DESIGN AND DEVELOPMENT OF A PULSE THRESHER OPERATED BY BULLOCKS IN ROTARY MODE

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BHUBANESWAR

2020

DESIGN AND DEVELOPMENT OF A PULSE THRESHER OPERATED BY BULLOCKS IN ROTARY MODE

A Thesis submitted to the Odisha University of Agriculture and Technology in Partial fulfillment of the Requirement for the degree of Master of Technology (Agricultural Engineering) in Farm Machinery and Power

BY

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CERTIFICATE – I

This is to certify that the thesis entitled "**Design and Development of A Pulse Thresher Operated by Bullocks in Rotary Mode**" submitted in partial fulfillment of the requirements for the award of the degree of Master of Technology (Agricultural Engineering) in Farm Machinery and Power to the Odisha University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide and original research work carried out by **Mr. Narendra Choudhary, Adm. No. – 14182A13** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

(Dr. Ajaya Kumar Dash)
CHAIRMAN
ADVISORY COMMITTEE

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CERTIFICATE - II

This is to certify that the thesis entitled "**Design and Development of A Pulse Thresher Operated by Bullocks in Rotary Mode**" submitted by **Mr. Narendra Choudhary, Adm. No. – 14182A13** to the Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of Master of Technology (Agricultural Engineering) in Farm Machinery and Power has been approved/disapproved by the students' advisory committee and the external examiner.

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ACKNOWLEDGEMENT

I wish to express my sincere gratitude to the enormous lord Jagannatha for His blessings without which nothing would have been possible. My profound gratitude goes to my Institution College of agriculture and technology, Odisha university of agriculture and technology, bhubaneswar for the opportunity given to me to further my studies.

My sincere gratitude also goes to the AICRP on UAE, CAET, OUAT ODISHA and the entire staff of the Institution for the support and courage they gave me during the program.

My major supervisor, Prof. A. K. Dash whose moral support, patience and diligence enabled me to complete this work, sir, thank you. My appreciation is also due to my co-supervisor, Prof. S. K. Swain and Dr. A. K. Mohapatra for his contribution throughout this work

My deepest gratitude to Dr. S.K. Dash, Dean, CAET, Bhubaneswar for his constant inspiration, relevant suggestion and facilities provided during the course of this research.

I would like to express my deepest sense of gratitude and obligation to Dr. D. Behera, Professor and Head, Department of FMP, CAET, Bhubaneswar and Member of my advisory committee for his valuable advice and encouragement and inspiration throughout my research work.

I am very thankful all the workshop staff who assisted me in one way or the other during the fabrication of the Pulse prototype machine.

I also acknowledge the assistance of entire staff of the department of farm machinery and power, college of agriculture and technology, bhubaneswar and also other department of Institute of his support, my friends Er Nirmalya Kumar Nath, Er. Megha Meshram, Er. Soumya Surbhi Savar, Er. Vikrant Patel, and Er Yogendra Kumar Jyoti for those support at every time in project work and life.

I am also grateful and loving thanks to my parents for his undesirable and lovely support financially and mentally, Specially my brother Dileep Choudhary in monetary support. Finally, my profound gratitude goes to my parents and my family.

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LIST OF ABBREVATIONS AND SYMBOLS

AMD	Arithmetic mean diameter
Al	Aluminium
As	Surface area
AICRP	All India Co-Ordinate research programme
CAET	College of agricultural engineering and technology
CIAE	Central institute of Agricultural Engineering
CRD	Completely randomized design
D_g	Geometric mean diameter
D_a	Arithmetic mean diameter
D_s	Square root mean diameter
D_e	Equivalent diameter
E-NAM	E-national agriculture marketing
FAO	Food and agriculture organization
GMD	Geometric mean diameter
GI	Galvanized iron
μ	Co- efficient of friction
$\boldsymbol{\theta r}$	Angle of repose
ε	Porosity
$\boldsymbol{\rho}t$	True density
$\boldsymbol{\rho}b$	Buk density
IIPR	Indian Institute of Pulse Research
ICMR	Indian Council of Medical Research
INM	Integrated Nutrient Management
KVK	Krishi Vigyan Kendra
LSD	Least significant difference
MSP	Minimum support price
MDF	Medium density fibreboard
Mc	Moisture content
R_a	Aspect ratio
R_d	Density ratio
RPM	Revolutions per minute
S_P	Sphericity
SMD	Square root mean diameter
St	Stainless steel
UAE	Utilization of Animal Energ
"	Inches
%	Percentage

₹	Rupees
°C	Degree celsius
dia	Diameter
EER	Energy expenditure rate
et al.	Et alibi
g	Gram
GI	Galvanised iron
GPS	Global positioning system
ha	Hectare
h `	Hour
l	Litre
kg-f	Kilogram force
kg	Kilogram
kcal	Kilo calories
mm	Millimetre
m	Metre
m^2	Square meter
min	Minute
PMFBPY	Pradhan Mantri Fasal Bima Yojana
V_t	Terminal velocity
V_{grain}	Volume of grain
$V_{toluene}$	Volume of toluene
W_{1000}	Test weight
WHO	World Health Organisation
W.b	Wet basis
OUAT	Orissa University of Agriculture and Technology
q/ha	Quintal per hectare
t/ha	Tonnes per hectare
viz.	Namely

ABSTRACT

Properties of crop grain or seed are very imperative in the functioning of various post harvesting operations like grading, cleaning, separating, milling and sieving etc, designing and development of many machineries like material processing and handling (transport). These properties (dependent) of green gram crop (independent) are the function of moisture content (independent). So, author tried to determine or evaluate effect of moisture content on wet basis in the range of 10.31 to 26.17%. Because of all functions like cutting, threshing and other operation performed between 10 to 30 % of moisture content. In the evaluation of effect of 5 level of moisture content on physical, frictional and aerodynamic property like length, thickness, width, aspect ratio, arithmetic mean diameter(AMD), geometric mean diameter(GMD), square mean diameter (SMD) and equivalent diameter (EQD) surface area, sphericity, test weight, true density, bulk density, density ratio, volume, porosity, angle of repose, co-efficient of friction and terminal velocity of variety (independent) of green gram were studied and presented by the researcher. The study shows that length, thickness, width, AMD, GMD, SMD, EQD, surface area, test weight, porosity, angle of repose, co-efficient of friction and terminal velocity were increase with increase of moisture content in the rage of (length: 4.42 – 4.89 mm, width: 3.13 – 3.63 mm, thickness: 3.03 – 3.47 mm, AMD: 3.41 – 3.89 mm, GMD: 3.47 – 3.96 mm, SMD: 5.66 – 6.42 mm, EQD: 4.22 – 4.79 mm, test weight: 35.51- 43.37 gm, volume: 8.12 mm^3 - 11.87 mm^3, surface area 37.83 - 49.45 mm^2. angle of repose: 29.830 - 31.500, porosity: 43.53- 45.12%, co-efficient of friction on - (stainless steel: 0.255-0.353, galvanized iron: 0.295- 0.398, wood: 0.305- 0.465, aluminium: 0.266-0.366) and terminal velocity: 7.24-7.84 ms-1 Respectively. But the true density, bulk density and density ratio decreased with increase in moisture content in the range of (true density: 1335.38- 1300.08 Kg.m-3 and bulk density: 754.08- 713.55 Kg.m-3 and density ratio: 0.57-0.55). And sphericity and aspect ratio not influence at greater level which were presented later, while ranged in (sphericity: 0.786- 0.809 and aspect ratio: 0.708- 0.746). study shows that co-efficient of friction is also the function of surface area, texture of grain and varied with material of sliding surface. And porosity of fine(heavy) texture (small sized seed) is higher than light texture (large sized seed) also finds in experiment tests. This study presented with a view of trying to show variation in properties of green gram which is dependent parameters of this study by the effect of independent parameters moisture and variety of green gram. The performance of the modified machine was evaluated using Green gram 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 3 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 55.50 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 effect 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.

Key word: Crop, Design, Moisture, Property, Researcher, Texture and Variety.

Chapter : 1

INTRODUCTION

1.1 Background of the Study

Pulses are important commodity group of crops that can play a vital role to address national food and nutritional security and also tackle environmental challenges, provide high quality protein complementing cereal proteins for pre-dominantly substantial vegetarian population of the country. Pulses form an integral part of cropping system of the farmers all over the country because they fit well in crop rotation and crop mixture as well. Pulses are the most important component of the balanced diet in vegetarian country like India.

A pulse(legume) is a plant in the family of Leguminosae, or the fruit or seed of such a plant (also called a pulse, especially in the mature, dry condition). Legumes are grown agriculturally, primarily for human consumption, for livestock forage and silage, and as soil-enhancing green manure. Well-known as pulse. Pulse produce a botanically unique type of fruit- a simple dry fruit that develops from a simple carpel and usually dehisces (opens along a seam) on two sides. Pulses are annual leguminous crops yielding between one and 12 grains or seeds of variable size, shape and colour within a pod, used for both food and feed. The term "pulses" is limited to crops harvested solely for dry grain, thereby excluding crops harvested green for food, which are classified as vegetable crops, as well as those crops used mainly for oil extraction and leguminous crops that are used exclusively for sowing purposes.

In India, pulses can be produced with a minimum use of resources and hence, it becomes less costly even than animal protein. In comparison to other vegetables, pulses are rich in protein which are less expensive and can be cultivated as an inter-crop and also as mixed crop. Pulses are mostly cultivated under rainfed conditions and do not require intensive irrigation facility and this is the reason why pulses are grown in areas left after satisfying the demand for cereals/cash crops. Even in such conditions, pulses give better returns. Apart from this, pulses possess several other qualities such as they are rich in protein, improve soil fertility and physical structure, fit in mixed/inter-cropping system, crop rotations and dry farming and provide green pods for vegetable and nutritious fodder for cattle as well. Pulses are commonly known as food legumes which are secondary to cereals in production and consumption in India. Pulses play an important source of dietary protein, energy, minerals and vitamins for the mankind. Pulses provide 20-25 per cent of protein requirements of predominantly vegetarian population. The World Health Organisation (WHO) recommends a per capita consumption of pulses at 80 gram per day and the Indian Council of Medical Research (ICMR) has recommended a minimum consumption of 47 gram. In 1968, the average consumption in India was 56 gram per person per day (Anonymous, 2004). But at present, the actual consumption however is much less at around 30-35 gram. Pulses play an important role in Indian Agriculture as they restore soil fertility by fixing atmospheric nitrogen through their nodules. Pulses are less water requiring crop and prevent soil erosion due to their deep root system and good ground coverage, because of these good characters; pulses are called as "Marvel of Nature". Pulses can also be referred to as mini fertilizer factory, as they fix atmospheric nitrogen through symbiosis. Pulses are cheaper than meat, they are often referred to as "poor man's meat" in developing countries like India.

