ_s = the allowable stress of the steel shaft (N/m^2)

K_b and K_t = combined shock and fatique factors for bending and torsional moment respectively

M_b = bending moment (Nm)

M_t = torsional moment (Nm)

3.4 Construction and Assembly of the Machine

The construction and the assembly of the machine was carried out based on the results of the design calculations using locally available materials as highlighted in table 3.1. After constructing all the design components of the machine were assembled into an integral system i.e. the developed soyabean threshing machine.

Table 3. 1: Construction and Assembly of the Machine

S/N	Component	Description	Construction materials	Construction tools	Construction method
1	Hopper	Trapezoidal in shape, having a dimension of 290 × 440 × 210 mm and inclined at an angle of 46 with the base	Guage 18 mild steel sheet	Scriber Guillotine Electrodes Welding machine	The sheet was cut to size using the cutter, the sheets were then welded (arc)to form the hopper
2	Cylinder	The threshing unit was made up of cylinder, beaters and a perforated concave plate.	The cylinder is made of mild steel sheet metal formed into 180 mm diameter.	Cutting machine Guillotine Electrodes Welding machine Measuring tape	The sheet was cut to size and bent to form a cylinder of 180 and 870 mm diameter and length respectively and then welded.
3	Shafts	Two set of shafts were used. A 25 mm diameter for the cylinder and a 20 mm for the blower	Mild steel (C1040)	Bending machine	Turned to size using bending machine. Keyways were formed using same machine
4	Blower	The blower is enclosed by the blower casing. It consists of blades mounted on a shaft	Galvanized steel plate of guage 18	Measuring tape cutting discs hammer electrodes welding machine	The casing of 30 mm diameter and the blades were made from the metal sheet. Arc welding was used to fix the blades on the shaft
5	Grain outlet	Positioned beneath the threshing chamber and covered the width of the machine	Galvanized steel plate of guage 18	Tape for measurement, cutting tools, hammer and arc welding tools	Cut to size and bent to form a rectangular shape. Welded using arc welding
6	Frame	The frame was formed using angle iron with a dimension of 800 × 1000 × 50 mm	Angle iron of 2 ×2 inch	Cutting disc Cutting machine Measuring tape Engineer's square Welding machine	The angle iron was cut to the respective sizes and welded to form the frame
7	Concave grates	Designed as rounded openings arranged in a staggered pattern	Metal sheet	Drilling machine, Tape cutting tools, hammer welding tools	The metal sheet was cut to size, drilled to form the holes and then fitted (welded) in the frame as a concave

3.5 Bill of Quantity

The cost estimate (bill of quantity) for the production of the soyabean threshing machine is presented in table 3.2

Table 3. 2**:** **Cost Estimate for the Production of the Soyabeans ThreshingMachine**

S/N	Materials	Quantity	Rate (#)	Amount (#)
1	Sheet metal (5 mm)	1/8 sheet	1,000	1,000
2	Angle iron (2 in)	4 length	2,800	11,200
3	Angle iron (1.5 in)	1 length	1,500	1,500
4	Shaft (30 mm)	1m	5,000	5,000
5	Shaft (25 mm)	1m	3,000	3,000
6	Flat bar (1.5 in)	1 length	1,800	1,800
7	Flat bar (0.5 in)	1 length	750	750
8	Rod (5 mm Ø)	1m	1,500	1,500
9	Bearing (206 flat)	2pcs	3,000	6,000
10	Bearing (205)	2pcs	1,600	3,200
11	Shoes (Shelling bars)	12pcs	700	8,400
12	Sieve (500 mm width, round hole)	1pcs	4,000	4,000
13	Sieve (500 mm width, rectangular hole)	1pcs	4,000	4,000
14	Hinges	4pcs	400	1,600
15	Pulleys	3pcs	2,500	7,500
16	V – Belt	2pcs	400	800
17	Bolts and Nuts			3,000
18	Electrodes	3pct	1,400	4,200
19	Cutting disc	4pcs	500	2,000
20	Grinding disc	2pcs	500	1,000
21	Labour			20,000
22	Prime mover	1pc		40000
23	Miscellaneous			5000

Total	**136,450**

3.6 Description of the Machine

An isometric view of the soyabean thresher is shown in Appendix H, while plate A and B depicts the soyabean thresher. Its main features are the feeding, threshing, cleaning, grain outlet and chaff outlet units. All other parts are accessories to the basic units. The thresher works on the principle of rotary impact.

3.7 Operation of the Thresher

The operation of the thresher is based on the use of beaters (spike tooth) which thresh the crop by impact and the use of centrifugal type of fan whichgenerate a blast of air to clean the threshed soyabean. The thresher is operated by one person who after assembling the thresher, starts and sets the engine to the required speed. Then, feeds the soyabean pods into the machine which flow by gravity into the threshing chamber; the chaff is blown away while clean grains are collected at the grain chute.

3.8 Performance Evaluation of the Machine

The performance evaluation of the machine involves the determination of the parameters that facilitate the calculation of the following performance indices as expressed by various equations as given below and these performance parameters are:

i. Output capacity,(kg/hr)

ii. Threshing efficiency, (%)

iii. Cleaning efficiency, (%)

iv. Scatter loss, (%)

v. Damaged grain, (%)

i) Output capacity

The thresher capacity was determined using the relationship as determined by Ndirika (1994):

$$C = \frac{Q}{t} \qquad (3.21)$$

Where: C = Capacity (Output) (kg/h)

Q = weight of threshed grain collected in unit time (kg)

t = threshing time (hr)

ii) Threshing efficiency

The threshing efficiency was determined using the relationship as determined by Ndirika (1994):

$$T_E = 100 - \left(\frac{A}{T_G}\right) x\ 100 \qquad (3.22)$$

Where: T_E = threshing efficiency (%)

A = weight of un-threshed grain in unit time (kg)

T_G = total grain input in unit time by weight (kg)

iii) Cleaning efficiency

The cleaning efficiency was determined using the relationship as determined by Ndirika (1994):

$$C_E = \left(\frac{B}{D}\right) x\ 100 \qquad (3.23)$$

Where: C_E = cleaning efficiency (%)

B = weight of cleaned grain in the sample from the grain outlet (kg)

D = weight of whole material collected in the sample from the grain outlet (kg)

iv) Scatter loss

The scatter loss was determined using the relationship (3.24) (Ndrika, 1994).

$$L_s = \left(\frac{E}{T_G}\right) x\ 100 \qquad (3.24)$$

Where: L_s = scatter loss (%)

E = weight of scattered grain collected per unit time (kg)

T_G = total grain input per unit time (kg)

v) Grain Damage

The damaged grain was determined using the expression as outlined by Ndrika, (1994):

$$D_g = \left(\frac{G}{100}\right) x\ 100 \qquad (3.25)$$

Where: D_g = damaged grain (%)

G = weight of visually damaged grain isolated in 100 grams of threshed sample (g)

3.8.1 Experimental procedure

The soyabean variety used was TGX 1448-2E. For the development of this threshing machine, the existing soyabean threshing machine developed by Amadu, (2012) was studied for its performance and identification of its weakness and faults. The properties of aforementioned variety of soyabean was determined based on which, the machine was designed and fabricated. A subsequent evaluation of the machine performance was carried out using the same variety and the results obtained were analyzed eventually. Finally, the performance of the existing machine(Amadu, 2012) and that of the modified one were compared to assess their differences.

3.8.2Experimental design and layout

The machine was subjected to three experimental factors, thus:

i. Concave clearance (C), at 3 levels (C_1 = 10mm, C_2 = 13mm and C_3 = 16mm)

ii. Feed rate (F), at 3 levels. (F_1 = 3 kg/min, F_2 = 4 kg/min, and F_3 = 5 kg/min)

iii. Cylinder speed (S), at 4 levels. *(S_1* =500 rpm, S_2 = 600 rpm, S_3 = 700 rpm and S_4 = 800).

The layout of the factorial experiment and the outline of the ANOVA are shown in Appendices A_1 and A2. CompleteRandomized Design (CRD). Four different levels of cylinder peripheral speeds; 52.4, 62.9, 73.3 and 83.8 m/s (500, 600, 700 and 800 rpm) while three levels each of feed rates (3, 4, and 5 kg/min) and concave to cylinder clearances (10, 13and 16 mm) with three replications were considered for the evaluation of the developed machine using soyabeans.

Table 3. 2: Layout of the Experiment

$C_1S_1F_1$	$C_1S_2F_2$	$C_1S_3F_3$	$C_2S_1F_1$	$C_2S_2F_2$	$C_2S_3F_3$	$C_3S_1F_1$	$C_3S_2F_2$	$C_3S_3F_3$
$C_1S_2F_2$	$C_1S_3F_3$	$C_1S_4F_3$	$C_2S_2F_2$	$C_2S_3F_3$	$C_2S_4F_3$	$C_3S_2F_2$	$C_3S_3F_3$	$C_3S_4F_3$
$C_1S_3F_3$	$C_1S_4F_2$	$C_1S_1F_1$	$C_2S_3F_3$	$C_2S_4F_2$	$C_2S_1F_1$	$C_3S_3F_3$	$C_3S_4F_2$	$C_3S_1F_1$
$C_1S_4F_1$	$C_1S_1F_1$	$C_1S_2F_2$	$C_2S_4F_1$	$C_2S_1F_1$	$C_2S_2F_2$	$C_3S_4F_1$	$C_3S_1F_1$	$C_3S_2F_2$

RI

$C_1S_1F_1$	$C_1S_2F_2$	$C_1S_3F_3$	$C_2S_1F_1$	$C_2S_2F_2$	$C_2S_3F_3$	$C_3S_1F_1$	$C_3S_2F_2$	$C_3S_3F_3$
$C_1S_2F_2$	$C_1S_3F_3$	$C_1S_4F_3$	$C_2S_2F_2$	$C_2S_3F_3$	$C_2S_4F_3$	$C_3S_2F_2$	$C_3S_3F_3$	$C_3S_4F_3$
$C_1S_3F_3$	$C_1S_4F_2$	$C_1S_1F_1$	$C_2S_3F_3$	$C_2S_4F_2$	$C_2S_1F_1$	$C_3S_3F_3$	$C_3S_4F_2$	$C_3S_1F_1$
$C_1S_4F_1$	$C_1S_1F_1$	$C_1S_2F_2$	$C_2S_4F_1$	$C_2S_1F_1$	$C_2S_2F_2$	$C_3S_4F_1$	$C_3S_1F_1$	$C_3S_2F_2$

RII

$C_1S_1F_1$	$C_1S_2F_2$	$C_1S_3F_3$	$C_2S_1F_1$	$C_2S_2F_2$	$C_2S_3F_3$	$C_3S_1F_1$	$C_3S_2F_2$	$C_3S_3F_3$
$C_1S_2F_2$	$C_1S_3F_3$	$C_1S_4F_3$	$C_2S_2F_2$	$C_2S_3F_3$	$C_2S_4F_3$	$C_3S_2F_2$	$C_3S_3F_3$	$C_3S_4F_3$
$C_1S_3F_3$	$C_1S_4F_2$	$C_1S_1F_1$	$C_2S_3F_3$	$C_2S_4F_2$	$C_2S_1F_1$	$C_3S_3F_3$	$C_3S_4F_2$	$C_3S_1F_1$
$C_1S_4F_1$	$C_1S_1F_1$	$C_1S_2F_2$	$C_2S_4F_1$	$C_2S_1F_1$	$C_2S_2F_2$	$C_3S_4F_1$	$C_3S_1F_1$	$C_3S_2F_2$

RIII

3.8.3Analysis of data

The data were analyzed statistically using analysis of variance (ANOVA) and least significant difference (LSD) methods were used to assess the effect of the variables, their interactions, their significant differences, and to determine the most appropriate concave clearance, speed and feedrates among the selected ones.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Physical Properties of Soyabean

4.1.1 Dimensions and one thousand grain mass of soyabean

The result of soyabean size and mass at three moisture contents (10, 12, 14 %) are shown in Table 4.1. All the dimensions increased with moisture content in the moisture range of 10.0 %–14.0 % (db).