Against the production of 19.78 million tonnes during 2013-14 (from 25.21-million-hectare area), consumption of pulses in India has been around 22-23 million tonnes. Thus, India needs to import pulses every year to fulfil the domestic demand. It is estimated that Indian population will be around 1460 million by 2030 and demand for pulses would further grow in the years to come. The production of pulse crops in India in general and especially green gram in particular is not enough to meet the domestic demand of the ever-growing population. The present productivity is far below the potential and provides substantial scope for improvement with the adoption of improved technologies. Among various other factors, application of nutrients through foliar application which increases the fertilizer use efficiency, thus increasing yield and reducing cost of production in pulses. This is considered to be an efficient and economic method of supplementing part of nutrients requirements at critical stages. Green gram contains about25 per cent protein, this being about two third of the protein content of soybean, twice that of wheat and thrice that of rice. The protein is comparatively rich in lysine, which is deficient in cereal grains. Hence, a diet combining green gram and cereal grains forms a balanced amino acid diet. Every 100 g of green gram seeds contains 132 mg calcium, 6.74 mg iron, 189 mg magnesium, 367 mg phosphorus and 124 mg potassium and vitamins like 4.8 mg ascorbic acid, 0.621 mg thiamine, 0.233 mg riboflavin, 2.251 mg niacin, 1.910 mg pantothenic acid and 114 IU vitamin A. It is also used as green manuring crop. Being a legume, it has the capacity to fix the atmospheric nitrogen (30-50 kg/ha). It also helps in preventing soil erosion in India.

Besides serving as an important source of protein for a large portion of the global population, pulses contribute to healthy soils and climate change mitigation through their nitrogen-fixing properties by builds up a mechanism to fix atmospheric nitrogen in their root nodules and thus meet their nitrogen requirements to a great extent. Pulse are notable in that most of them have symbiotic nitrogen-fixing bacteria in structures, called root nodules. For that reason, they play a key role in crop rotation.

1. Bengal Gram (Desi Chick Pea / Desi Chana),
2. Pigeon Peas (Arhar / Toor / Red Gram),
3. Green Beans (Moong Beans),
4. Chick Peas (Kabuli Chana),
5. Black Matpe (Urad / Mah / Black Gram),
6. Red Kidney Beans (Rajma),
7. Black Eyed Peas (Lobiya),
8. Lentils (Masoor),
9. White Peas (Matar) are major pulses grown and consumed in India.

Mungbean (Greengram)

Green gram is scientifically known as *Vigna radiata* and it is commonly known as *Mung or mungbean* in India, and believed to be originated from India. It is commonly known as Mung in India. It is a short duration legume crop grown mostly as a fallow crop in rotation with rice. Similar to the leguminous pulses, green gram, enriches soil nitrogen content. It is grown mostly in Asian region traditionally while its cultivation has spread to Africa and Americas relatively in the recent times. More than 70% of world's green gram production comes from India is excellent source of high-quality protein. similar to other pulses, mung is grown primarily for its protein rich seeds. Mung contains 20-25% protein. Moong is consumed as whole grains, sprouted form as well as dhal in a variety of ways in homes. Mungbam is a leguminous crop. It has the capacity to fix atmospheric nitrogen through symbiotic nitrogen fixation, being a short duration crop it make available an excellent green fodder to the animals. also used as green manuring crop.

With usual productivity of 476 kg/ha. India ranks first not only in the production, but also in consumption of pulses. *Green gram* accounts about 8-10% of total pulse *production* in the country. According to the FAO of the united nations, India is the number one producer and consumer of the pulses in the world and accounts about 25 percent of the worlds production. And more than 70% of world's green gram production comes from India.
It is grown mostly in Asian region traditionally while its cultivation has spread to Africa and Americas relatively in the recent times. Mung production in the country is largely intense in five states viz, Rajasthan, Maharashtra, Andhra Pradesh, Gujarat and Bihar. These five states together subsidize for about 70% of total Mung production in the country. As per the latest available estimates, Rajasthan, Madhya Pradesh occupies the first two positions in production, contributing over 45%. Andhra Pradesh contributes about 10% while together Gujarat and Bihar account for about 13% of total production in the country.
Nearly 8 per cent of the pulse area is occupied by green gram, which is the fourth most important pulse crop of India in terms of area cultivated and production after chick pea, pigeon pea and black gram.
India is producing 1.61mt. of green gram from an area of 3.38Mha with an average yield per hectare of 474 kg (IIPR, Kanpur 2013-14). Jharkhand accounts for production of 10.3 (000't). green gram from an area of 16.1 (000'.ha) with productivity of 637 kg per hectare Important green gram growing states in India are Rajasthan, Odisha, Andhra Pradesh, Maharashtra, Tamil Nadu, Madhya Pradesh, Gujarat, Karnataka, and Bihar among which Rajasthan occupies larger area and production (1020 thousand ha and 391.2 thousand tones, respectively). Tamil Nadu leads first in productivity with an average yield of 775 kg ha^{-1}

During 2017-18, the total coverage under mungbean has been about 41 Lha with a production of 19 Lt. There has been phenomenal increase in area of mungbean in the country from 2015-16 onwards. Rajasthan with >42 per cent area and 39 per cent of production outshined in the total mungbean contribution in the country during year report.

More than 80 per cent of mungbean production comes from 10 states of Rajasthan, Madhya Pradesh, Maharashtra, Bihar, Karnataka, TN, Gujarat, Andhra Pradesh, Odisha and Telangana (Table-2.9)

Blackgram (Vigna Mungo L.), is an important pulse crop containing 24 per cent protein and is an important part of Indian diet. The crop is resistant to adverse climatic conditions and is also a good source of fodder. Blackgram crop is mini-fertiliser factory as it restores soil fertility by fixing atmospheric nitrogen and thus producing nitrogen equivalent of around 22 kg per hectare.

Blackgram cultivation is distributed mainly in tropical to sub-tropical countries. The traditional cultivation of black gram is confined to the South-Asia and adjacent regions. The production of black gram globally is around 8.5 million tonnes, from the major producing countries such as India, Myanmar and Thailand.

India contributes nearly 70 per cent of world's production followed by Myanmar and Thailand. The major black gram exporting countries are Myanmar, Singapore, Thailand, New Zealand, Hong Kong, Sri Lanka and Pakistan. Myanmar, with annual production of 0.5 million MT, exports more than 60 per cent of its output.

The major consuming-cum-importing countries of black gram are India, China, Pakistan, Japan and Thailand. These countries import mainly from countries like Myanmar, Thailand, Singapore and Australia.

Black gram, also known as urad bean, mash and black maple is short-duration pulse crop is grown in many parts of India. India is the largest producer as well as consumer of black gram. Blackgram accounts for about 10 per cent of India's total pulse production. Blackgram is cultivated in India in about 3.24 million hectares with average productivity of at 469 kg a hectare. The production of the black gram was 1.82 million tonnes in the year 2010-11, with around 78 per cent production (1.4 million tonnes) from kharif season and 0.42 million tonnes from rabi season. The average production in India over the last decade was 1.4 million tonnes.

During 2017-18 the crop was cultivated over an area of > 5 Mha. The success of this crop was released with a harvest of about 3.5 Mt at an ever-highest yield levels of 352 kg/ha.

More than 90 per cent of urdbean production comes from 09 states of Madhya Pradesh, Rajasthan, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Maharashtra, Jharkhand, Gujarat and West Bengal.

The major producing states in India are Madhya Pradesh, Rajasthan, Uttar Pradesh, Andhra Pradesh and Bihar has the highest productivity with 800 kg a hectare followed by Uttarakhand (786 kg a ha) and West Bengal (714 kg a hectare).

The major trade centres for black gram in India are Mumbai, Jalgaon, Delhi, Guntur, Chennai, Akola, Gulbarga and Latur. Prices in India are governed by domestic production and influenced by prices in Myanmar. India being the large consumer of pulses is also largest pulses processor in the world. India imported 0.71 million tonnes black gram in 2009-10, showing a rise of 60 per cent over the previous year. India imports nearly 85 per cent of black gram requirements from Myanmar followed by Singapore and Thailand.

Health benefits of Black gram

- Best source of protein, fat and carbohydrates.
- Black gram also contains iron, folic acid, calcium, magnesium, potassium and vitamin B which are necessary for our body
- It has two types of fibres: soluble and insoluble. Insoluble fibre helps to prevent constipation and soluble fibre helps in our digestion system.
- It also helps to reduce cholesterol which ultimately improves cardiovascular health.
- High amount of magnesium and folate of Black gram support blood circulation.
- Black gram has medical properties which help to heal Rheumatic pains, stiff shoulder and contracted knee.

Usage in daily life

Main and important use of Black gram is to make Dal, even split lentil is used for same purpose. Apart from this it is also used in making Uttappa, Dosa, Idali, Vada, Dal Makhhani etc.

1.1.1 Area, Production and Productivity in India

Since ages, pulses have been well integrated into the farming system of our country as the farmers could produce them by using their own seeds and family labour without depending much on external inputs. But

With the advent of Green Revolution, which promoted rice and wheat using external inputs and modern varieties of seeds, pulses were pushed to the marginal lands. This resulted in decline in productivity and land degradation. Thus, pulses are still cultivated on the marginal and sub marginal land, predominantly under unirrigated conditions. The trend of commercialisation of agriculture has further heightened the status of pulses in the farming system.

As India is a largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. Gram is the most dominant pulse crop having a share of around 45 % in the total production followed by Tur/Arhar at 15 to 20 %, Urad/Black gram at 14 % and Moong at around 8-10 %.

1.1.2 India's status of pulse production

The total world acreage under pulses is about 85.40 (Mha) with production of 87.40 (Mt) at 1023 kg/ha yields level. India, with >29 Mha pulses cultivation area, is the largest pulse producing country in the world. It ranks first in area and production with 34 per cent and 26 per cent respectively. During 2017-18 the country's productivity at 835 kg/ha, is a significant increase over Eleventh (662 kg/ha) and Twelfth plans (745 kg/ha).

1.1.3 A giant leap in production

During 2017-18, pulses were cultivated over > 29 million ha (Mha) of area and recorded the highest ever production of 25.23 million tonnes (Mt) at a productivity level of 841 kg/ha. The exponential growth rate in production of pulses during last year was > 9 per cent.