Table 4. 1: Principle dimensions, geometric mean diameter, sphericity and thousand grain mass of soyabean

M_c (%)	L(mm) Mean±SD	W (mm) Mean±SD	T (mm) Mean±SD	D_g (mm) Mean±SD	Ø Mean±SD	TGM (g) Mean±SD
10	6.57±0.27	5.54±0.26	4.54±0.24	5.42±0.22	0.8332±0.020	103.55±0.42
12	6.66±0.26	5.60±0.21	4.56±0.20	5.53±0.17	0.8339±0.019	104.88±0.59
14	6.75±0.24	5.66±0.24	4.66±0.19	5.56±0.17	0.8417±0.015	108.97±0.40

Mc = moisture content, L = length, W = width, T = thickness, Dg = geometric mean diameter, S = sphericity of grains, and TGM = one thousand grain mass

Table 4.1 Principal dimensions, geometric mean diameter, sphericity and thousand grain. All the dimensional properties were significantly correlated to different moisture content. The result indicates that the soyabeans increased in length, width, thickness and geometric mean diameter within the moisture range 10.0 to 14.0 %. Thousand grain mass and sphericity was also found to increase with the increase in moisture content in the same moisture range.

Similar investigations have been made to evaluate the mass and dimensional properties and similar results were found by Wandkar *et al*. (2012), Deshpande *et al*. (1993) for soyabeans.

4.1.2 Bulk density, true density and porosity

The bulk density of soyabean decreased from 749.7 to 643.4 kg m^{-3}, respectively, as moisture content increased from 10.0 % to 14.0 % (db). The true density of soyabean was found to decrease from 1251 to 1121.12 kgm^{-3} with the increase in moisture content from 10.0 % to 14.0 % respectively (Table 4. 2). The reason for the decrease in densities with increase in moisture content is that the volume of the seeds increased when it contains more moisture. Deshpande et al,(1993), Polat et al. (2006), Isik (2007) and Wankar et al. (2012) also reported the same trend for soyabean.

Table 4. 2: Bulk density, true density, porosity and angle of repose of soyabean

Mc (%)	$\boldsymbol{\rho_b}$ **(kg/m^3)** Mean±SD	$\boldsymbol{\rho_t}$ **(kg/m^3)** Mean±SD	**ε̇ (%)** Mean±SD	**Θ (^{o})** Mean±SD
10	749.7±3.76	1251±4.76	40.07±0.59	26.55±0.69
12	701±4.63	1175.97±3.12	40.39±0.66	27.90±0.39
14	643.4±8.74	1121.12±5.13	42.60±0.52	31.02±0.70

Mc = moisture content, Pb= bulk density, Pt = true density, ε̇ = porosity and Θ = angle of repose of soyabean

The porosity of soyabeans at the three moisture content was found to increase from 40.07 % to 42.60 % with the increase in moisture content from 10.0 % to 14.0 % (db). The similar trend for porosity was reported by (Isik, 2007; Wandkar *et al.,* 2012).

4.1.3 Angle of repose

The experimental data obtained for angle of repose of soyabean is also given in Table 4.2. The angle of repose increases linearly with the increase in moisture content. The value of angle of repose increases from 26.55 to 31.02 degrees as moisture content increases from 10.0 % to 14.0 % (db). Similar increasing trend was reported by Munde (1997) and Wandkar *et al*. (2012) for green gram and soyabeans respectively.

4.1.4 Static coefficient of friction

At the three moisture contents, the static coefficient of friction was the highest (0.8) for soyabean against wood and least (0.51) for glass. As the moisture content of soyabean increased, the static coefficient of friction increased linearly. At 10.0 % (db) moisture content static coefficient of friction of soyabean was 0.70 on wood, 0.53 on glass (Table 4.3). Similar trend was represented by Polat *et al*. (2006) and Wandkar *et al*. (2012) for wooden material and glass.

Table 4. 3: Values of static coefficient of friction for soyabean against different surfaces

Mc (%)	**Glass** Mean±SD	**Wood** Mean±SD
10	0.54±0.026	0.71±0.017
12	0.55±0.017	0.72±0.02
14	0.58±0.017	0.79±0.026

4.2. Effects of variable factors on the machine performance

4.2.1 Effects of cylinder speed on threshing efficiency at three feed rates

The threshing efficiency ranges from 93.17 to 97.53 %. The minimum efficiency was obtained at a speed of 73.3 m/s (700 rpm) and a feed rate of 3 kg/min while the maximum was also at a speed of 73.3 m/s and a feed rate of 5kg/min (Appendix C_2). The threshing efficiency increased with increase in cylinder speed at different feed rates which may be due to increase in force of impact on the pods. The results of the analysis of variance shows that the effect of speeds, feed rates and their interactions were highly significant on threshing efficiency at 1% level of confidence (Table 4.4). A further analysis to assess the effects of these variables and their interactions using LSD method indicated that the speeds level; 52.4 and 62.9 m/s are statistically equal but speed level 73.3 and 83.8m/s are greater. The feed rates level; 5, 4 and 3kg/min were statistically not equal, with feed rate 3kg/min having contributed least to the threshing efficiency. Similarly, concave clearance 16mm and 13mm were statistically equal but greater than that of 10mm. A combination of speed level of 73.3m/s and 3kg/min feed rate were ranked the best interaction (Appendix D), and may be the best treatment combination for the thresher.

Table 4. 4: Analysis of Variance for the Soyabeans Threshing Efficiency

SV	DF	SS	MSS	Fcal	Ftab 5%	Ftab 1%
Replication	2	0.45	0.22	1175.93**	3.13	4.92
Speed	3	3.280	1.093	5754.39**	2.74	4.08
Feed rate	2	34.918	17.459	91889.38**	3.13	4.92
Clearance	2	6.485	3.242	17064.81**	3.13	4.92
S × F	6	14.287	2.381	12532.65**	2.23	3.07
S×C	6	12.772	2.129	11203.22**	2.23	3.07
F×C	4	2.114	0.529	2781.92**	2.5	3.6
S×F×C	12	34.849	2.904	15284.76**	1.89	2.45
Error	70	0.013	0.00019			
Total	107	109.139				

4.2.2 Effects of cylinder speed on threshing efficiency at three concave clearances

The threshing efficiencyshowsan increasing pattern with increase in concave clearance (appendix C_2).It was also observed that 13mm concave clearance gave a greater threshing efficiency than 10 and 16 mm in the overall threshing efficiency of the machine. The results of the analysis of variance shows that the effect of concave clearance on the threshing efficiency was highly significant at 1% level of confidence while the effects of its interactions with the cylinder speed were also highly significant on threshing efficiency at 1% level (Table 4.4). A further analysis to assess the effects of its interactions using LSD method indicated that a combination of speed level of 52.4 m/s and 13 mm concave

clearance were ranked the best interaction even though all their interactions were found statistically not equal to the subsequent interactions (Appendix D).

4.2.3 Effects of cylinder speed on cleaning efficiency at various feed rates

The cleaning efficiency of the machine ranges from 74.4 % to 98.44 % at a cylinder speed of 52.4 m/s (500 rpm) and 83.8 m/s (800 rpm) respectively. The minimum cleaning efficiency was obtained at a feed rate of 4 kg/min while the maximum was at 3 kg/min (Appendix C_2). The cleaning efficiency increases with increase in cylinder speed at different feed rates which could be due to the increase in fan speed. As the fan speed increases there was more stream of air flowing across the falling objects thereby blowing off the materials. Hence, a higher speed with a lower feed rate resulted in higher cleaning efficiency. The results of the analysis of variance shows that the effects of speeds and feed rates were highly significant on cleaning efficiency at 1% level of confidence while the effects of their interactions were not significant at 5% level (Table 4.4). A further analysis to assess of the effects of these variables using LSD method indicated that the effects of the speed levels were statistically equal while the highest speed level of 83.8 m/s has the highest effect and was ranked the best followed by 73.3m/s and so on. Likewise, the feed rates levels exhibit the same that 5 and 3kg/min, 3 and 4 kg/min were statistically equal though 5 kg/min was greater than 4 kg/min (Appendix D). The interaction between the speed and the feed rates further indicated that the combination of speed level 83.8m/s and a feed rate level of 3kg/min gives the best cleaning efficiency for the threshing process.

Table 4. 5: Analysis of Variance for the Soyabeans Cleaning Efficiency

SV	DF	SS	MSS	Fcal	Ftab 5%	Ftab 1%
Replication	2	10.85	5.43	0.66^{NS}	3.13	4.92
Speed	3	469.476	156.492	18.93**	2.74	4.08
Feedrate	2	220.954	110.477	13.36**	3.13	4.92
Clearance	2	14.954	7.477	0.90^{NS}	3.13	4.92
S × F	6	222.048	37.008	4.48**	2.23	3.07
S×C	6	70.052	11.675	1.41^{NS}	2.23	3.07
F×C	4	41.100	10.275	1.24^{NS}	2.5	3.6
S×F×C	12	419.703	34.975	4.23**	1.89	2.45
Error	70	578.679	8.26684			
Total	107	2047.820				

4.2.4 Effects of cylinder speed on cleaning efficiency at three concave clearances

The cleaning efficiency increases with the increase in cylinder speed at the three concave clearances while it decreased with the increase in concave clearance. This could be as a result of the fact that with the increase in clearance at the lower speed level there would be more materials to thresh at a time. This could results in chocking which is power demanding and could reduce the speed of the machine hence, reducing the cleaning efficiency. The level at which the cleaning efficiency increased with the increase in cylinder speed at various clearances reflected more with a clearance of 13 mm. The result

of the analysis of variance shows that, both the effect of concave clearance and its interactions with the cylinder speed were not significant on cleaning efficiency at 1% level (Table 4.5).

4.2.5 Effect of cylinder speed on grain damage at three feed rates

The grain damage ranges between 0.4 – 2.2%. The minimum grain damage occurs at speed level 52.4m/s and feed rate level of 4kg/min and speed level 62.9m/s and feed rate level 5kg/min, while the maximum occurs at a speed level of 83.8m/sand feed rate of 3kg/min. This could be as a result of the fact that the grains were subjected to high impact force due to high speed. This indicated that grain damage increases with cylinder speed. This means that the higher cylinder speed gives rise to higher grain damage.

Analysis of variance for grain damage show s that the effects of feed rate is not significant at 5% degree of confidence (Table 4.6).

Table 4. 6: Analysis of Variance for the Soyabeans Grain Damage

SV	DF	SS	MSS	Fcal	Ftab 5%	Ftab 1%
Replication	2	0.10	0.05	0.07^{NS}	3.13	4.92
Speed	3	5.074	1.691	2.25^{NS}	2.74	4.08
Feedrate	2	3.034	1.517	2.02^{NS}	3.13	4.92
Clearance	2	4.410	2.205	2.94^{NS}	3.13	4.92
S×F	6	5.518	0.920	1.23^{NS}	2.23	3.07
S×C	6	41.749	6.958	9.27**	2.23	3.07
F×C	4	6.064	1.516	2.02^{NS}	2.5	3.6
S×F×C	12	66.931	5.578	7.43**	1.89	2.45
Error	70	52.516	0.75023			
Total	107	80.361				

4.2.6 Effect of cylinder speed on grain damage at the three concave clearances

As the cylinder peripheral speed increases the grain damage also increases for the 10 and 16mm cylinder to concave clearances (appendix C_2), but in the case of 13mm clearance the pattern is not well defined. This may be due toa reason that the higher the concave clearance the more the grains will be subjected to crushing and this results to higher grain damage. Analysis of variance shows that the interaction of the concave clearance and the speed is highly significant. Further analysis using LSD showed that all the combination are statistically not equal with a combination of speed level 52.4m/s and cylinder concave

clearance 10mm may be the best in terms of contributing least to grain damage for the threshing process.

4.2.7 Effect of cylinder speed on scatter loss at the three feed rates

A maximum scattered loss of 2.9 % was obtained at a speed of 83.8 m/s (800rpm) with a feed rate of 3kg/min while a minimum of 0.36 % was obtained at the same speed of 83.8 m/s and feed rate of 5kg/min (Appendix C_2). The scattered losses of the machine increased with the increase in cylinder speed at various feed rates. These were because of the reduction in speed when there were more materials in the threshing chamber resulting in the reduction in the volume of air stream required to blow off the chaffs at the lower speed level. With the little materials in the threshing chamber at higher speed level there were tendency of the split and premature grains to be blown off; being their aerodynamic requirement might have been exceeded. The analysis of variance shows that the effects of speeds and feed rates were highly significant at 1% level on the scattered losses and their interactions were also highly significant at 1% level (Table 4.7). Further analysis shows that the effects of the speed levels were statistically unequal while the highest speed level of 83.8 m/s was ranked the worst in terms of scatter loss. The feed rates levels exhibit different pattern that; 3 and 4 kg/min, 4 and 5kg/min were statistically equal though 3kg/min was less than 5 kg/min (appendix D). However, this signifies that a speed level of 62.9 m/s and feed rate of 5 kg/min could give the best in terms of minimum scattered losses.

Table 4. 7: Analysis of Variance for the Soyabeans Scatter Loss

SV	DF	SS	MSS	Fcal	Ftab 5%	Ftab 1%
Replication	2	0.31	0.15	2.15^{NS}	3.13	4.92
Speed	3	2.086	0.695	9.72**	2.74	4.08
Feedrate	2	3.717	1.858	25.97**	3.13	4.92
Clearance	2	0.560	0.280	3.91*	3.13	4.92
S × F	6	4.422	0.737	10.30**	2.23	3.07
S×C	6	1.292	0.215	3.01*	2.23	3.07
F×C	4	0.917	0.229	3.20*	2.5	3.6
S×F×C	12	8.399	0.700	9.78**	1.89	2.45
Error	70	5.009	0.07156			
Total	107	26.709				

4.2.8 Effect of cylinder speed on scatter loss at the three concave clearances

The scatter loss of the machine shows an increasing pattern with an increase in cylinder speed at different cylinder to concave clearances. It however decreased with an increase in concave clearance. It could be observed that concave clearance 16mm has a maximum scatter loss of 1.18and minimum of 0.62% while 10 and 13mm clearances have maximum of 1.7 and 1.5% and minimum of 0.68 and 1.0% respectively (Appendix C_2). It could also be observed that the losses were more with concave clearance level of 10 mm. These could be as a result of the tendency of the materials to be crushed was more with clearance of 10 mm than 13 and 16 mm. This could render the grains liable to split and blown off, thereby

increasing the percentage losses. The analysis of variance shows that the effects of concave clearance levels were highly significant at 1% level on the scattered losses and its interactions with other variables were also significant at 5% level (Table 4.7). Further analysis shows that the effects of the clearance levels; 10 and 13mm, 13 and 16 mm were statistically equal though 10 mm was greater than 16 mm in terms of higher losses (appendix D). However, it implies that 16mm clearance could be the best in terms of minimum scatter loss. The analysis also showed that a combination of speed level 52.4m/s and the cylinder concave clearance of 13mm gives the best in terms of minimum scatter loss.

4.2.9 Effect of cylinder speed on output capacity at the three feed rates

The maximum output capacity of 108.5 kg/h was obtained at a speed of 73.3 m/s (700 rpm) and a feed rate of 5 kg/min while a minimum of 30.92 kg/hr was obtained at a speed of 52.4 m/s (500 rpm) with a feed rate of 4 kg/min (Appendix C_2). The output capacity shows an increasing pattern with the increase in cylinder speed at various feed rates. The effect of cylinder speeds on the output capacity was highly significant at 1% level and that of feed rates and cylinder concave clearance were also highly significant at 1% level and their interactions were also highly significant at 1% level (Table 4.7). When these effects were further analyzed, the speed levels; 52.4 and62.9 m/s were statistically equal, while 83.8 and 73.3 m/s were statistically not equal. Likewise feed rate level 5and 3kg/min were statistically equal, with 5kg/min being greater. The interaction between the speed and the feed rate indicated that speed level 83.8m/s and feed rate level 4kg/min gave the best output capacity. (Appendix D).

Table 4. 8: Analysis of Variance for the Soyabeans Output Capacity

SV	DF	SS	MSS	Fcal	Ftab 5%	Ftab 1%
Replication	2	1496.42	748.21	16.42**	3.13	4.92
Speed	3	22704.394	7568.131	166.06**	2.74	4.08
Feedrate	2	2613.886	1306.943	28.68**	3.13	4.92
Clearance	2	1074.361	537.180	11.79**	3.13	4.92
S × F	6	2756.391	459.398	10.08**	2.23	3.07
S × C	6	2655.870	442.645	9.71**	2.23	3.07
F × C	4	998.333	249.583	5.48**	2.5	3.6
S×F×C	12	10087.356	840.613	18.44**	1.89	2.45
Error	70	3190.308	45.57583			
Total	107	47577.318				

4.2.10 Effect of cylinder speed on output capacity at the three concaveclearances

The output capacity shows an increased with increase in concave clearance. This could be related to the actual crop requirement that the 16 mm clearance may best fit the size of the crop variety used. This implies that the output capacity increased with increase in cylinder speed at different concave clearance. Both the effects of concave clearance and its interactions with the other variables were highly significant at 5% level of confidence (Table 4.8). Further analysis showed that cylinder concave clearance, 16 and 10mm clearance were statistically equal, with 16mm being greater. Combination of speed level 83.8m/s and concave clearance 16mm also gave the best output capacity for the threshing operation (appendix D).

4.3 Comparison between the Existing and the Modified Thresher

An independent t-test shows that there is a significant difference between the efficiencies of the machines. The comparison between the existing soyabean thresher developed by Amadu, (2012 and the modified thresher using student t-test showed that threshing and cleaning efficiencies are both significant at 1%. The scatter loss and the output capacity are highly significant. The grain damage was found to be not significant. This revealed that the performance of the new modified soyabean thresher is superior to that of the old one (Table 4.9).

Table 4. 9: Comparisonbetween the Existingand the Modified Thresher

	Mean value				
	Existing	Modified	Alpha	P(T<=t)	Significance
Threshing efficiency	99.0	99.97	0.05	0.009989	*
Cleaning efficiency	95	97.64	0.05	0.000134	*
Grain damage	1.01	1.0	0.05	0.024549	NS
Scatter Loss	2.7	0.86	0.05	0.122078	**
Output capacity	25.5	86.96	0.05	1.06E-06	**

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Soybean is considered as one very important grain grown commercially in more than 35 countries of the world and the leading producer is the USA (41%) followed by Brazil (23%), Argentina (16%) and China (9%), (F A O 1988). Soybean contains 40% protein, 35% total carbohydrate and 20% cholesterol-free oil (Deshpande *et al.*, 1993). Soybean is becoming increasingly important in agriculture because it is a food source in human and animal nutrition. So many varieties have been developed around the world considering desired traits. The properties of the developed cultivars could be considered to vary from one cultivar to the other.

Manuwa (2000, 2007), Manuwa *et al.*(2004; 2005) reported on improved varieties of Soybean that were developed in Nigeria. The major improvements made on soybean varieties from 1987 through 1992 at IITA were to increase grain yield by about 20%, improve resistance to pod shattering and to maintain the level of all other traits constant. In order to design equipment for threshing, winnowing, separation, grading, sorting, size reduction, storage, and other secondary processing of soybean, especially the new improved cultivars, the physical properties should be determined.

Some design related physical properties of the test variety (TGX 1448-2E) were determined at various moisture contents.The average length, width and thickness of soyabean grains ranged from 6.57 to 6.75 mm, 5.54 to 5.66 mm and 4.54 to 4.66 mm as the moisture content increased from 10.0 to 14.0 % (db) respectively. The geometric mean

diameter increased from 5.42 to 5.53 mm. The one thousand grain mass increased from 103.55 to 108.97 g and the sphericity increased from 0.8332 to 0.8417 with the increase in moisture content from 10.0 to 14.0 % (db). The bulk density decreased from 749.7 to 643.4 kg m^{-3}, whereas the true density decreased from 1251 to 1121.12 kg m^{-3}. While porosity increased from 40.07 to 42.60% with the increase in moisture content from 10.0 to 14.0 % (db). The angle of repose increased linearly from 26.55 to 31.02 degrees with the increase in moisture content. The static coefficient of friction increased for both surfaces, namely, glass (0.54 to 0.58) and wood (0.71 to 0.79). Soyabean thresher was designed, constructed and evaluated using the locally available materials. All the performance indices showed an increase pattern with an increase in cylinder speed. The best performance of the developed thresher was obtained at a speed of 700rpm at a feed rate level of 4kg/min and a cylinder concave clearance of 13mm. The threshing efficiency, cleaning efficiency, scatter loss, grain damage and the output capacity were found to be 99.97, 97.64, 0.86, 1.0% and 86.96kg/hr respectively. In comparison between the existing machine developed by Amadu (2012) and the modified machine using student t-test, the results indicated that the modified machine is better in terms of threshing efficiency, cleaning efficiency, scatter loss and output capacity but were found to be statistically similar in terms of mechanical grain damage as indicated in Table 4.9.

5.2 Conclusion

The following conclusions were deduced from the results of this research work.

1) Some basic design related physical properties; the length (major diameter), width (minor diameter), thickness (intermediate diameter), sphericity, angle of repose and coefficient of friction for the test variety were determined.
2) An improved soyabeans thresher was designed, constructed and evaluated using the locally available materials. The best performance of the developed thresher was obtained at a speed of 73.3 m/s (700 rpm) at a feed rate level of 4 kg/min and a concave clearance of 13 mm. The threshing efficiency, cleaning efficiency, scatter loss, grain damage and the output capacity were found to be 99.97, 97.64, 0.86, 1.0 % and 86.96 kg/hr respectively.
3) In comparison with the soyabean thresher developed by Amadu, (2012) (99.0 %, 95 %, 1.01 %, 2.7 % and 25.5 kg/h), it showed that the overall performance of the modified machine (99.97 %, 97.64 %, 0.86 %, 1.0 % and 86.96 kg/h) is better than that of the existing machine and therefore, an improvement has been achieved.

5.3 Recommendations

The following recommendations were drawn;

1) The size of the hopper should be increased to accommodate more materials at a time so as to improve the feeding rate of the thresher.
2) The speed of the fan should be increased by reducing the size of the blower pulley used. This will increase thevolume of air to blow off the chaffs and hence improving the cleaning efficiency.
3) Further studies to evaluate the machine using other soyabean varieties should be conducted.

4) An on-farm trail of the improved thresher should be carried out by the farmersfor assessment.