Twelve states were the major producers contributing > 90 per cent pulses. These were

1. Madhya Pradesh (> 8 Mt),
2. Rajasthan (>3 Mt),
3. Maharashtra (>3 Mt),
4. Uttar Pradesh (>2 Mt),
5. Karnataka (2 Mt) and
6. Andhra Pradesh (>1 Mt), followed by
7. Gujarat, Jharkhand, Tamil Nadu, and Chhattisgarh producing <1.0 Mt each.

Being a largest pulse crop cultivating country, India is the largest producer and consumer of pulses in the world accounting for 32 per cent of world area and 25 % of production under food grains and contribute around 7-10 per cent of the total food grains production in the country. Though pulses are grown in both Kharif and Rabi seasons, Rabi pulses contribute more than 60 per cent of the total production.

Urad (Blackgram), the 3rd important crop group, was cultivated over an area of 5.44 Mha (kharif + rabi) and recorded a production of 3.56 Mt at a productivity level of 655 kg/ha.

This was the highest ever area, production and productivity in this crop. Major contributing states have been MP, Rajasthan, AP, UP, Tamil Nadu, Maharashtra, Jharkhand and Gujarat.

Similarly, Mung (Greengram) was sown over an area of 4.26 Mha in (kharif + rabi) and recorded a production of 2.01 Mt at and yield level of 472 kg/ha. Rajasthan, MP, Maharashtra, Karnataka, Bihar, AP, Odisha, Tamil Nadu, Gujarat and Telangana have been the major states.

1.1.4 Equilibrium Production and demand

As per the Report of the Working Group on Crop Husbandry, demand & supply projection for XII Plan (2012-17) of NITI Aayog (erstwhile Planning Commission), the demand of pulses @ 3.09 per cent per annum growth during 2016-17 and 2017-18 has been worked out at 22.74 Mt and 23.44 Mt respectively.

It was for the first time since plan-interventions on pulses that the nation inscribed a success by achieving higher pulse production at 23.13 Mt and 25.23 Mt during 2016-17 and 2017-18. The country witnessed near self-sufficiency in pulses.

1.1.5 Significant growth with additional return

During 2017-18, significant growth was registered under total pulse production, both over the base year (2014-15) and the normal/XIIth Plan (2012-13 to 2016-17) at the level of 47 per cent and 34 per cent respectively.

Major increment was recorded in kharif production i.e. 62 per cent mainly due to lion share contributed by urad (82 per cent) followed by tur (52 per cent) and mung (34 per cent).

Rabi pulses recorded a 39 per cent hike over the base year (2014-15) and was mainly contributed by gram (53 per cent) and lentil (55 per cent).

A total pulse area was increased to about 27 per cent over the period. Under seasonal increase, it was 41 per cent during kharif followed by rabi 17 per cent. Under individual crop category, major increment in area has been recorded in urad (68 per cent) followed by Mung (41 per cent), gram (28 per cent) and tur (15 per cent).

The total pulse productivity increase during the same period has been about 15 per cent over the base year (2014-15), comprising rabi and kharif increment at about 19 per cent and 15 per cent respectively.

As regards the crop-wise yield performance during 2017-18 over the period, the highest yield increments have been recorded in lentil (47 per cent) followed by tur (32 per cent), gram (20 per cent) and urd (8 per cent) over the base year (2014-15).Pulses import falls by 03 million tonnes in financial year- 2018

1.1.6 Saving of foreign currency

Despite being the largest producer, India is also the largest importer and consumer (23-24 million tonnes) of pulses in the world.

The year 2014-15 and 2015-16 were adverse crop years owing to drought and erratic behavior of rainfall across the major pulse growing states.

The government, however ensured the availability/supply as per demand by way of enhanced imports between 2014-15 to 2016-17 at about 5-6 million tonnes (Mt) per year in their buffer stock on one hand and swung in to action to combat the natural calamities through development programmes, risk management through PMFBY, PSS and PSF procurement etc., on the other.

Farmer-friendly policy measures have helped to reduce import of pulses. Import of pulses during 2017-18 has declined by about 30 lakh tonnes from previous year, resulting in saving of foreign exchange amounting to Rs 7,698 crore. It is expected that pulses production will be sustained in the country and India's import dependence on pulses will come down substantially.

1.1.7 Area, Production and Productivity in Odisha

Green gram and black gram is the major cultivating crop in odisha. The contribution of green gram to the total pulse area and production is 42% and 39% respectively. There are 46.67 lakh operational holdings in the state out of which marginal and small holdings account for 91.8%, medium 8.0% and large, less than 1% (Status of Agriculture in Odisha 2014-15). Small and marginal operational holdings dominate the agriculture sector with bullock farming system. Green gram and black gram are grown in an area of 4.26 Mha and 5.44 Mha with a production of 2.01 MT and 3.56 MT in India respectively. (Ministry of Agriculture & Farmers Welfare, Govt of India, 2018-19).

High pulse producing districts of Odisha are Ganjam, Kalahandi, Bolangir, Nayagarh, Bargarh and Cuttack (Odisha Agriculture Statistics 2013 - 14). Leading varieties of pulses cultivated in Odisha are green gram PDM-139 (Samrat), HUM-12 (Malviya Janchetna), SML-668, IPM-2-3, IPM-2-14). And black gram (PU-30, PU-31, Shekhar-2, IPU-2-43, Azad Urd). The area, production and yield of green gram of Odisha in 2013-14 are 8,57,070 ha, 4,07,990 tones and 476 Kg/ha respectively. The area, production and yield of black gram of Odisha in 2013-14 are 5,68,500 ha, 456Kg/ha and 2,59,000tones respectively. (Odisha Agriculture Statistics 2013-14).

1.1.8 Contribution of ICAR and Indian Government

In India, pulses have always received due attentions both in terms of requirement by consumers and adequate programmatic support from the government at the production front. Besides the game changing efforts under the 'Prime Minister's Krishi Sinchai Yojna' pulse production has received adequate importance. The IT initiatives in extension/apps to access market, Soil Health Cards, INM, crop advisories and E-NAM, involvement of KVKs in seed hub, additional breeder seed production, strengthening Bio-fertilizer/Bio-control production units and FPOs etc., are other specific efforts. Creation of buffer stock, imposition of stock limits and offering pulses at low cost through mobile vans including encouraging Foreign Direct Investment (FDI) in food processing etc., are the other policy interventions. Increasing pulses production has been central to agricultural policy. The Indian Institute of Pulses Research, Kanpur, is the premier organisation under the aegis of ICAR, for pulses research and capacity building. Government has provided Rs 300 crore in the present financial budget to increase the production of pulses and oilseeds, for organising 60,000 pulses and oilseed villages in rain-fed areas. As India imports significant quantity of black gram, Government regulates its flow by changing trade policy; presently black gram import does not attract any import duty.

The Government agencies such as MMTC, STC, PEC and NAFED have started importing pulses from 2007, as trade was dominated by private players. To give impetus to production the minimum support price (MSP) was increased to Rs 3,300 a quintal from Rs 2,900 a quintal in 2011-12, an increase of 13 per cent over the last year.

Pulses, as an important source of protein, have an important role in maintaining nutritional standards in India predominately being a vegetarian country. During the last decade pulses production in India has been around 13-15 million tonnes as compared to the domestic demand 18-19 million tonnes.

Although, in the recent years, the production of black gram has increased due to availability of high yielding varieties and increase in MSP, more favourable policies are needed to meet the increasing domestic demand. India needs to device long term strategy to increase black gram production by increasing acreage, research initiatives for new varieties of seeds and swift dissemination of extension services. Private participation through contract or corporate farming needs to be promoted domestically and in Myanmar and Africa to achieve self-sufficiency in pulses.

1.2 Statement of the Problem

According to Sanusi, (2016) some of the problems encountered by farmers in crop production have been the method of threshing of the crop. Most threshers in the country still operate at subsistence level. according to report of Indian govt (MINISTRY OF AGRICULTURE & FARMERS WELFARE,2016) threshing of green gram and black gram by beating with sticks or by trampling with bullocks. pulse threshing is accomplished by striking the grain with sticks or bamboo flails on the bare ground known as hand beating. 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 (Bullocks). **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 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.

One of the major problems facing the farmers in odisha is the issue of efficient pulse threshing. Conventional threshers, modified to accommodate pulse gets easily chocked up because of the stalk hardness and low grain/straw ratio. In the market there is no thresher especially for green gram and black gram. And existing threshers are not affordable by most of the farmers because of odisha state has 46.67 lakh operational holdings, out of which marginal and small holdings account for 91.8%, medium 8.0% and large, less than 1% (Status of Agriculture in Odisha 2014-15). Report shows that 91.8% of farmers are economically beaker in state so that is why.

Other problem also observed by researcher in threshing of green gram and black gram by existing threshers that is chocking and quality deceasing of grains and straw chaff. A preliminary study revealed that the 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 design and development of pulse thresher introducing stationary knives that will shred and cut the stalk in small piece to prevent the problem of chocking and improve quality of chaff for catle feeding.

1.3 Traditional methods of threshing pulse

Fig. 1.1 Traditional method: Hand beating

Fig. 1.2 Traditional method: Bullock treading

1.4 Justification

The increase in demand for nutrients and products makes pulse inevitable for efficient threshing machine to be developed since pulses are rich in nutrients. The demand for pulses is on the increase both at local and global markets to satisfy the growing feed and food processing industries. would contribute immensely to the green gram and black gram processing activities. 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 green gram and black gram those are major cultivated crop in odisha, In condition of odisha state which has 46.67 lakh operational holdings in the state out of which marginal and small holdings account for 91.8%, medium 8.0% and large, less than 1%(Status of Agriculture in Odisha 2014-15). which is major objective or problem of aim of this study, A pulse thresher utilising bullock power suitable to small and marginal farmers may substantiate economic benefits. In addition, such works would continue to aid the process of perfecting green gram and black gram thresher operated by bullock power in rotary mode for marginal and small Therefore, there is need to design the small scale thresher in addition of blades attachment with flate stud to the threshing bar so that the stalk of the green gram and black gram are easily slash and converting in small pieces to prevent chocking and easiest to animal feeding. Also, based on the limitations observed in some of the earlier research, this design and fabrication of pulse threshing machine hopes to overcome those problems stated above.

1.5 Objectives

The objectives are:

I. To design and develop a pulse thresher, operated by bullocks in rotary mode
II. To evaluate the performance of developed pulse thresher
III. To study the cost-economics of a pulse thresher

Chapter : 2

REVIEW OF LITERATURE

2.1 Introduction

Reviews are the collection of previous work done in particular field of research. Researcher attempt to develop a small-scale threshing machine for pulse (especially for green gram and black gram) operated by bullock power in rotary mode under the AICRP on UAE. For the design and development of machine prerequisite of previous work done on development of threshing machine and its result for analysis of parameters related to the design of machine parts. So, for the fulfilment of these essential obligations, effort made by researcher and collect reviews on design and development with many design parameters of machine. Also, researcher categorize reviews according to particular parameter for convenience.