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APPENDICES

Appendix A: **An Outline of the Analysis of Variance (ANOVA) for 4x3x3 Factorial Experiments in Complete Randomized Design (CRD)**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Computed F	Tabulated F	
					5%	1%
Replication (R)	(r-1) = 2					
Feed rate (F)	(f-1) = 2					
Cylinder speed (S)	(s-1) = 3					
Concave clearance (C)	(c-1) = 2					
F*S	(f-1)(s-1) = 6					
F*C	(f-1)(c-1) = 4					
S*C	(s-1) (c-1) = 6					
F*S*C	(f-1)(s-1)(c-1) = 12					
Error	(r-1)(fsc-1) = 70					
Total	(rfsc-1) = 107					

Appendix C_1: Average Experimental Data for the Evaluation of the SoyabeansThresher

S/N	TRTM	CRC (mm)	SPD (m/s)	FDRT (kg)	T (s)	D (kg)	A (kg)	B (kg)	L_S (kg)	G (g)
1	S1F1C1	10	52.4	3	40.25	0.62	0.150	0.54	0.60	15
2	S1F2C1	10	52.4	4	60.20	0.72	0.203	0.58	0.75	13
3	S1F3C1	10	52.4	5	70.25	1.2	0.215	1.00	0.80	14
4	S2F1C1	10	62.9	3	35.00	0.7	0.180	0.60	0.63	15
5	S2F2C1	10	62.9	4	60.10	0.75	0.190	0.70	0.75	16
6	S2F3C1	10	62.9	5	60.20	1.2	0.190	1.07	0.50	14
7	S3F1C1	10	73.3	3	30.00	0.87	0.194	0.75	0.43	10
8	S3F2C1	10	73.3	4	40.10	0.6	0.150	0.50	0.48	12
9	S3F3C1	10	73.3	5	50.10	1.72	0.210	1.50	1.20	16
10	S4F1C1	10	83.8	3	20.00	0.64	0.140	0.63	1.00	10
11	S4F2C1	10	83.8	4	40.00	1.00	0.160	0.82	1.75	17
12	S4F3C1	10	83.8	5	50.00	1.20	0.120	1.10	1.20	15
13	S1F1C2	13	52.4	3	42.00	0.8	0.148	0.72	1.47	14
14	S1F2C2	13	52.4	4	60.00	1.25	0.197	0.93	1.13	14
15	S1F3C2	13	52.4	5	65.00	1.10	0.204	1.00	0.86	15
16	S2F1C2	13	62.9	3	40.30	0.60	0.182	0.54	1.00	15
17	S2F2C2	13	62.9	4	55.10	1.10	0.167	0.90	1.00	13
18	S2F3C2	13	62.9	5	62.00	1.10	0.180	0.94	0.64	12
19	S3F1C2	13	73.3	3	40.20	0.70	0.132	0.60	0.47	15
20	S3F2C2	13	73.3	4	54.10	0.80	0.150	0.73	2.25	15
21	S3F3C2	13	73.3	5	40.30	1.10	0.127	1.074	0.86	17
22	S4F1C2	13	83.8	3	30.00	0.90	0.162	0.855	1.37	16
23	S4F2C2	13	83.8	4	48.20	0.85	0.142	0.81	1.00	20
24	S4F3C2	13	83.8	5	46.00	1.12	0.160	1.06	0.36	18
25	S1F1C3	16	52.4	3	40.00	0.87	0.135	0.77	1.00	18
26	S1F2C3	16	52.4	4	65.00	1.10	0.180	0.91	1.50	14
27	S1F3C3	16	52.4	5	72.00	1.51	0.190	1.38	0.50	13
28	S2F1C3	16	62.9	3	40.10	0.83	0.144	0.74	1.53	14
29	S2F2C3	16	62.9	4	62.00	1.50	0.147	1.28	0.75	14
30	S2F3C3	16	62.9	5	70.00	1.48	0.190	1.27	0.56	12
31	S3F1C3	16	73.3	3	45.00	0.90	0.187	0.78	1.20	13
32	S3F2C3	16	73.3	4	50.00	1.23	0.140	1.08	1.13	10
33	S3F3C3	16	73.3	5	70.00	1.67	0.170	1.53	0.80	9
34	S4F1C3	16	83.8	3	30.00	1.01	0.130	0.90	2.90	8
35	S4F2C3	16	83.8	4	50.10	0.96	0.180	0.86	1.13	10
36	S4F3C3	16	83.8	5	65.00	1.60	0.210	1.43	1.00	

Appendix C_2: Average Calculated Data for the Evaluation of the Soyabeans Thresher

S/N	TRTM	CRC (mm)	FDR (kg/min)	SPD (m/s)	TE (%)	Ce (%)	SL (%)	GD (%)	Cp (kg/h)
1	S1F1C1	10.00	3.00	52.40	95.00	87.10	0.60	0.50	42.04
2	S1F2C1	10.00	4.00	52.40	94.93	80.56	0.75	0.40	30.92
3	S1F3C1	10.00	5.00	52.40	95.70	83.33	0.80	0.50	50.48
4	S2F1C1	10.00	3.00	62.90	94.00	85.71	0.63	1.00	53.49
5	S2F2C1	10.00	4.00	62.90	95.25	93.33	0.75	0.50	33.54
6	S2F3C1	10.00	5.00	62.90	96.20	89.17	0.50	0.40	60.40
7	S3F1C1	10.00	3.00	73.30	93.53	86.21	0.43	0.50	81.12
8	S3F2C1	10.00	4.00	73.30	96.25	83.33	0.48	1.10	40.40
9	S3F3C1	10.00	5.00	73.30	95.80	87.21	1.20	1.20	108.50
10	S4F1C1	10.00	3.00	83.80	95.33	98.44	1.00	1.60	90.00
11	S4F2C1	10.00	4.00	83.80	96.00	82.00	1.75	1.80	75.60
12	S4F3C1	10.00	5.00	83.80	97.60	91.67	1.20	2.10	77.76
13	S1F1C2	13.00	3.00	52.40	95.07	90.00	1.47	1.70	55.89
14	S1F2C2	13.00	4.00	52.40	95.08	74.40	1.13	0.90	63.18
15	S1F3C2	13.00	5.00	52.40	95.92	90.91	0.86	1.10	49.62
16	S2F1C2	13.00	3.00	62.90	93.93	90.00	1.00	2.00	37.34
17	S2F2C2	13.00	4.00	62.90	95.83	81.82	1.00	2.00	60.96
18	S2F3C2	13.00	5.00	62.90	96.40	85.45	0.64	0.60	53.42
19	S3F1C2	13.00	3.00	73.30	95.60	85.71	0.47	1.40	50.87
20	S3F2C2	13.00	4.00	73.30	96.25	91.25	2.25	0.70	43.25
21	S3F3C2	13.00	5.00	73.30	99.97	97.64	0.86	1.00	86.92
22	S4F1C2	13.00	3.00	83.80	94.60	95.00	1.37	1.00	88.56
23	S4F2C2	13.00	4.00	83.80	96.45	95.29	1.00	0.60	52.88
24	S4F3C2	13.00	5.00	83.80	96.80	94.64	0.36	0.60	75.13
25	S1F1C3	16.00	3.00	52.40	95.50	88.51	1.00	0.90	66.15
26	S1F2C3	16.00	4.00	52.40	95.50	82.73	1.50	1.20	50.95
27	S1F3C3	16.00	5.00	52.40	96.20	91.39	0.50	0.90	66.00
28	S2F1C3	16.00	3.00	62.90	95.20	89.16	1.53	1.10	61.59
29	S2F2C3	16.00	4.00	62.90	96.33	85.33	0.75	1.20	78.56
30	S2F3C3	16.00	5.00	62.90	96.20	85.81	0.56	1.40	66.34
31	S3F1C3	16.00	3.00	73.30	93.77	86.67	1.20	2.10	57.04
32	S3F2C3	16.00	4.00	73.30	96.50	87.80	1.13	2.00	78.48
33	S3F3C3	16.00	5.00	73.30	96.60	91.62	0.80	1.80	77.14
34	S4F1C3	16.00	3.00	83.80	95.67	89.11	2.90	2.20	105.60
35	S4F2C3	16.00	4.00	83.80	95.50	89.58	1.13	2.00	56.05
36	S4F3C3	16.00	5.00	83.80	95.80	89.38	1.00	1.70	76.98

Appendix D: Operation Parameters Ranks based on Fisher's Least SignificantDifference (LSD) Method for the Soyabean Thresher

Performance indices	TE(%)			C_E (%)		S_L (%)				C_P (kg/h)	
Operation parameters	Speed	FDR	CLR	Speed	FDR	Speed	FDR	CLR	Speed	FDR	CLR
Ranks	800^{a}	5^{a}	16^{a}	800^{a}	3^{a}	800^{a}	3^{a}	16^{a}	800^{a}	3^{a}	16^{a}
	700^{b}	4^{b}	13^{ab}	700^{ab}	4^{ab}	700^{ab}	4^{ab}	13^{ab}	700^{b}	5^{ab}	10^{ab}
	600^{c}	3^{c}	10^{c}	600^{bc}	5^{c}	500^{bc}	5^{bc}	10^{bc}	600^{c}	4^{bc}	13^{bc}
	500^{cd}			500^{d}		600^{d}			500^{cd}		

Where: *FDR = Feed rate, CLR = Concave clearance*

Appendix E:Design Calculations

Determination of power required by the thresher

i) Power required to thresh the Crop

According to Nwakaire et al. (2011), the power required to thresh is given by:

$$P_1 = F \times V$$

$P_1 = power\ (W)$

$F = force\ required\ to\ thresh\ (N)$

$V = \ velocity\ of\ the\ shaft\ (ms^{-1})$

$force\ required\ to\ thresh\ \ is\ given\ by$:

$F = \quad m\omega^2\ r$

$where\ r = radius\ of\ the\ shaft\ (m)$

$\omega = angular\ velocity\ of\ the\ shaft$

$m = mass\ of\ the\ threshing\ beaters\ (kg)$

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

$N = speed\ of\ threshing\ in\ rev.per\ min$

$m = 6.79kg\ (appendix\ E)$

$N = 700rpm$

$V = \frac{\pi DN}{60}$

$D = 25mm$

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

$= \frac{\pi \times 700 \times 0.0125}{60} = 0.4581ms^{-1}$

$\omega = \frac{2\pi N}{60} = 73.3ms^{-1}$

$threshing\ force, F = m \times \omega^2 \times r$

$= 6.79 \times 73.3^2 \times 0.0125$

$= 3283.37N$

$P = F \times V$

$= 3283.37 \times 0.4581$

$$= 1.504\ kW$$

ii) Power consumed by the fan

This was calculated by the following equation (Felezi, 2004)

$P_2 = \mathrm{Cp} \times \rho \times \mathrm{w}^3 \times \mathrm{d}_2^5$

Where;

P_2= Power consumed by the fan (kW)

C_p = Power coefficient (0.165 for centrifugal blade fan)

ρ = Mass density of air (1.2 kg/m^3)

w = Blade velocity (94.24 rad/s)

d = blade outside diameter (0.0255 m)

$$P_2 = 0.165 \times 1.12 \times 94.24^3 \times 0.520.0255^5$$

$$\mathrm{P}_2 = 1.62 \times 10^{-3}\mathrm{kW}$$

iii) Power required to turn the unloaded cylinder

The power to turn the unloaded cylinder was calculated by the formular used by Olaoye *et al* (2011).

$$\mathrm{P}_3 = \frac{2\pi \times \mathrm{N\ x\ r} \times \mathrm{Mc}}{60 \times 75}\left(\mathrm{g} + \frac{\mathrm{Vt}^2}{\mathrm{r}}\right) \qquad 3.12$$

Where:

N = speed of the threshing cylinder (700 rpm)

Mc = Mass of threshing cylinder = 26.235 kg (appendix E)

r = radius of cylinder (123 mm)

V_t = peripheral velocity of the threshing mechanism (9.02 m/s)

$$P_3 = \frac{2 \times \pi \times 700 \times 0.123 \times 26.235}{60x75}\left(9.81 + \frac{9.02^2}{0.123}\right)$$

$$P_3 = 2.117\ kW$$

Therefore, the total power requirement for the machine is:

$$P_1 + P_2 + P_3 = 1.504 + 1.62 \times 10^{-3} + 2.117$$

$$= 3.623\ kW$$

Weight of the fan blades:

The weight of the fan blades was determined using the following equation:

$W_f = \delta g v$(Mohammed, 2009);

Where:

W_f = weight of the fan blade (N)

δ = density of the fan galvanized steel blade = 7850 kg/m^3

g = acceleration due to gravity = 9.81 m/s^2

v = volume of the fan blades = 2.850x10^{-4} m^3

W_f = 7850 × 9.81 × 2.850 × 10^{-4}

$W_f = 21.94$ N

Air discharge by the blower:

The air discharge through the blower was determined using the following equation (Joshua, 1981);

$$Q = V \times D \times W$$

Where: Q = air discharge rate (m^3/s)

V = terminal velocity for soyabeans = 9.24 m/s (Vijasit and salokhe, 2004)

D = depth of air stream = 0.25 m

W = width over which the air is required = 0.8 m

$$Q = 9.24 \times 0.25 \times 0.68$$

Q = 1.848 m^3/s

Since the efficiency of a blower is 30% (Hem, 1981) the actual air flow rate was given as:

$0.3 \times 1.848 = 0.5544 m^3/s$

Determination of pulley size

The following equation was used as outlined by Sanjay (2010) as;

i) Threshing Pulley

$$D_2 = \frac{N_1 \times D_1}{N_2}$$

N_1 = 1500rpm, D_1 = 80mm, N_2 = 700rpm

$$D_2 = \frac{1500 \times 80}{700} = 170 \text{ mm.}$$

Pulley size of 160mm was used because it is a standard size

ii) Centrifugal fan Pulley

$$D_3 = \frac{N_2 \times D_2}{N_3}$$

N_3 = 900rpm, D_2 = 160mm, N_2 = 700rpm

$$D_3 = \frac{700 \times 160}{900} = 124.44mm$$

The standard nearest pulley size is 120 mm

Belt length

The effective belts length was determined using the equation Hannah and Stephen (1984) thus:

$$L = \frac{\pi}{2}(d + D) + 2C + \frac{(D-d)^2}{4c}$$

Where: D= Diameter of driver pulley (cm)

d = Diameter of driven pulley (cm)

C = Center distance between the driver and driven pulley (cm)

The machine design required a set of 4 pulleys as prime mover pulley (D_P = 8cm), cylinder shaft pulleys (D_{c1} = 16cm, D_{c2} = 16cm) and fan shaft pulley (D_f = 12cm). Hence, the fan belt was determined 164.05cm while the cylinder belt was 142.01cm

Centre distance:

The center to center distance between the driver and driven pulley was estimated using the expression given by Khurmi and Gupta (2007) as;

$$D < x < 3(D + d)$$

The prime mover to fan pulleys center distance was determined as 8cm $< x <$ 72cm but 52 cm was chosen as appropriate while the fan to cylinder pulleys center distance was determined as 12cm $< x <$ 84 cm and 60 cm was chosen as appropriate.

Belt speed:

Belt speed was determined using the equation ;

$$V = \frac{\pi DN}{60}$$

Where: V = belt speed (m/s)

N = drive speed (rpm)

D = diameter of drive pulley (m)

Based on the above equation , the cylinder driven belt speed was determined 12.57 m/s and that of fan belt was 4.39 m/s.

Determination of angle of contact

$\theta = 180° - 2\sin^{-1}\left(\frac{\mathrm{D}-\mathrm{d}}{\mathrm{C}}\right)$

Where θ is the angle of contact

The angle of contact between the cylinder pulley and the belt was found to be 170.8^{o} while that of blower pulley and the belt was 172

Power transmitted by the belt:

The power transmitted by the belt was determined as expressed by Sanjay (2010) as follows;

$P_b = (T_t - T_s)V$

Where: $P_b =$ power transmitted by the belt (W)

$V =$ velocity (m/s) = 5.86 m/s

T_t =1157.2 N and

T_s =4.696x10^{-17} N respectively (see appendix E)

Based on the equation above, the power transmitted by the belt from the cylinder pulley to the blower pulley was determined to be 5.08kW.

Determination of shafts torsional moment

The following equation was used in determining the torsional moment of the shafts:

$M_t = \frac{60P}{2\pi N}$

(a) Fan shaft

Where: P = 5080 W

S = speed of the cylinder drum (rpm) = 900 rpm

M_t = 53.9 Nm

(b) Cylinder shaft

$P = 3.623\ kW$ (power required for threshing the crop)

N = 700 rpm (Vijasit and Salokhe, 2004)

$M_t = 22.53\ Nm$

But the torque required by the fan shaft is derived from the cylinder shaft, therefore;

Total torsional moment on the cylinder shaft = 22.53 + 53.9 = 76.49 Nm

Belt tension:

The following expressions were used to determine the belt tension(Sharma and Kamlesh 2006; Sanjay 2010);

$$M_t = (T_t - T_s)R$$

$$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta}$$

Where: T_t and T_s = Tension in tight and slack side of belt respectively (N)

R = radius of the shaft pulley (m) = 0.08m

μ = coefficient of friction between the pulley and belt

θ = angle of contact between the pulley and belt (^{o})

β = one half angle of groove of the pulley (^{o}) when μ = 0.25, $2\beta = 34^o$, and $\theta = 170.8^o$

Therefore, the tensions in the tight and slack side of the fan belt were determined 898.25 N and 2.665×10^{-17} N respectively while those of cylinder belt were 1157.2 N and 4.696×10^{-17} N respectively.

Forces Exerted by the Threshing Drum Beaters and the Chaff Throwers were Determined as Follows

$W = \delta g v$

Where:

W= weight of material (N)

δ= density of the material (kg/m^3)

V= volume of material (m^3)

The weight of the threshing drum was obtained as follows:

δ= 7850 kg/m^3

g = 9.81 m/s^2

v = 2.282×10^{-3} (m^3)

$W_1 = 7850 \times 9.81 \times 2.282 \times 10^{-3} = 175.73$ N

The weight of the beaters was obtained as follows

δ= 7850 kg/m^3

g= 9.81 m/s^2

$v = \left(\frac{\pi D^4}{4}\right) L = 8.65\ x\ 10^{-4} (m^3)$

$W_2 = 7850x9.81x8.65\ x\ 10^{-4}$=66.61 N

The weight of the chaff thrower was obtained as follows

$g = 9.81\ ms^{-1}$

$\delta = 7850\ kgm^{-3}$

$v = 1.951\ x\ 10^{-4}\ (m^3)$

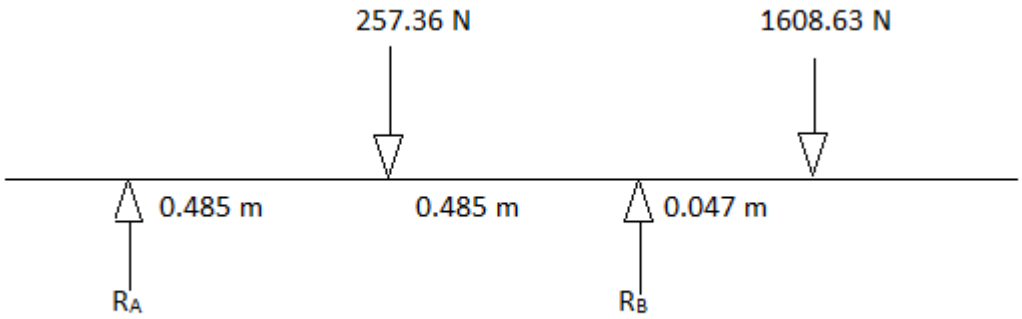
$W_3 = 7850\ x\ 9.81\ x\ 1.951\ x\ 10^{-4} = 15.02\ N$

Hence total weigh $W = 175.73 + 66.61 + 15.02 = 257.36\ N$

The force exerted on the shaft by the threshing drum beaters, and chaff throwers was 257.36 N

The forces acting on the shaft are shown on the free body diagram below

Vertical loadings on cylinder shaft:



$\sum F = 0$

$$R_A + R_B = 257.36 + 1608.63$$

$R_A + R_B = 1865.99$ (1)

taking moment about R_A

$\sum M = 0$

$R_B(0.97) = 257.36(0.485) + 1608.63(1.017)$

$$R_B = \frac{1760.8}{0.97}$$

$$R_B = 1815.3\ N$$

$from\ equation\ 1$

$$R_A = 1865.99 - R_B$$

$$R_A = 1865.99 - 1815.3$$

$$R_A = 50.73\ N$$

$shear\ force\ calculations$

$$50.73 - 257.36 = -206.63\ N$$

$$-206.63 + 1815.3 = +1608.67$$

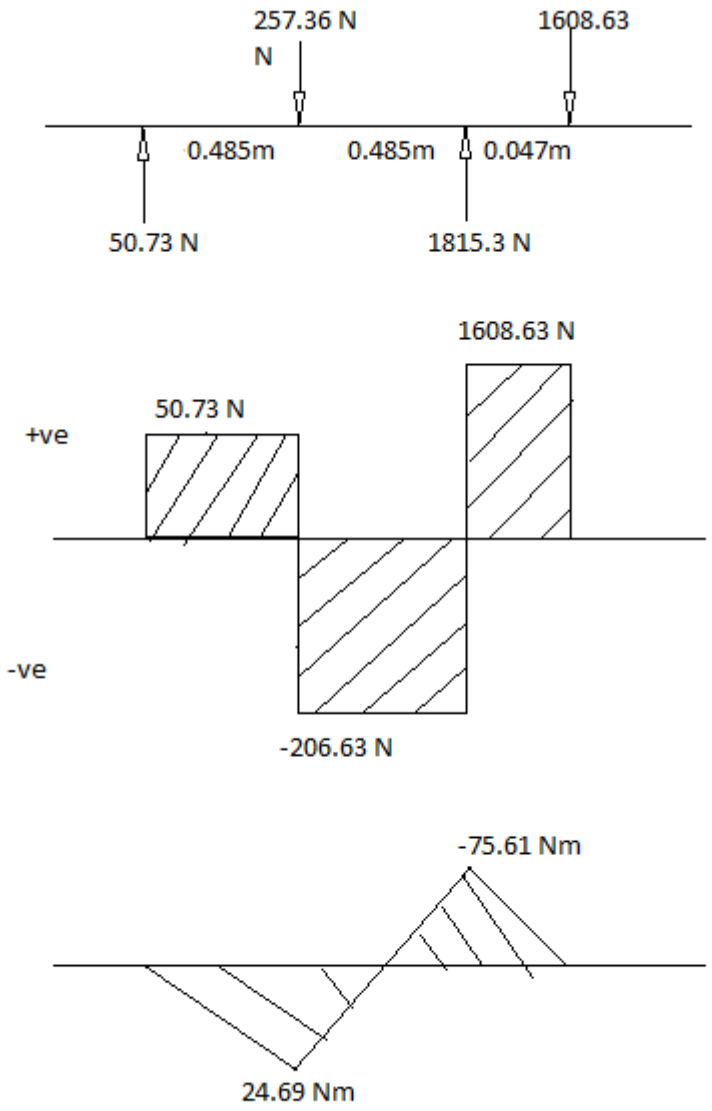
$bending\ moment\ calculations$

$$50.73(0.485) = 24.604\ Nm$$

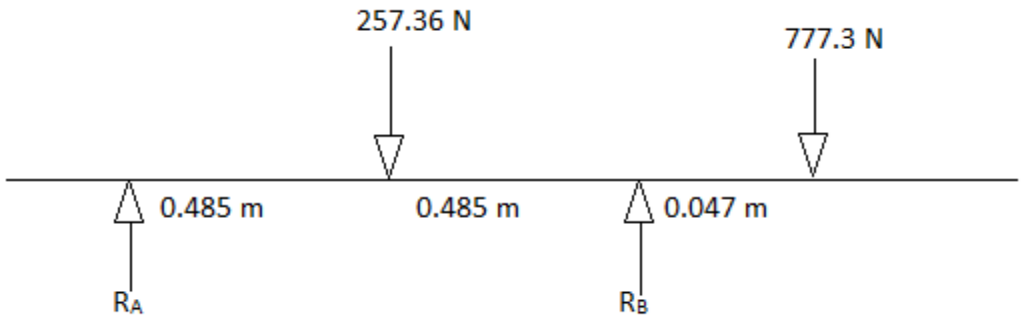
$$24.604 - (206.63 \times 0.485) = -75.612\ Nm$$

$$-75.612 + (1608.67 \times 0.047) = 0.004 \approx 0$$

Bending moment and shear force diagram for the vertical loadings on the cylinder shaft



Horizontal loadings



$\sum F = 0$

$R_A + R_B = 257.36 + 777.3$

$R_A + R_B = 1034.66$ (1)