2.2 Physical and Mechanical Properties of green gram and black gram

Shankar and Pandiarajan (2019) were conducted study on "Engineering properties of black gram grain at various moisture content" In this study, the effect of three levels of moisture content on engineering properties of black gram grains (Vigna mungo) were studied and presented. Properties like dimensions of grains, sphericity, surface area, bulk and true density, porosity, angle of repose and frictional coefficient. The three levels of moisture content 10.31%, 12.39% and 14.19% were taken for the study as it is safe storage levels for storing either grains or seeds. As the moisture content (w.b.%) increases, the grain dimensions like length, width, thickness were also increased linearly which ranging from 5.08 ±0.26 mm to 5.50 ±0.21 mm, 4.50 ±0.28 mm to 4.97 ±0.28 mm and 3.31 ±0.21 mm to 3.66 ±0.23 mm respectively. As the results of increase in three axial dimensions, the sphericity, surface area, arithmetic and geometric mean diameter of the grains were also increased with increasing moisture content. In contrast to the bulk density and true density, which were decreased with increase in moisture content of the grains ranging from 823 to 761 kg/m3 and 1340 to 1284 kg/m3 respectively. Increase in porosity and angle of repose were measured with increase in moisture content. Frictional properties like angle of repose and coefficient of friction were also increased when the moisture content increased from 10% to 14%. The maximum friction coefficient was observed with mild steel surface followed by plywood, aluminium sheet and rubber. also, it was varied with material to material because of the wetness and texture of the grains.

Inekwe G et al. (2019) conducted a study on "Effect of Moisture Content on Physical Properties of Mung Bean". This study investigated the effect of Moisture Content on some physical properties of Mung bean. The length, width, thickness, and geometric diameter of mung beans were determined at moisture contents of 7.29, 10.41, 14.8, 16.6 and 20.4% (dry basis). Also, all dimensions of grain increased with the increase of moisture content. For the increase of moisture contents from 7.29 to 20.40% (dry basis), the increase of length, width, thickness, volume and geometric mean diameter were 1.9, 6.2, 6.4, 11.0 and 14.0% respectively. The geometric mean diameter was lower than the length and higher than the width and thickness. The terminal velocity and angle of repose increased linearly from 4.86 to

5.29m/s, and 25.87 to 29.380, respectively. The static coefficient of friction on various surfaces increased linearly with increase in moisture content. Physical properties of mung bean vary with changes in moisture content. Length, width, thickness, volume and geometric mean diameter increased with increase in moisture content. Volume of mung bean increases linearly with increase in moisture content and bulk density of mung bean decreases with an increase in moisture content. The parameters used to indicate mung bean grain mechanical behaviour were dependent on the shell moisture content for along the axes. As moisture content increased from 7.29 to 20.40%.

Akhoon Asrar Bashir and Indore Navnath Sakharam (2018) were conducted a study on "Moisture-dependent engineering properties of SML-668 variety of green gram". Seen that seed moisture content is significant in the handling, storage and processing of seeds. This study was carried out to determine the physical properties of green gram seeds as function of seed moisture content in the moisture range of 6-24% dry basis (d.b). The average length, width, thickness, geometric mean diameter, thousand grain mass, angle of repose and water activity increase as the moisture content increased from 6 to 24% (d.b) and the sphericity was found to decrease from 0.928 to 0.625. Also, bulk density was found to decrease from 1096 to 913.34 kg m-3, whereas true density decreased from 1369.5 to 1237 kg m-3, while the porosity was found to increase from 18.09 to 30.73%. The static co-efficient of friction of green gram increased against various surfaces such as, wood, glass, GI sheet and mild steel sheet, as the moisture content increased from 6 to 24% (db.).

R. Pandiselvam (2017) were studied on "Important Engineering Properties of Green Gram (Vigna radiate)" Determiner that Engineering properties of green gram are important for designing and fabricating food processing equipment's. Physical and mechanical properties of green gram as a function of moisture content in the range of 10.86 to 22.30% (d.b) are very important in designing the storage bin. The average length, width, thickness, geometric mean diameter, sphericity, thousand grains weight and angle of repose ranged from 4.40 to 4.59 mm, 3.27 to 3.44 mm, 3.23 to 3.41 mm, 3.59 to 3.88 mm, 0.816 to 0.822, 38.60 to 46.48 g, and 32.81 to 35.49° as the moisture content increased from 10.86 to 22.30% d.b., respectively. The bulk density was found to decrease from 722.78 to 689.95 kg.m-3, whereas the true density and porosity were found to increase from 1159.04 to 1179.60 kg.m-3 and 37.64 to 41.50%, respectively. Static coefficient of friction of green gram on various surfaces, namely, card board, mild steel, galvanized iron and stainless steel also increased linearly with increase in moisture content. The card board surface offered maximum friction and stainless steel recorded minimum values.

Bakane *et al.* (2016) were conducted a study on "Physical properties of green gram split". The study revealed that physical and frictional properties of splitted green gram increased with increase in moisture content except bulk density, true density and sphericity. As the moisture content increased from 9.89% (wb) to 64.04% (wb), length increased from 4.84mm to 6.90mm, width increased from 3.49mm to 4.33mm, thickness increased from 1.88mm to 2.67mm, thousand seed mass increased from 23gm to 44.51gm, porosity increased from 43.84% to 45.19% and angle of repose increased from 22.88° to 48.84°.Whereas bulk density and true density decreased from 831.95 to 568.3kgm^{-3}, from 1481.45 to 1037kgm^{-3}, respectively.

Sharon, m. e. m. et al (2015) were conducted a study to evaluate "some moisture-dependent physical properties of black gram" and reported that grain dimensions, thousand grain mass, surface area, sphericity, bulk density, true density, porosity and angle of repose. as the moisture content increased from 8.696% to 21.951% d.b., the three axial dimensions of the black gram increased and the arithmetic and geometric mean diameter ranged from 3.736 ± 0.14 to 4.276 ± 0.14 mm and 3.797 ± 0.13 to 4.322 ± 0.13 mm respectively. the hundred grain mass of black gram were 42.52 ± 1.03 and 48.18 ± 0.45 kg. the sphericity values of black gram increased from 79.69% to 82.82%. the bulk and true densities values for black gram decreased with increase in moisture content. the porosity and angle of repose of black gram increased from 38.06 to 42.60% and 28.4 to 32.2° respectively with increase in moisture content from 8.696% to 21.951% d.b.

Gowda, N. N., Alagusundaram, K., & Abirami, C. K. (2014). were conducted a study on "Effect of Moisture Content on Physical Properties of Black Gram (Vigna mungo L.) for Designing Post Harvest Machineries" The physical properties of black gram are important in design and fabrication of structures and machineries for harvesting, handling, transporting, processing and storage, and also for quality assessment. And measured that the physical properties of black gram were studied as a function of moisture content varying from 10.31 to 25.44 % d.b. In the studied moisture range, the seed length, width, thickness, and geometric mean diameter varied from 5.16 to 5.31 mm, 4.42 to 4.85 mm, 4.25 to 4.45 mm, and 4.59 to 4.85 mm respectively. The sphericity, seed surface area, and seed volume varied from 0.891 to 0.914, 66.22 to 74.02 mm2, and 46.37 to 60.23 mm3 respectively. The bulk density and true density decreased from 815.96 to 749.37 kgm-3 and 1425.74 to 1383.11 kgm-3 respectively, while the porosity increased from 42.75 to 45.80 % with an increase in moisture content from 10.31 to 25.44 % d.b. The terminal velocity increased from 8.58 to 10.54 ms-1 and emptying angles of repose also increased from 24.80° to 29.24° with an increase in moisture content in the selected range. The coefficient of static friction of the black gram increased from 0.27 to 0.32, 0.25 to 0.30 and 0.26 to 0.28 against plywood, galvanized iron and stainless-steel surfaces respectively with an increase in moisture content from 10.31 to 25.44 % d.b.

Liny, P., Manish, S. K., & Shashikala, M. (2013). Were conducted a study on "Geometric and gravimetric characteristics of black gram" and reported that, in this experimental study, some raw material characteristics were determined for the blackgram to get the idea for proper equipment design. The engineering properties of black grams such as axial dimensions, sphericity, surface area, bulk density, true density, porosity and volume are useful in design and construction of the processing and handling equipment's, drying, storing, sorting units and transporting. The average values of physical properties of black gram length, width, thickness, unit mass and volume were determined at a moisture content of 11.11% (dry basis) were 3.53 mm, 2.22 mm, 2.29 mm, 0.0406 g, and 9.56mm3 respectively. The calculated physical properties like arithmetic mean diameter , geometric mean diameter, equivalent mean diameter, surface area, aspect ratio, sphericity, true density, bulk density and porosity were found to be 2.679mm, 2.612 mm, 4.24mm, 21.591 mm2 ,65.606%, 74.35%, 1335kg/m3 ,805.1kg/m3 and 39. 697 % respectively.

Pham Tri Thonga (2010) Were conducted a study on "Physical properties of green bean (Vigna radiata L.)". at Nong Lam University, Thu Duc District, Ho Chi Minh City, Vietnam. These study shows that Determination of physical properties of green bean (mung bean) is important in the design of planting, harvesting, post harvesting, and processing machines and equipment. Some physical properties of green bean were evaluated as a function of moisture content. Studies on rewetted seed showed that the average length, width, thickness, the geometric mean diameter and the sphericity varied from 5.28 to 5.5, 4.14 to 4.31, 4 to 4.18, 4.44 to 4.63 mm, and 84.1 to 84.18%, respectively with an increase in moisture content from 10.08% to 15.22% wb. In the same moisture content range considered, the bulk density and solid density decreased from 0.88 to 0.81, 1.3686 to1.3429 gcm-3, respectively while the porosity increased from 35.86 to 39.75%. The thousand seed mass increased from 68.34 to 73.36 g, and the angle of repose from 27.9 to 30.1o, within the moisture range studied. The coefficient of friction of green bean increased linearly against surfaces of four structural materials, namely stainless steel (0.2237–0.27), galvanized iron (0.2743–0.3565), wood (0.2844–0.377), and aluminum (0.3339–0.3904) with increasing moisture content.