$taking\ moment\ about\ R_A$

$\sum M = 0$

$777.3(1.017) + 257.36(0.485) = R_B(0.97)$

$R_B = 943.64\ N$

$from\ equation\ 1$

$R_A = 1034.66 - R_B$

$R_A = 1034.66 - 943.64$

$R_A = 91.02\ N$

$shear\ force\ calculations$

$91.02 - 257.36 = -166.34\ N$

$-166.34 + 943.64 = 777.3\ N$

Bending moment calculations

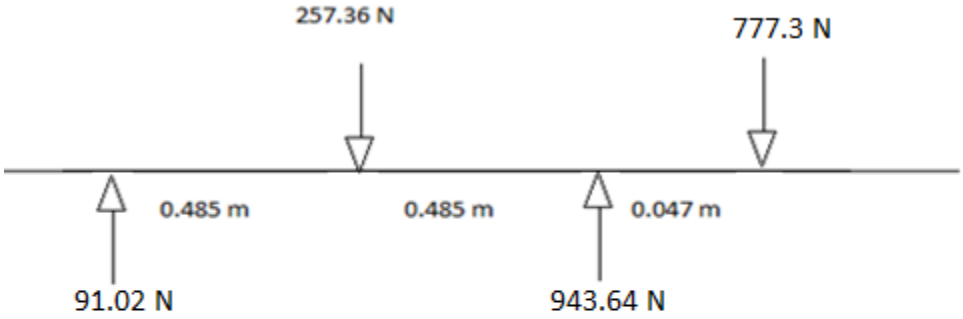
$777.3(0) = 0$

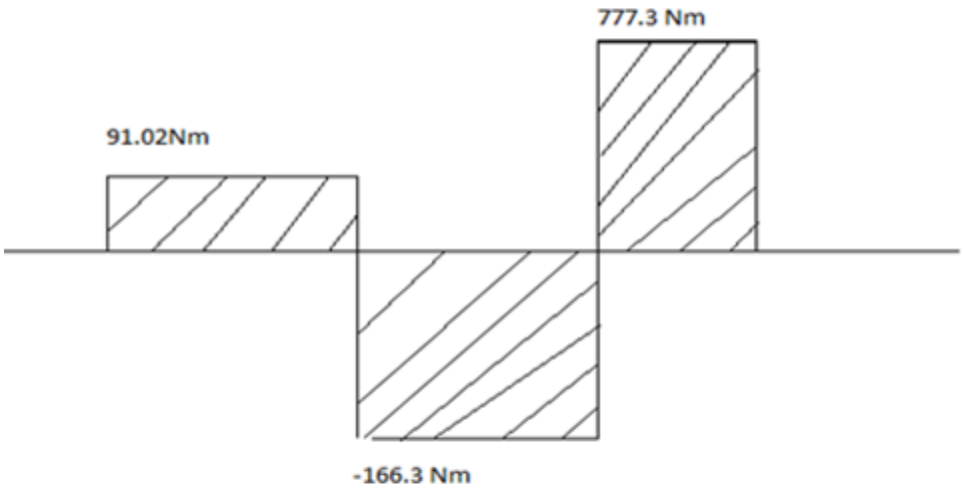
$777.3(0.047) = 36.53\ Nm$

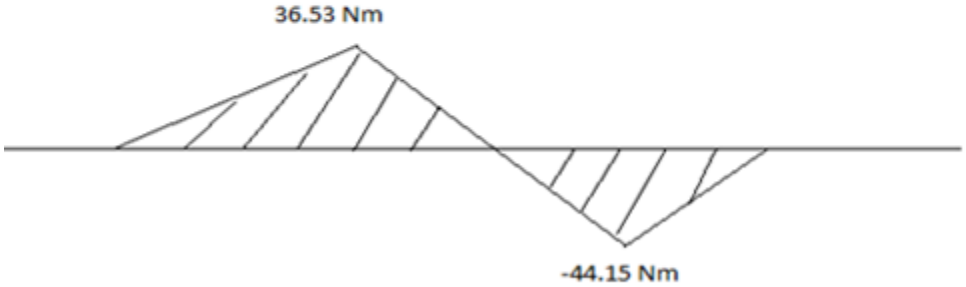
$777.3(0.047 + 0.48) - 943.64(0.485) = -44.15\ Nm$

$777.3(0.0047 + 0.458 + 0.485) - 943.64(0.485 + 0.485) + 257.36(0.485) = 0$

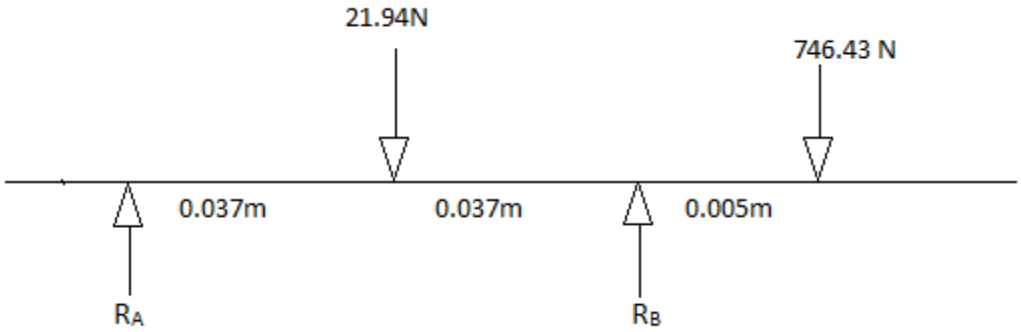
Horizontal loadings on cylinder shaft







Fan shaft Vertical loadings



$\sum F = 0$

$R_A + R_B = 21.94 + 746.43$

$R_A + R_B = 768.37$ (1)

Taking moment about R_A

$\sum M = 0$

$taking\ moment\ about\ R_A$

$21.94(0.037) + 746.43(0.079) = R_B(0.074)$

$R_B(0.074) = 59.78$

$R_B = 807.83\ Nm$

$from\ equation\ 1$

$R_A = 768.37 - R_B$

$R_A = 768.34 - 807.83$

$R_A = -39.46\ N$

Shear force calculations

$807.83 - 21.94 = 785.89\ N$

$785.89 + (-39.46) = 746.34\ N$

Bending moment calculations

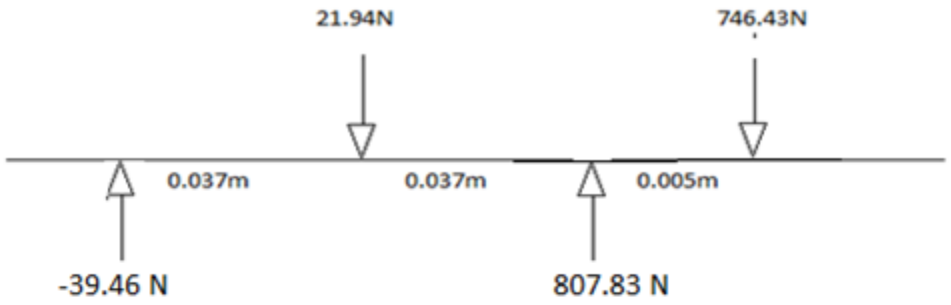
$746.43(0) = 0$

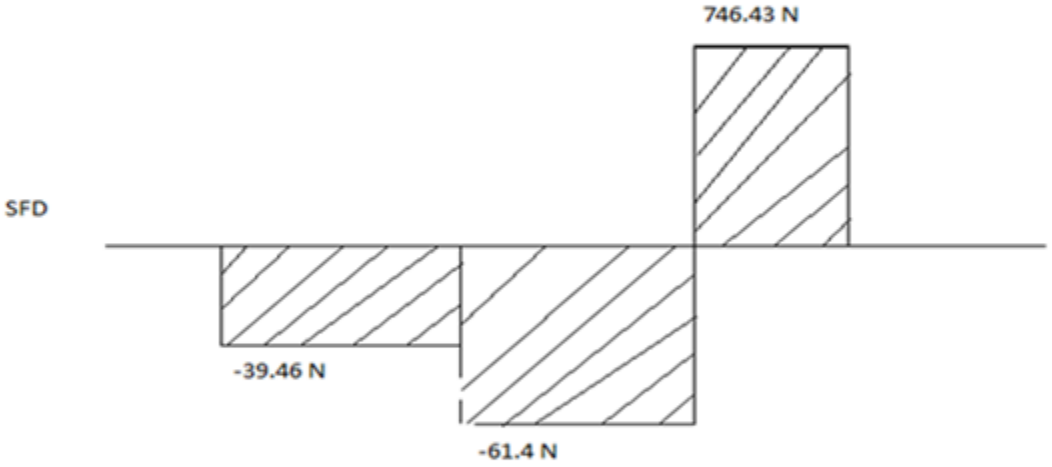
$746.43(0.005) = 3.73\ Nm$

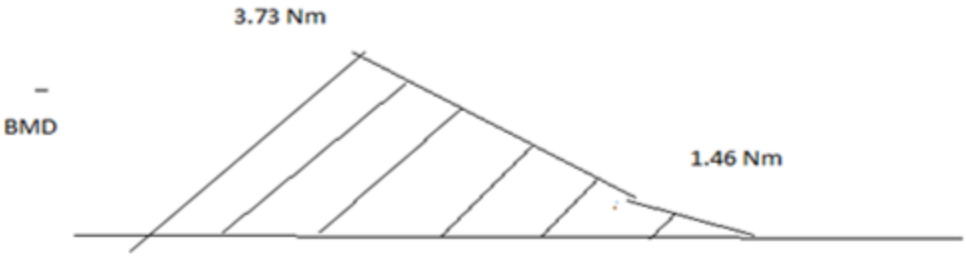
$746.43(0.005 + 0.037) - 807.83(0.037) = 1.46\ Nm$

$746.43(0.005 + 0.037 + 0.037) - 807.83(0.037 + 0.037) + 21.94(0.037) = 0$

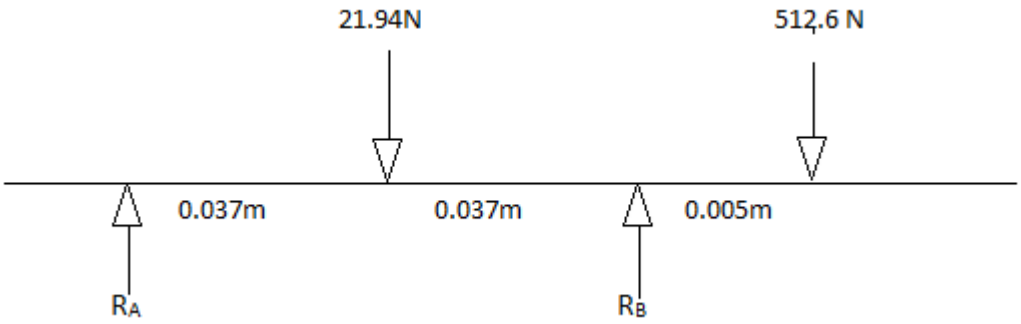
Vertical loadings on fan shaft







Horizontal loadings



$\sum F = 0$

$R_A + R_B = 21.9 + 512.6$

$R_A + R_B = 534.5$ (1)

$\sum M = 0$

$512.6(0.079) + 21.9(0.037) = R_B(0.074)$

$R_B(0.074) = 41.31$

$R_B = 558.19\ N$

$from\ equation\ 1$

$R_A = 534.5 - R_B$

$R_A = 534.5 - 558.19$

$R_A = -23.69\ N$

Shear force calculations

$-23.69 - 21.94 = -45.63\ N$

$-45.63 + 558.19 = 512.56$

Bending moment calculations

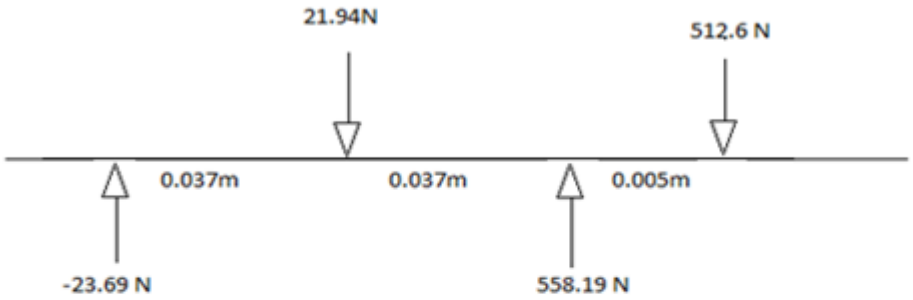
$512.6(0) = 0$

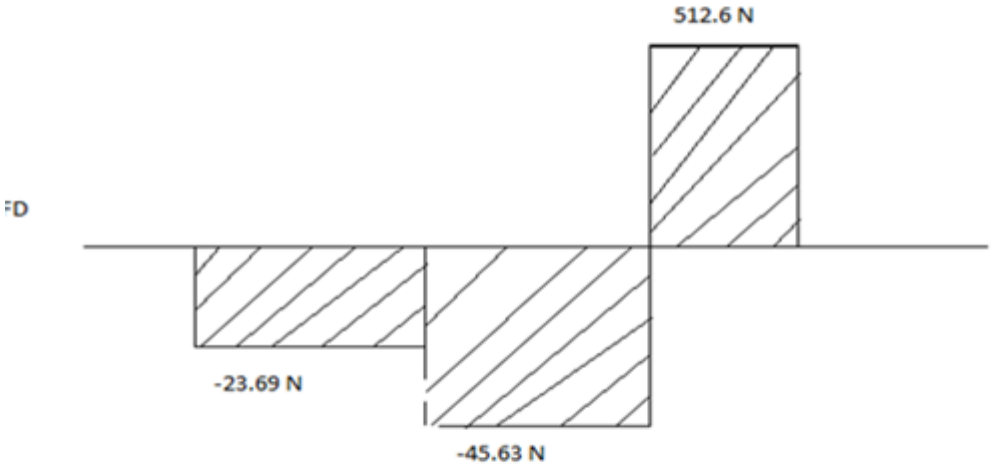
$512.6(0.005) = 2.56\ Nm$

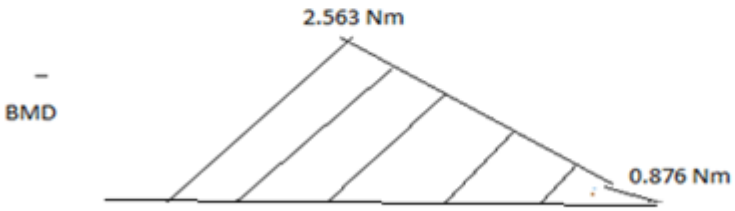
$512.6(0.005 + 0.037) - 558.19(0.037) = 0.876\ Nm$

$512.6(0.005 + 0.037 + 0.037) - 558.19(0.037 + 0.037) + 21.94(0.037) = 0$

Bending moment and shear force diagrams for horizontal loadings on fan shaft







Determination of the shaft diameter

Design of a shaft involves determination of the minimum diameter of the shaft material that can withstand certain loading conditions. Shaft may be subjected to torsion, to bending, to axial tension or compression or to a combination of any or all of these actions. Therefore there is the need to take all of the above into consideration to avoid shaft failure. The selected material used for the shaft in this machine is medium carbon steel (C1040).

Tensile stress St of 668.8 MN/m^2

Yield stress, Sy of 568.7MN/m^2

- Conditions on allowable maximum stress

The maximum allowable shearing 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). They further stated that the allowable shear stress is reduced by 25% when there is a keyway in the shaft.

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 and 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.

$S_a = 120.38 X 0.75$

$90.3MN/m^2$

To get the shaft diameter (d) the following relationship by (Hall et *all*, 1989) was used.

i) **Cylinder shaft diameter:**

The shaft size was determined using the relationship given by Hall and Hallowenko, (1982). As;

$$d^3{}_s = \frac{16}{\pi\tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (3.15)$$

Where: d_s = Shaft diameter (mm)

K_b = Shock and fatigue factor applied to bending moment = 1.5

K_t = Shock and fatigue factor applied to torsional moment = 1.0

$M_b = resultant\ bending\ moment = 44.04\ Nm$

M_t = Torsional moments = 76.49 Nm

τ_s= Allowable stress of the steel shaft = 90.3 N/m^2

$$d^3 = \frac{16}{\pi(90.3 \times 10^6}\sqrt{(1.5 \times 44.04)^2 + (1 \times 76.49)^2}$$

$$= 5.64 \times 10^{-8}(101.067)$$

$$d^3 = 5.71 \times 10^{-6}$$

$$d = \sqrt[3]{5.71\ \times\ 10^{-6}}$$

$$d = 0.0180\ m$$

A factor of safety of 1.3 was chosen to take care of deformation due to fatigue caused by cyclic loadings.

$$therefore, 18.0 \times 1.3 = 23.4\ mm$$

$$hence, for\ reliability\ and\ safety\ a\ standard\ 25\ mm\ diameter\ shaft\ was\ used.$$

ii) Fan shaft diameter:

The shaft size was selected using the relationship given by Hall and Hallowenko, (1982). As;

$$d_s = \frac{16}{\pi \tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Where: d_s = Shaft diameter (mm)

K_b = Shock and fatigue factor applied to bending moment = 1.5 K_t = Shock and fatigue factor applied to torsional moment = 1.0

M_t = Torsional moments = 53.9 Nm

$M_b = resultant\ bending\ moment = 4.59\ Nm$

τ_s= Allowable stress of the steel shaft = 90.3 N/m^2

$$d^3 = \frac{16}{\pi(90.3 \times 10^6}\sqrt{(1.5 \times 4.59)^2 + (1 \times 53.9)^2}$$

$$= 5.64 \times 10^{-8}(54.34)$$

$$d^3 = 3.065 \times 10^{-6}$$

$$d = \sqrt[3]{3.065 \times 10^{-6}}$$

$$d = 0.0165\ m$$

A factor of safety of 1.3 was chosen to take care of deformation due to fatique caused by cyclic loadings.

$$therefore, 16.5 \times 1.3 = 20.2\ mm$$

$hence, for\ reliability\ and\ safety\ a\ standard\ 20\ mm\ diameter\ shaft\ was\ used.$

Determination of belt tension

The following expressions were used to determine the belt tension (Sharma and Kamlesh 2006; Sanjay 2010);

$M_t = (T_t - T_s)R$

$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta}$

Where: T_t and T_s = Tension in tight and slack side of belt respectively (N) $R =$ Radius of the shaft pulley (m)

μ = coefficient of friction between the pulley and belt

θ = angle of contact between the pulley and belt (^{o})

β = half angle of groove of the pulley (^{o}) when μ = 0.25, $2\beta = 34^o$, and $\theta = 170.8^o$, R = 0.025m and $M_t = 76.49\ Nm$

$76.49 = (T_t - T_s) \times 0.08$ (i)

$T_t = 1157.2 + T_s$ (ii)

$$\frac{T_t}{T_s} = e^{0.08\times 170.8\times \csc 17}$$

$$\frac{T_t}{T_s} = 2.46 \times 10^{19}$$

$$T_t = (2.46 \times 10^{19}) \times T_s (iii)$$

$from\ eqn\ (ii)$

$$1157.2 + T_s = (2.46 \times 10^{19}) \times T_s$$

$1157.2 = (2.46 \times 10^{19} - 1) \times T_s$

$T_s = 4.696 \times 10^{-17}\ N$

$T_t = 1157.2\ N$

(ii) fan belt

$M_t = (T_t - T_s)R$

$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta}$

μ = 0.25, 2β = 34°, and θ = 172°, R = 0.06 m and $M_t = 53.9\ Nm$

$53.9 = (T_t - T_s) \times 0.06$

$T_t = 898.36 + T_s$ (i)

$\frac{T_t}{T_s} = 3.372 \times 10^{19}$

$T_t = (3.372 \times 10^{19}) \times T_s$ (ii)

Equating eqn (i) and (ii)

$898.36 + T_s = (3.372 \times 10^{19}) \times T_s$

$T_s = \frac{898.36}{(3.372 \times 10^{19} - 1)}$

$T_s = 2.66 \times 10^{-17}\ N$

$T_t = 898.25\ N$

Determination of angle of contact

$\theta = 180° - 2\sin^{-1}\left(\frac{D-d}{C}\right)$

Khurmi and Gupta (2005)

Where θ is the angle of contact

Cylinder

D = 160 mm

d = 80 mm

C = 1000 mm

$\theta_1 = 180° - 2\sin^{-1}\left(\frac{160-80}{1000}\right)$

$\theta_1 = 170.8$

Fan

D = 160 mm

d = 120 mm

C = 560 mm

$$\theta_2 = 180° - 2\sin^{-1}\left(\frac{160 - 120}{560}\right)$$

$$\theta_2 = 172$$



Plate A: Front View of the ModifiedSoyabean Thresher

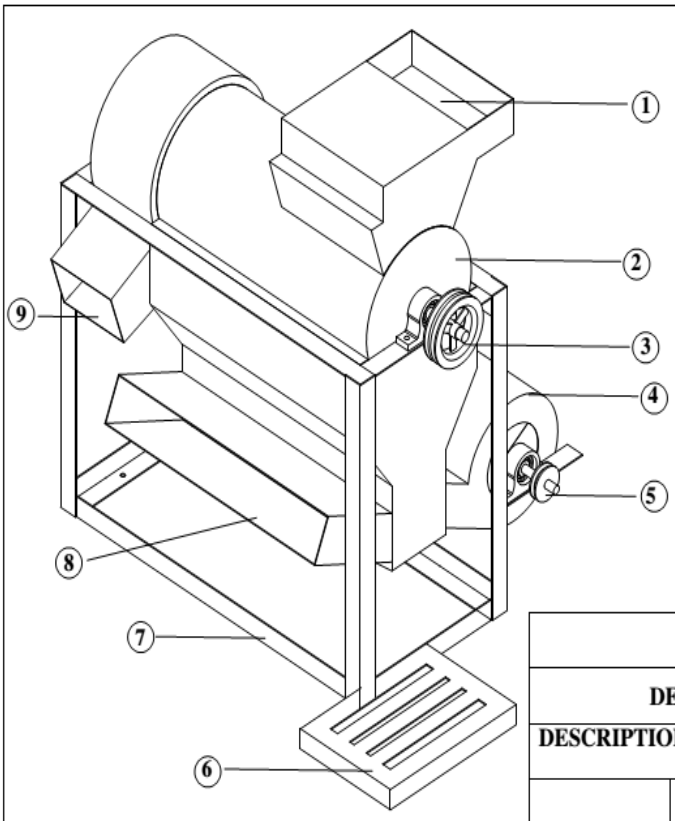


Plate B: Side View of the Modified Thresher



Plate C: Existing Thresher Developed by Amadu, (2012)

Appendix H: Working Drawings of the Machine

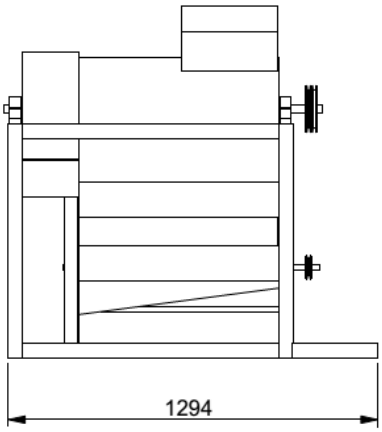


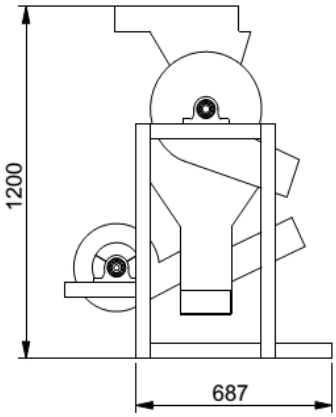
Isometric View of the Machine

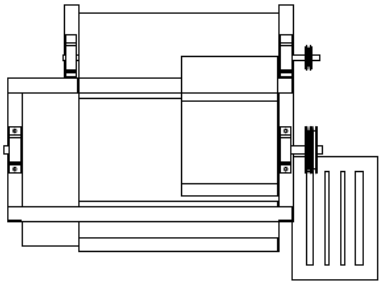
S/No	Name of Part
1	Hopper
2	Threshing Concave
3	Cylinder Pulley
4	Blower Casing
5	Blower Pulley
6	Prime Mover Seat
7	Main Frame
8	Chaff Outlet
9	Straw Outlet

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DRAWN BY	HASSAN A, SAEED			
C.A.D.D	HASSAN A, SAEED			
CHECKED BY	PROF. U. S, MOHAMMED PROF. D. D. YUSUF			
APPROVED BY	PROF. U. S, MOHAMMED PROF. D. D. YUSUF			All Dim. in mm