Sawant, B. P., Sawant, S. A., & Munde, P. A. (2009). Evaluated "the Effect of moisture content on selected physical properties of pulses" and reported that physical properties like true density, bulk density, porosity per cent and angle of repose were estimated at different moisture levels [10, 15, 20, 25 and 30 per cent (w.b.)] with an accuracy of ± 0.5 per cent in each level, with standard procedures. From the study it is concluded that the true density and bulk density decreases and the porosity per cent and angle of repose increases with increase in the moisture levels. The true density was observed highest in the Bengal gram (1415.09 kg/m3) at 10 ± 0.5 per cent (w.b.) moisture level and lowest in Green gram (1229.52 kg/m3) at 30 ± 0.5 moisture level. The bulk density was found highest in Pigeon pea (875.00 kg/m3) at 10 ± 0.5 per cent (w.b.) and lowest in Black gram (669.00 kg/m3) at 30 ± 0.5 per cent (w.b.) moisture content. The highest porosity per cent (47.59 per cent) was observed in Black gram at 30 ± 0.5 per cent (w.b.) and lowest in Pigeon pea (35.91 per cent) at 10 ± 0.5 per cent (w.b.) moisture levels. The angle of repose increased with increase in moisture levels. The highest angle of repose (41.980) was found in Bengal gram at 30 ± 0.5 per cent (w.b.) and lowest in Pigeon pea (30.110) at 10 ± 0.5 per cent (w.b.) moisture contents.

El Fawal, Y. A., Tawfik, M. A., & El Shal, A. M. (2009). Evaluated "Study on physical and engineering properties for grains of some field crops" Study aimed to determine and recognize a database of physical and engineering properties of grains of some main and popular feed, industrial crops which play an important role in designing and developing of specific machines and their operations such as planting, harvesting and grading .The studied crops namely fennel flower, rice (Giza101), rice (Giza 177), broad bean, corn (hyb. 310), corn (hyb. 352), wheat (Giza9) and wheat (Giza 168) and their selection based on their recent coverage area and the expected future expansion of each variety. Various physical properties including grain dimensions (length, width and thickness), the weight of thousand grain, bulk density, percent of sphericity, projected area , and the mechanical properties including angle of repose and coefficient of friction, in addition to the aerodynamic properties including terminal velocity, drag coefficient and Reynold's number, were determined at storage moisture content 7–12%(wb).The obtained data showed that it is recommended to use the stainless steel or galvanized iron in manufacturing of seed hopper used in planting machines, silos and storage containers with sides inclination of 40º to allow an easily sliding for the studied grains.. The physical properties of seed play an important role to select the proper separating and cleaning equipment and the main dimensions are considered in selecting and designing the suitable size of the screen perforations. Also, the average terminal velocities of grains were 4.17, 7.32, 7.02, 20.16, 15.34, 14.69, 8.00 and 7.58 m/s for fennel flower, rice (Giza101), rice (Giza 177), broad bean, corn (hyb. 310), corn (hyb. 352), wheat (Giza9) and wheat (Giza 168) respectively. Reynold's number of the terminal velocities of the studied grains exceeds the critical velocity of Reynold's number (RN=2100) in the range of turbulent flow except the fennel flower seeds.

Unal, H., Isık, E., Izli, N., &Tekin, Y. (2008). Were conducted a study on "Geometric and mechanical properties of mung bean (vigna radiata l.) grain: effect of moisture". And selected geometric and mechanical properties of mung bean grain were evaluated as a function of moisture content. Five levels of moisture content ranging from 7.28 to 17.77% d.b. (dry basis) were used. The average length, width, thickness, arithmetic and geometric mean diameters, sphericity, thousand grain mass and angle of repose ranged from 5.145 to 6.199 mm, 3.760 to 4.474 mm, 3.537 to 4.223 mm, 4.147 to 4.965 mm, 4.090 to 4.893 mm, 0.795 to 0.789, 52.3 to 64.6 g, and 25.87 to 29.38° as the moisture content increased from 7.28 to 17.77% d.b., respectively. The bulk density was found to be decreased from 821.3 to 745.2 kg/m3, whereas the grain volume, true density, porosity, terminal velocity, and projected area were found to be increased from 27.88 to 47.33 mm3, 1230.0 to 1456.7 kg/m3, 30.43 to 46.57%, 4.86 to 5.29 m/s, and 17.48 to 19.26 mm2, respectively. There is a 43% increase in surface area from grain moisture content of 7.28 to 17.77% d.b. The static coefficient of friction on various surfaces increased linearly with the increase in moisture content. The rubber as a surface for sliding offered the maximum friction followed by galvanised iron, medium density fibreboard, stainless steel, aluminium and glass sheet. As moisture content increased from 7.28 to 17.77%, the rupture forces values ranged from 67.39 to 39.44 N; 63.86 to 42.18 N, and 53.96 to 41.79 N for thickness (Z axis), length (Y-axis) and width (X-axis), respectively.

Isik, E. (2007). Measured patameters on "Some Engineering Properties of Soybean Grains" and reported that Engineering Properties as a function of moisture content in the range of 10.62-27.06% dry basis (d.b.). The average length, width and thickness were 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 6.369 to 8.048 mm 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 soybean 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 kg m^{-3}, the porosity from 40.36 to 54.16% and the terminal velocity from 8.01 to 9.1 m s^{-1}. The bulk density decreased from 650 to 550 kg m^{-3} with an increase in the moisture content range of 10.62-27.06% d.b. The static coefficient of friction of soybean grains increased the 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 MDF (medium density fiberboard) (0.2126-0.2679) as the moisture content increased from 10.62-27.06%.

Amin, M. N., Hossain, M. A., & Roy, K. C. (2004) Studied on "Effects of moisture content on some physical properties of lentil seeds "This study was carried out to determine the effect of moisture content on some physical properties of lentil seeds. Four levels of moisture content ranging from 10.33% to 21.00% (wet basis) were considered in this study. The shape of the lentil seed was a disc shape with dimensions of diameter and thickness. Diameter, thickness, porosity, mass of 1000 seeds and angle of repose increased linearly from 3.84 to 4.06 mm, 2.18 to 2.48 mm, 34.48 to 37.00%, 20 to 25.5 g and 24.80 to 27.78°, respectively with increase in moisture content from 10.33% to 21.00%. Bulk density and kernel density decreased linearly from 832 to 768 kg/m3and 1270 to 1212kg/m3, respectively with increase in moisture content from 10.33% to 21.00%. Static and kinetic coefficients of friction of lentil seeds were determined on a smooth concrete, galvanized iron, plywood and glass sheets at various moisture contents. They varied from material to material and depended on the roughness and wetness of the seeds. The highest static and kinetic coefficients of friction were found on the concrete surface and the lowest on the glass sheet among the materials tested.

Chowdhury, M. M. I., Sarker, R. I., Bala, B. K., & Hossain, M. A. (2001) study was carried out on "Physical properties of gram as a function of moisture content" and determine the effect of moisture content on some physical properties of gram. Six levels of moisture content ranging from 10.83 to 31.20 percent (dry basis) were considered for this study. Length, width, thickness, diameter of equivalent sphere, mass of 1000 grains and porosity increased linearly from 7.968 to 8.758 mm, 5.864 to 6.554 mm, 5.713 to 6.359 mm, 6.770 to 8.795 mm, 137.97 to 172.73 g, and 33.17 to 35.85% respectively with the increase of moisture content from 10.83 to 31.20%. The angle of repose increased from 27.03 to 33.27° with the increase of moisture content. Bulk density and true density decreased linearly from 787.31 kg/m^3 to 712.61 kg/m^3 and 1398 kg/m^3 to 1250 kg/m^3, respectively. Static coefficient of friction was determined over plywood, galvanized steel, celluloid sheet, and glass sheet. Static coefficient of friction varied from material to material and depended on the roughness and wetness of the true. The highest coefficient of static friction was found over plywood and lowest for glass sheet among the materials tested.

Nimkar, P. M., & Chattopadhyay, P. K. (2001). Measured on "some physical properties of green gram" and Various physical properties of green gram were evaluated as a function of moisture content in the range of 8·39 to 33·40% d.b. The average length, width, thickness and thousand grain mass were 4·21 mm, 3·17 mm, 3·08 mm and 28·19 g at moisture content of 8·39% d.b. The geometric mean diameter increased from 3·45 to 3·77 mm, whereas sphericity decreased from 0·840 to 0·815. Studies on rewetted grains showed that the bulk and true densities decreased from 807 to 708 and 1363 to 1292 kg m^{-3}, whereas the corresponding bulk porosity increased from 40·77 to 45·16%. The terminal velocity increased from 10·1 to 12·1m s^{-1}. The static coefficient of friction varied from 0·344 to 0·625 over different material surfaces, while angle of repose varied from 26·6 to 31° within the studied moisture range.

Chowdhury, M. M. I., Sarker, R. I., Bala, B. K., & Hossain, M. A. (2001) were conducted a study on "Physical properties of gram as a function of moisture content". At Bangladesh This study was carried out to determine the effect of moisture content on some physical properties of gram. Six levels of moisture content ranging from 10.83 to 31.20 percent (dry basis) were considered for this study. Length, width, thickness, diameter of equivalent sphere, mass of 1000 grains and porosity increased linearly from 7.968 to 8.758mm, 5.864 to 6.554mm, 5.713 to 6.359mm, 6.770 to 8.795mm, 137.97 to 172.73g, and 33.17 to 35.85% respectively with the increase of moisture content from 10.83 to 31.20%. The angle of repose increased from 27.03 to 33.27 with the increase of moisture content. Bulk density and true density decreased linearly from 787.31kgm^3 to 712.61kg.m^3 and 1398kg=m3 to 1250kg=m3, respectively. Static coefficient of friction was determined over plywood, galvanized steel, celluloid sheet, and glass sheet. Static coefficient of friction varied from material to material and depended on the roughness and wetness of the true. The highest coefficient of static friction was found over plywood and lowest for glass sheet among the materials tested.

Dutta, S. K., Nema, V. K., & Bhardwaj, R. K. (1988). Evaluate the "Physical properties of gram" and accomplish that the dependence of physical properties of gram on moisture content was determined. The best approximate shape was found to be a prolate spheroid. At 10·9% moisture content d.b., the measurements yielded an average 1000 grain weight of 0·173 kg, a mean surface area of 133·4 mm^2, and sphericity and roundness of 74% and 70% respectively. In the moisture range from 9·64 to 31·0% d.b., studies on rewetted gram showed that the bulk density changed from 780 to 708 kg/m^3, kernel density from 1311 to 1257 kg/m^3; porosity from 40·5 to 43·7% and static coefficient of friction from 0·384 to 0·651 over surfaces of different materials. The angle of repose was observed to change from 25·5° to 30·4° in the moisture range from 8·62 to 17·6% d.b.