Orthographic View of the Machine

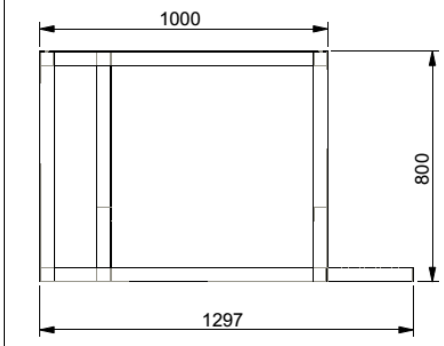


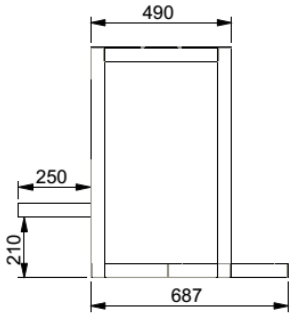


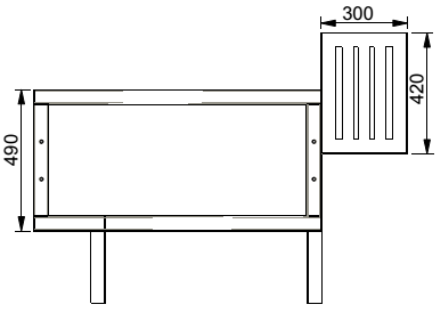


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APPROVED BY	PROF. U. S, MOHAMMED PROF. D. D. YUSUF			Scale: 1:0.06

Main Frame

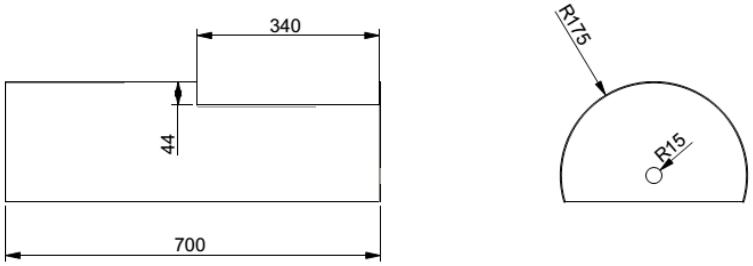


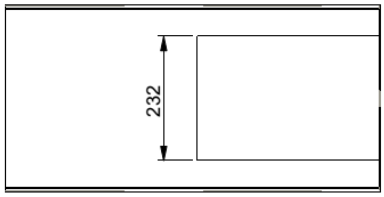




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APPROVED BY	PROF. U. S, MOHAMMED PROF. D. D. YUSUF			Scale: 1:0.07

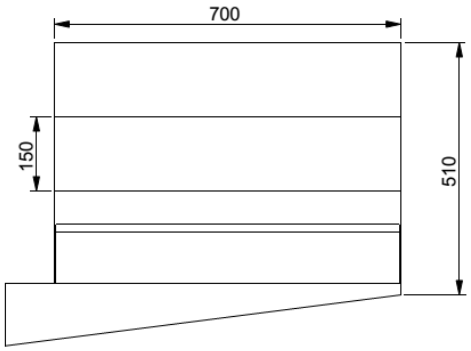
Top Concave

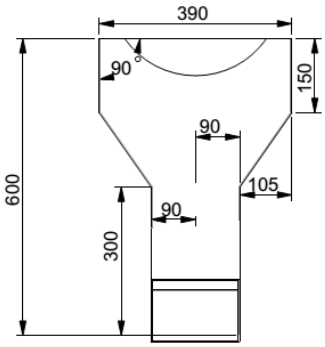


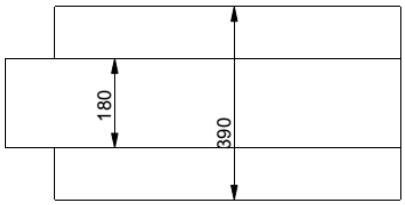


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APPROVED BY	PROF. U. S, MOHAMMED PROF. D. D. YUSUF			Scale: 1:0.13

Bottom Hopper

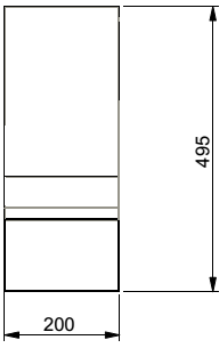




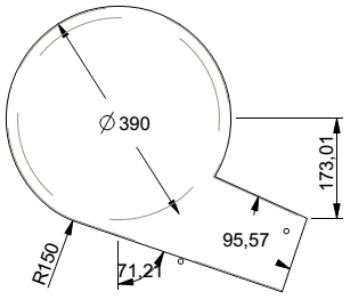


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APPROVED BY	PROF. U. S, MOHAMMED PROF. D. D. YUSUF			Scale: 1:0.12

Straw Outlet

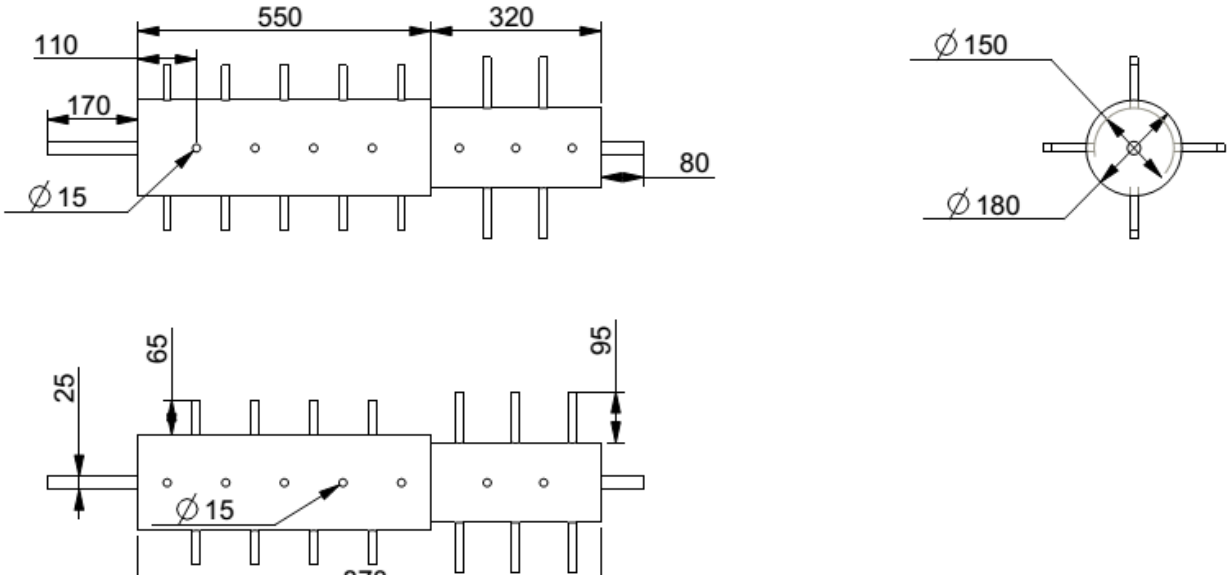




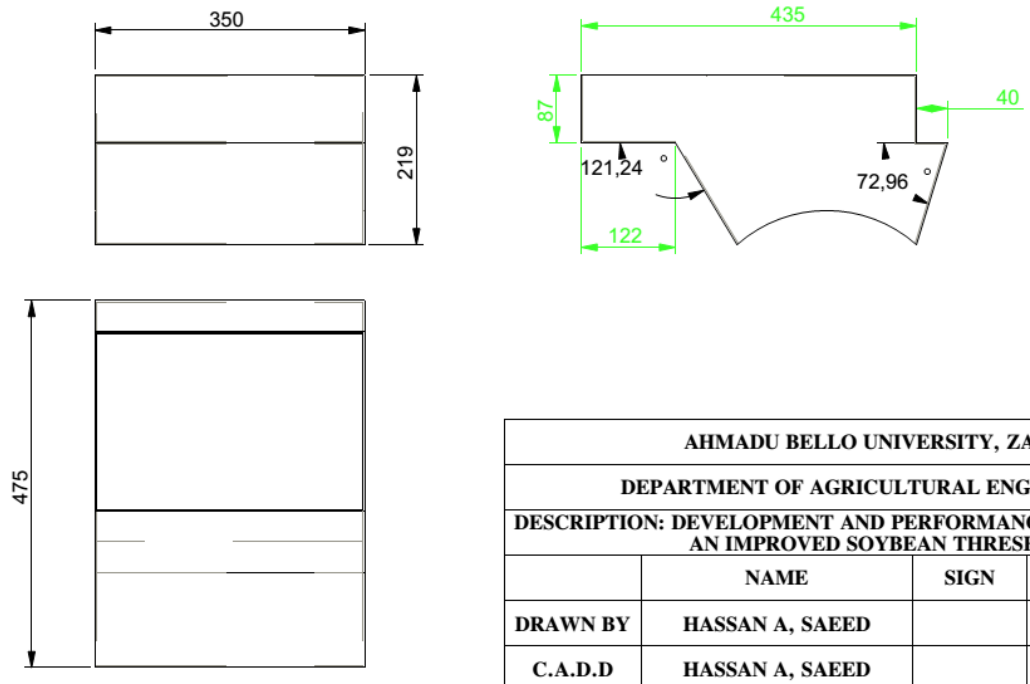


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Threshing Cylinder

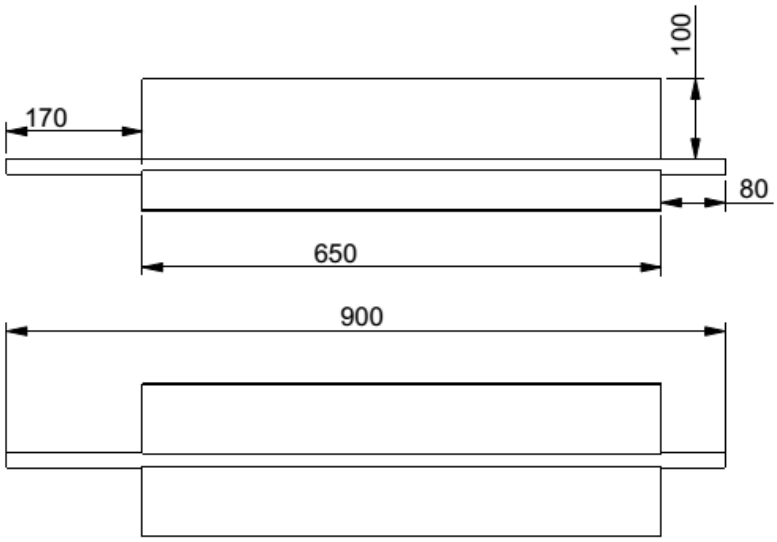


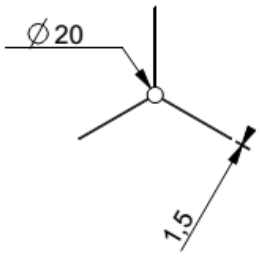
Hopper



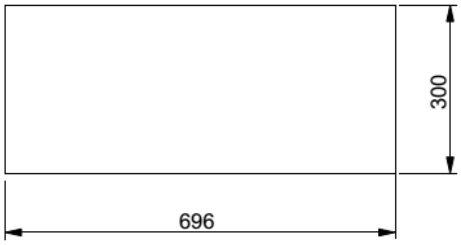
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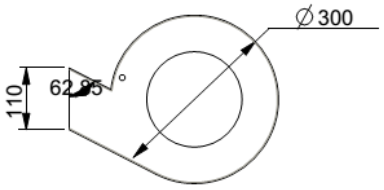
Blower Fan





Blower Casing

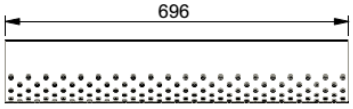


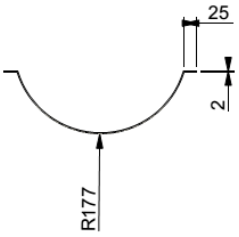


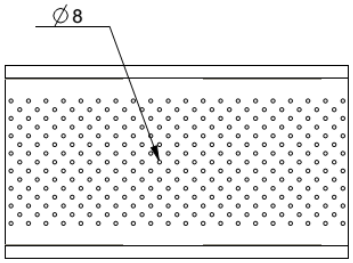


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Screen







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