Kanawade *et al*. (1990) determined the particle density, bulk density, porosity and angle of repose of pigeonpea, chickpea, cowpea, pea, green gram (vigna radiata) black gram (V. Mungo), soyabean and moth bean (vigna aeonitifolial) seeds at 5 moisture levels. Results indicated that bulk density of all seeds decreased with increasing moisture content. The relationship between the moisture content and bulk density was found curvilinear.

H. Kibar *et. al* Performed the physical and mechanical properties of soybean. In this moisture range, grain length, width, thickness, arithmetic average diameter and geometric average diameter increased from 7.24 to 8.19, 6.79-7.12, 5.78-6.23, 6.60-7.18, 6.57-7.14 mm, respectively. The volume of grain and area of grain surface increased linearly from 130.97 to 160.32 and from 125.46 to 144.39 mm2, respectively. The spericity, bulk density, true density and porosity decreased linearly from 0.91 to 0.87, 766.12-719.00, 983.33-905.67 kg m-3 and 22.58 to 20.61%, respectively. The angle of internal friction increased linearly from 27.37 to 31.81 with the increase of moisture content. The static coefficient of friction increased from 0.385 to 0.571, 0.304-0.441 and 0.164-0.286 for concrete, wood and galvanized steel surfaces, respectively.

2.3 Research and Development efforts for thresher

2.3.1 Effect of Threshing Element on Threshing Performance

Tiwari *et al. (*2018) reviewed on “Power threshers for effective threshing of crops since green revolution - a review”. review showed that for higher threshing efficiency, fine straw quality and minimum specific power consumption, rectangular spiked threshing cylinder of 600mm tip diameter and spike thickness of 6mm have given best performance results with total grain loss within permissible limit. The spike thickness of 6mm had minimum broken grain loss with fine straw quality. The round spiked (plain spike) threshing cylinder with same configuration of threshing cylinder showed best results. But from mass manufacturing point of view, tip diameter of 600mm and 8mm round spike thickness will be appropriate for manufacturers.

Saha B. K., & Mandal S. K. (2018). Studied on “Design of Innovative Pulse Thresher” and reported that, in manual pulse thresher, input rotary motion is converted into reciprocating motion of beaters. Due to indefinite swing angle of beaters usual four bar linkage cannot be used for this purpose. In this proposed investigation, a novel mechanism has been designed to overcome the problem of indefinite swing angle as is necessary for meaningful operation of manual pulse thresher. Here, Grash of mechanism has been modified to generate the desired kinematics. At first, particular four bar linkage satisfying Grash-off’s criteria has been designed considering definite swing angle of beaters, followed by a suitably designed slot has been incorporated into the coupler design to obtain indefinite swing angle. This modified linkage mechanism has been tested successfully to generate variable (may vary even on every cycle) swinging of beaters while taking rotary motion as input

Surendra khuntia *et al.* (2017) Combined threshing & crushing actions are executed by multiple progressive shears between a set of radial rotary beaters and a stationary beater inside a vertical hopper. The crops flow vertically downwards into shear zones by scissoring actions of the beaters and gravity. Therefore, power consumption is reduced drastically and this machine is operated by 2.0 hp single phase electric motor for threshing of 150 to 250 kg seeds or 400 to 500 kg dry crops per hour. Winnowing of seeds is carried out by a winnower-cum-grader which can be attached to the thresher during need. The principle of threshing in the vertical flow Pulse thresher is completely different than any other threshers developed so far in the world. The pulse thresher comprises a set of simple moving beater, a fixed beater and a cylindrical hopper. Primarily combination of these three components executes threshing and crushing operations of different pulses without adjusting any parts or parameters. A number of flat plates welded symmetrically and radially on a circular disc constitute the moving beater or moving blade. The moving beater is fixed at one end of a shaft which is mounted vertically on the chassis of the machine through a set of bearings. The fixed beater is rigidly fixed inside the cylindrical hopper. The hopper with fixed beater is mounted vertically on the chassis over the moving beater, and all these three parts have a single vertical axis.

Abdullahi Saeed Hassan (2016). Studied on “Modification and performance evaluation of an improved soyabean thresher” 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 undependable variables - cylinder speed, feed rate, and concave clearance have a significant effect 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.

Oduma *et at.* (2014) conducted a study on “Performance evaluation of a locally developed pigeon pea thresher”. Study showed that the threshing was done by the rotating shaft (dia 30mm) through the impact of the beaters (spikes) on the pigeon pea pods against stationary spikes with cylinder clearance of 25mm and the size of the screen holes of 12.6mm diameter. The best working condition was found at a cylinder speed (600rpm) and feed-rate of 2kg/min or 3kg/min. The thresher had high threshing efficiencies of 99.95% and 99.99% respectively, with average percentage seed losses through the chaff outlet of 0.22% and 0.08% respectively and minimum losses of 0.02% through the cylinder. The cleaning efficiency of the thresher at this speed under the two different feed-rates were observed to be 97.65% for feed rate of 2kg/min and 96.36% for 3kg/min. the average seed damages at these feed rates were found to be 0.2% respectively of crop.

Erkut Peksen et al. (2013) designed and manufactured a stationary chickpea threshing unit and evaluated with three different beater types (spike-tooth, lama tooth and wire loop, two different types of concave (manufactured from PVC and chrome), five peripheral speeds (19.0, 14.5, 12.5, 10.5 and 8.0 ms-1), five concave clearances (15, 20, 25, 30 and 35 mm) and four feeding rates (360, 540, 720 and 900 kgh-1) and concluded that the wire loop was the best one among all beaters for threshing due to minimal seed breakage, lowest invisible injury of the seeds accompanied with high field emergence and highest threshing efficiency. Any of PVC and chrome concave can be recommended for use in the threshing unit as these were not different from each other in their performance.

Yadav (2007), conducted study on design refinement of thresher for soybean seed purpose. Refinements incorporated in the spike tooth type thresher design have been highlighted in the report for soybean seed purpose.

Yadav (2004) conducted comparative test of three different type of threshers namely spike tooth round bar type cylinder, spike tooth flat beater type and rasp bar type threshing cylinder on soybean variety JS 335. He reported the performance of round bar type thresher was superior as compared to other designs in terms of seed damage and germination of seed. Scope of design refinement of machine components was suggested in the paper.

Vejasit, A., & Salokhe, V. (2004). Studies on "machine-crop parameters of an axial flow thresher for threshing soybean" and reported that, effect of machine-crop variables on the performance, a threshing unit was fabricated and tested. The same threshing unit will be used for the proposed axial flow soybean combine harvester. A peg tooth drum was used for the study. Four levels of drum speeds, three levels of feed rates and three levels of soybean moisture contents were studied. Test results indicated that the threshing efficiency varied from 98 to 100%. The grain damage and grain loss were less than 1 and 1.5% respectively at drum speeds of 600 to 700. The best combination of feed rate, drum speed at 14.34% (w.b.) seed moisture content to obtain higher output capacity, threshing efficiency, lower grain damage and grain losses was 600 to 700 rpm drum speed (13.2 to 15.4 m/s) at a feed rate of 720 kg (plant)/h. It was observed that the power requirement of the threshing unit increased as the speed of threshing drum, feed rate and crop moisture content were increased. These increases were due to greater compression of the material and increased friction between crop material and threshing system. The average power requirement at 540 to 720 kg (plant)/h feed rates at 14.34% (w.b.) grain moisture content was between 0.89 to 1.85 kW, when the drum speed was increased from 500 to 700 rpm (11.00 to 15.40 m/s). However, it was observed that the maximum power required was 2.29 kW at grain moisture content of 32.88% and at the drum speed of 700 rpm. The best combination of feed rate, drum speed at 14.34% (w.b.) seed moisture content to obtain higher output capacity, threshing efficiency, lower grain damage and grain losses was 600 to 700 rpm drum speed (13.2 to 15.4 m/s) at a feed rate of 720 kg (plant)/h.

Vejasit (1991) compared the performance of the rasp bar 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.

Banga et al. (1984) studied the spikes tooth threshing system for wheat crop. The studies revealed that:

- Increased cross-sectional area of spikes increased grain crackage and power consumption and produced fine straw;
- Longer spikes reduced grain crack age;
- Less number of spikes in rows consumed more power due to more retention time and caused less grain damage and poor-quality straw and
- More number of spikes consumed more power due to higher impact forces.
  They were also reported that the performance of flat spikes were better over round and square shaped spikes. It was due to fine quality of straw with minimum specific power requirement.

Kaul and Kumar (1975) reported that spike tooth cylinder type of machine is more popular in India due to their compact design, less energy requirement and less grain damage. However, the performance of these threshers varies considerably in terms of energy consumption, grain out and grain loss.

Pathak (1970) reported that hammer mill type threshers bruised the straw very fine but the specific energy requirement was highest among all types of threshers.

2.3.2 Study of factors affecting of Threshing Performance

Threshing of green gram and black gram 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).

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:

- 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.
- 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.
- Choudhury and Kaul (1979) noted that 6-8 % of grains being manually winnowed is lost in the chaff.

Factors Affecting Efficiency of Threshing Operation

The factors affecting the thresher performance were classified into three groups

- Crop factors – Variety of crop – Moisture content of crop
- Machine factors – Feeding chute angle – Cylinder type and diameter – Spike shape, size and number – Concave size, shape and clearance

- operational factors – Cylinder speed – Feed rate – method of feeding – Machine adjustment

Tiwari, R. K., & Chauhan, S. K. (2018). Investigated "Investigations on effect of cylinder configuration of rectangular spiked tooth thresher on threshing performance of wheat crop" Investigation was taken for manufacturing of threshing cylinders with different configuration and their testing for standardization. The threshing cylinder of rectangular spike of 6 mm thickness and 600 mm tip diameter yielded maximum output capacity (372 kg/h) with minimum specific power consumption (0.971 kWh/q) at maximum feed rate ((780 kg/h). The maximum threshing efficiency (99.91%) and minimum wheat straw length (21 mm) was obtained corresponding to the same configuration and feed rate. The minimum broken grain (0.20%) and total loss (0.43%) were at tip diameter of 500 mm and spike thickness of 6 mm corresponding to maximum feed rate (780 kg/h). The output capacity was above 300 kg/h at maximum feed rate (780 kg/h) for all the tip diameter and spike thickness. The maximum wheat straw split (88.60%) was at 780 kg/h feed rate corresponding to tip diameter of 550 mm and spike thickness of 6 mm. The maximum cleaning efficiency (99.52%) was at maximum feed rate (780 kg/h) corresponding to tip diameter of 550 mm and spike thickness of 6 mm. The wheat straw size for maximum output capacity and threshing efficiency were 22.43 mm at tip diameter of 600 mm and spike thickness of 6 mm corresponding to maximum feed rate (780 kg/h). For higher threshing efficiency, fine straw quality and minimum specific power consumption, rectangular spiked threshing cylinder of 600 mm tip diameter and spike thickness of 6 mm gave best performance results with total grain loss within permissible limit.

S. Khuntia and J. S. Murty (2017) conducted a study on "Design and Development of Vertical Flow Semi-Automatic Pulse Thresher" and reported that Design and Development of Automatic Vertical Flow Pulse Thresher Suitable for Different Pulses Semi-automatic and power operated vertical flow pulse thresher-cum-winnower was developed by the author for efficient threshing and winnowing of matured crops of a variety of pulses having diverse physical characteristics, wherein threshing and winnowing operations were carried out separately. Therefore, it was upgraded to a compact, hybrid and fully automatic pulse thresher-cum-winnower by the author1 to overcome power constraints in villages as well as to obtain combined operations of threshing, crushing and winnowing together. Feeding of dry crop into thresher is manual, while rest of operations are automatic without human touch. Significant features are >99% threshing and winnowing efficiency, almost nil seed loss and seed breakage, crushing all crop residues into powdery animal fodder, dust free cleaning of seeds, and by 3 hp prime mover either oil engine with simplest clutch arrangement and/or with single phase electric motor. Threshing and crushing actions are executed by multiple progressive shears and impacts through a set of radial rotary beater and stationary beater inside a vertical hopper, like in semi-automatic pulse thresher. The crops flow vertically downwards into shear zones by scissoring actions of the beaters and gravity. Seeds are separated and cleaned by an improved winnower-cum-grader, and the crushed crop residues are disposed from the machine by a combined mechanism of walker and flat air jet.

Timothy Adesoye Adekanye (2016) conducted a study on “Evaluation of a soybean threshing machine for small scale farmers”. Evaluation was carried out with TGX 1448 soybean variety at different levels of moisture contents; 10%, 16% and 22% (wet basis) and at different drum speeds; 320 rpm, 385 rpm, 450 rpm, 515 rpm, with constant mass input of 600g and constant concave clearance of 23 mm. Evaluation results indicated that the threshing efficiency was 98.96% to 99.88% for the range of the variable of speed between 320 rpm to 515 rpm and 99.73% to 99.29% for the range of the variable of moisture content level from 10% to 22% (wet basis). The cleaning efficiency decreases (90.81% to 64.25%) as the speed increases (320 rpm into 515 rpm), at moisture contents of 10% and 22% (wet basis). These trend shows that the effect of speed on the threshing efficiency was due to the high impact of the threshing drum on the soybean due to the increase in speed. Also threshing efficiency gradually increases as the speed increases. it was observed that threshing efficiency gradually reduces as the moisture content increases irrespective of the increase in speed. This is an indication that at higher moisture content, pod cohesion will be low. Threshing efficiency was highest (99.98%) at 515 rpm and moisture content 10% (w.b) respectively due to high impact and high pod cohesion force.

Kumar Deves et al (2016). Performance Evaluation of Power Thresher for Wheat Crop. Studied the effect of front to rear clearance ratios of 3:1 to 1:1 and found very little difference in cylinder loss, visible damage and germination of wheat for any given mean clearance. Front to rear clearance convergence is generally desirable because the wider front opening tends to improve the feeding characteristics of cylinder. He also reported that increasing concave length increased separation of grain. Based on the design and operational parameters for a Wheat thresher Johnson (1959) a prototype. Thresher was modified, developed and evaluated. The thresher was evaluated at three different levels each of cylinder concave clearance (10, 20, 30 mm), seed moisture content (12.5, 14.0. 17.0%), two levels of cylinder speed (580,600 rpm peripheral speed 4.2m/s and 4.4m/s), and feed rate 10kg/hr of dried wheat. Performance parameters for the study were threshing efficiency, cleaning efficiency, total loss of seed and germination. The test results indicated a maximum of 97% threshing efficiency and 97.7% cleaning efficiency, a minimum of 3.3% total seed loss and a maximum germination of 85%. The average output capacity of machine was 6.3kg/hr of seed.

Abhishek Pandey and Stevens, R. M.(2016) Evaluated “Performance evaluation of high capacity multi crop thresher on 'gram' crop” The present study was undertaken on high capacity multicrop thresher for threshing gram crop at three different speeds of 550 rpm, 600 rpm and 650 rpm at corresponding feed rate of 16 q/h, 18 q/h, 20 q/h. Performance of the experimental thresher was evaluated with respect to threshing efficiency, cleaning efficiency, grain loss, grain breakage and the output capacity. In threshing gram, the maximum threshing efficiency was found to be 98.98 per cent at cylinder speed of 600 rpm and feed rate 20 q/h. Similarly cleaning efficiency was found 97.30 per cent at cylinder speed of 600 rpm and feed rate 20 q/h while the maximum total grain loss was found 3.3 per cent at cylinder speed 550 rpm and maximum feed rate 20 q/h. The grain breakage was found 1.70 per cent at cylinder speed of 650 rpm and feed rate 20 q/h. The output capacity was found 9.62 q/h at cylinder speed of 600 rpm and feed rate 20 q/h. The net saving with multicrop thresher in threshing cost compared to traditional threshing method was found to be 31 per cent for gram crop.

Timothy Adesoye Adekanye et al. (2016) designed, fabricated and evaluated a soybean threshing machine which consisted mainly of the feeding assembly, the threshing unit, fan assembly and power transmission unit. The thresher was evaluated at different moisture contents (10, 16 and 22 per cent wet basis) and at different drum speeds (320, 385, 450 and 515 rpm) with constant mass input of 600g and constant concave clearance of 23 mm. The performance evaluation revealed the following:

- The evaluation results indicated threshing efficiency of 98.96 to 99.88 per cent for the range of the variable of drum speed between 320 to 515 rpm and 99.73 to 99.29 per cent for the range of the variable of moisture content of 10 - 22 per cent (wet basis). The cleaning efficiency decreased (90.81 to 64.25 per cent) as the speed increased (320 to 515 rpm), at moisture contents of 10 and 22 per cent (wet basis).
- The threshing efficiency tend to increase with the increase in drum speed and decrease with the increase in moisture content while cleaning efficiency increase as the cylinder speed decrease and as the moisture content.
- High moisture content and low cylinder speed tend to reduce the percentage of damage seed, blown seed and seed loss respectively while low moisture content and high speed tends to increase the percentage of damage seed, blown seed and seed loss respectively. Moisture content state and impact on grain during threshing are paramount in determining crop mechanical damage (Allen and Watts, 1997; Dauda, 2001).
- The efficiency of the soybean threshing machine is significantly affected by the dependent variables viz., cylinder speed and moisture content.
- Spike tooth threshing drum tends to produce high threshing efficiency as seen from the results obtained (99.51 per cent) which compares well with the report by Peksen et al. (2013) for comparison of different beaters and concave for threshing chickpea.

Ajayi et al. (2014) investigated "the comparative quality and performance analysis of manual and motorized traditional portable rice threshers" and stated that the threshing effectiveness results from the combination of the factors viz., the peripheral speed of the threshing cylinder, cylinder concave clearance, and number of rows of concave teeth used with a spike tooth cylinder and the varieties of rice. The optimized value of 500 rpm of threshing cylinder speed resulted in time saving, reduction in percentage seed loss and percentage mechanical damage. The cost of operation is also reduced and the quality of produced rice is enhanced.

Bansal, N. K., & Lahan, S. K. (2009). were Evaluated the "Design and Development of an Axial Flow Thresher for Seed Crops" Based on the performance results, the optimum combination of cylinder speed and concave clearance at different seed moisture contents shows that, The maximum threshing efficiency of 99.43, 99.60, 99.40. 99.20, and 98.90% for threshing of green gram, black gram, soybean, chickpea and sunflower crop were Observed at higher cylinder speed (9.5 m/s), lower concave clearance (15 mm) and lower seed moisture content (10 w.b.). It was due to more impact and rubbing force delivered at higher cylinder speed. The threshing efficiency reduced with increase of concave clearance, which may be due to the reason that at higher concave clearance, the resistance of pods to the cylinder decreased and as a result the impact force and frictional force decreased. The threshing efficiency was within limits prescribed in BIS standards at slow drum speed (8.2 m/s) without adverse effect on seed quality. The seed germination and seed vigour were within limits of seed standards. It was observed that the cylinder speed was directly related to cleaning efficiency, which indicated that the cleaning efficiency increased with the increase in cylinder speed at all seed moisture contents and concave clearances. The maximum cleaning efficiencies of 93.20, 90.20, 90.20, 99.56 and 92.50% were observed in threshing of green gram, black gram, soybean, chickpea and sunflower crop at higher cylinder speed (9.5 m/s), lower concave clearance (15 mm) and lower seed moisture content (10 w.b.). At the lower seed moisture content, the pods were dried and the terminal velocity of straw was much lower than the seed. Thus, it was easy to separate the straw from seeds, making cleaning better.

Sinha et al. (2009) investigated the effect of moisture content, concave clearance and cylinder speed on visible injury, internal injury, germination percentage and threshing efficiency of chickpea seed crop with Three levels of moisture content (8, 10 and 12 per cent), three levels of cylinder peripheral speed (8.05, 8.94 and 13.42 ms-1), three levels of concave clearance (12, 14 and 16 mm) and two cultivars namely BG -1088 and BG -1103. The result showed that the cylinder speed is the most critical factor of affecting visible and internal injury extent. Moisture content adversely affected the internal injury levels in threshed seed. The cylinder speed of 8.94 ms^{-1}, concave clearance of 14 mm and moisture content at 10 per cent yielded the seed of optimum quality with minimal visible and internal injury, and optimum threshing efficiency.

Radwan et al. (2009) developed and evaluated a tangential flow caraway crop thresher with four levels of rotor speeds (500, 560, 630, and 700 rpm), three levels of moisture contents (10.36, 11.84 and 13.72 per cent, and three levels of air speeds on sieves (4.8, 5.7 and 6.8 ms-1), fixed hole diameter of sieves was 3 mm, feed rate was 540 kg h-1 and concave clearance was 15 mm. They obtained that the local threshing machine can be successfully used under the seed moisture content of 11.84 per cent, drum speed of 500 rpm and air speed of 4.8 ms-1 resulting seed losses of 2.2 per cent, threshing efficiency of 73.7 per cent, and criterion energy consumed 29.04 kW. $Hton^{-1}$.

Yadav, Singh and Udhaya Kumar (2008) reported the findings of the study on thresher development for soybean seed purpose. The findings of the study included the thresher test, and design data for soybean variety JS 335 during threshing at low moisture regime between 5.00-13.00 per cent moisture. They optimized the design parameters for soybean threshing and reported peripheral speed, concave clearance, rib spacing, crop feeding height, crop feeding angle and moisture content and their effect on seed damage, seed germination, threshing, cleaning efficiency, thresher output capacity and economics of thresher developed.

Sessiz, A., Koyuncu, T., & Pinar, Y. (2007). "Soybean Threshing Efficiency and Power Consumption for Different Concave Materials" It was concluded that the concave type has a significant effect on power requirement, specific power consumption and threshing efficiency. The power requirement and special power consumption of chromium type concave were lower than the others. The power consumption increased with all concave types depending on the increase in the speed and the feeding rate. The highest power consumption was obtained with the rubber-covered concave. The lowest consumption was obtained with the chromium type. The lowest specific energy consumption was with chromium type at all drum speeds and feed rates. Threshing efficiency increased with increasing BPS with all count beater types. The highest increase was achieved with the chromium type and the lowest with the rubber covered type.

Behera *et al.* (2007) conducted a study on "Design and development of a black and green gram thresher". The study resulted that design consideration showed that the threshing drum diameter could be 40cm with a rpm of 400. Concave was made of 9mm x 9mm square bar laterally spaced at 10 mm with a wrapping angle of 136°. The power consumption of the thresher was 1.58 and 1.49hp for green and black gram respectively for feed rates of 144 and 139kgh^{-1} respectively. It was found that the threshing efficiency was 95.30 and 94.70 per cent for green and black gram respectively. The cleaning efficiency was comparatively low (78.68%) which needs to be improved by providing a second sieve.

Ukatu, A. C. (2006). investigate "A modified threshing unit for soya beans" A threshing unit which reduces seed damage by combining lower rotor speeds with less severe impact of modified threshing fingers and appropriate clearances between the moving and stationary components, has been developed. The performance of the threshing unit with modified rotor pegs was compared with that with conventional pegs, using the same rotor drum as that for the modified pegs to serve as a control. The performance of the modified pegs was compared with that of the conventional pegs at a 5% level of significance. Soya beanTGX144-22Evariety of an average moisture content of 14.6% wet basis (wb) was used. For the conventional pegs, and at a rotor speed range of 300–550 min^{-1}, seed damage ranged from1.94–2.43%; threshing efficiency from 99.09% to 99.37%; throughput and output capacity ranges of1493–1658 and 482.4–504.8 kg/h, respectively. For the modified pegs, and at the same speed range, seed damage was from 0.83% to 0.98%; threshing efficiencies from 99.26% to 99.47%; throughput and output capacity ranges of 1525–1642 and 412.5–506^{-1} kg/h, respectively.

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%.

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.

Wacker (2003) investigated the effect of several wheat varieties on performance of threshing. The results showed that moisture content, cylinder speed and space between concave and cylinder were effective on wheat threshing.

Dauda (2001) reported that the high moisture content and low cylinder speed tend to reduce the percentage of damage seed, blown seed and seed loss respectively while low moisture content and high speed tends to increase the percentage of damage seed, blown seed and seed loss respectively. Moisture content state and impact on grain during threshing are paramount in determining crop mechanical damage.

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.

Yadav (1990-91) evaluated Nursery Master Elite plot combine for soybean harvesting at 7.3-10.9 m/s peripheral speed of the cylinder keeping concave clearance 20-10 mm front and rear respectively. The threshing efficiency, cleaning efficiency, broken grain, shattering and combining loss were recorded as 98.70 per cent, 95.00 to 96.00 per cent, 0.87 to 5.30 per cent, 0.15 to 0.45 per cent and 1.40 to 5.40 per cent respectively. Varietals seed mixing was observed to be negligible.

Anwar et al. (1991) tested extensively the axial flow thresher on chickpea (CM - 72). It is observed that cylinder speed, feed rate and cylinder concave clearance affected the thresher performance in terms of grain damage, total machine loss, threshing and cleaning efficiencies. It was observed that the thresher had maximum crop intake capacity of 380 kgh-1 due to difficult feeding, hence resulting in low grain output. Therefore, the study suggested that raspbar threshing system with easy feeding method should be tested for chickpea threshing.

Tandon S et al (1988) considered five parameters that influenced threshing efficiency and kernel damage, namely, cylinder peripheral speed, cylinder type, concave type, concave clearance and grain moisture content. They reported that concave clearance and cylinder peripheral speed had significant effect on the threshing efficiency and grain damage for pulse threshers.

Saxena and Ojha (1988) reported that percentage of un threshed grain decreased with an increase in cylinder speed and decrease in pod moisture content. The per cent of damage grain increased with an increase in cylinder speed while it decreased with the increase in grain moisture content. However, it was noticed that cylinder speed had more pronounced effect on un threshed and damage grain than moisture content of pod or grain. Similarly, the energy requirement increased with the increase in pod moisture content as well as cylinder speed.

Singh and Majumdar (1986) modified a commercial wheat thresher for different varieties of soybean. It consisted of a conventional spike tooth threshing cylinder, blower, concave and sieves. The aspirator blower was provided on the cylinder shaft. The recommended speed for threshing wheat was 1200 m/min which had to be lowered for soybean but the cleaning system did not work below 540 rpm. So, the speed was kept at 540 rpm (700 m/min) and the number of spikes in each row was reduced to one instead of seven. Different varieties of soybean were threshed at grain moisture range of 6.00 to 15.00 per cent. It was observed that the grain damage was less than 2.00 per cent. When grain moisture was more than 12.00 per cent, the output capacity of the thresher was 244, 270 and 254 Kg/h for Punjab-1, JS 7244 and JS 2 respectively with a 7.5 hp electric motor. The straw quality was poor.

Madan et al. (1985) reported that axial flow threshing system can handle high moisture crop while existing threshing system can handle dry crops only.

Kaul and Egbo (1985) stated that the performance of a thresher depends upon its size, cylinder speed, cylinder concave clearance, fan speed and the sieve shaker speed.

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.

Kamble *et al.* (1984) conducted a review on "Study of various factors affecting a thresher performance". review showed that an experimental thresher having provision for mounting rasp bar, round bar or spike bars on green gram indicated that threshing efficiency and grain damage increased with the increase in peripheral speed. For the round and rasp bar cylinder, grain was excessively high beyond the cylinder speed of 9 m/s. Spike tooth cylinder caused least grain damage over rasp bar and round bar for threshing green gram. It was due to fine quality of straw with minimum specific power requirement. They recommended peripheral speed of 7m/s and 5 to 10mm concave clearance for threshing crop. Safety feeding chute and recommended the minimum bottom length as 90cm and top cover length as 45cm also suggested a tilt angle up to 6° with horizontal for proper feeding of crop.

Studies conducted by **Kamble and Panwar (1984)** with an experimental thresher having provision for mounting rasp bar, round bar or spike bars on green gram indicated that threshing efficiency and grain damage increased with the increase in peripheral speed. For the round and rasp bar cylinder, the damage to grain was excessively high beyond the cylinder speed of 540 m/min. Threshing efficiency and grain damage varied inversely with the concave clearance. The influence of clearance, on grain damage was appreciably high at the higher speeds. Threshing efficiency and grain damage were inversely related to the grain moisture content.

Majumdar (1982) evaluated the thresher on JS 7244 variety of soybean indicated that the percentage of damaged beans was only 0.7 at a cylinder speed of 390 m/min and grain moisture of 9.30 per cent. The grain damage was more at higher cylinder speed and at low feed rate. The separation loss was about 1.00 per cent on above speed. The output capacity of this thresher was 143 Kg/h with a 3 hp electric motor. The thresher was provided with round spikes and could not produce very fine, bruised wheat straw of desired quality and was therefore not popular among the farmers in spite of its best features for threshing variety of crop.

Huynh et al. (1982) stated that the seed separation from the stalks and passage of seed through the concave grate is a function of some variables such as crop feed rate, threshing speed, concave length and cylinder diameter and concave clearance. These variables are also related to the threshing losses and seed separation efficiency.

Singh and Singh (1981) concluded that the un threshed grain increased with increase in pod moisture content whereas the grain damage decreased with an increase in grain moisture content.

Sharma K. D., & Devnani R. S. (1980). Were conducted a study on "Threshing studies on soybean and cowpea" and measured that, threshing trials on soya bean (Glycine max) and cowpea (Vigna unguiculate) were conducted in order to determine the effects of cylinder tip speed and concave clearance on threshing parameters and the optimum operating conditions of the thresher. Recommended cylinder tip speed and concave clearance for soya bean and cowpea threshing appeared to be 413.5 m/min at 12.0 mm and 496.0 m/min at 8.0 mm clearance for consumption purposes, and 330.0 m/min at 12.0 mm and 288.5 m/min at 8.0mm clearance for seed purposes, respectively.

Kepner et al. (1978) discussed the factors affecting the efficiency of threshing operation. They identified the factors as feeding method, cylinder speed, concave to cylinder clearance and moisture content.

Cain and Holmes (1977) observed that both the percentage of splits and the percentage of beans with cracked seed coats increased as impact velocity increased and as bean moisture content decreased. Studies have shown that fast cylinder speed is the main cause of threshing damage.

Hoki and Pickett (1973) reported that moisture content of beans was a major factor in controlling the damage. A decrease in moisture appeared to greatly increase in the brittleness of the beans. Beans with low moisture content were very much susceptible to splitting during impact from the side.

Pickett (1973) observed that the threshing loss was dependent on both the bean moisture and pod moisture. Excellent condition for harvest would be to have been moisture between 17.00 and 20,00 per cent and pod moisture as low as possible, preferably below 12.00 per cent. When bean moisture was low, harvesting could proceed only when the pods were especially dry so that low cylinder speed could be used without excessive threshing loss.

Mittal and Arya (1970) reported that the effect of the speed of the threshing cylinder on the output of the threshed grain varied with variety. Total grain losses increased with increased in threshing cylinder speed.

Nag and Devnani (1970) reported that the damage in the threshing of beans occurred mostly due to impact. The peripheral speed of the threshing cylinder was found to be the most critical factor to be considered to minimize seed and grain damage of soybean and other beans. A small (2 hp) soybean thresher was developed at the Mohanlal Sukhadia University, Udaipur (1971). The thresher consisted of a feeding tray, rasp bar cylinder, open concave and blower. On testing, the threshing efficiency was found to be 90.00 per cent with 0.20 per cent seed damage at 10 mm concave clearance. The output capacity of this threshing was 85 Kg/h at a cylinder speed of 6.89 m/s while the power consumption was 1.15 KW (Sharma and **Devnani (1980)**). They have also recommended the cylinder tip speed and concave clearance for soybean and cowpea threshing of 6.89 m/s at 12 mm and 4.8 m/s at 8 mm clearance for seed purpose, respectively.

Kemp et al, (1967) reported that lower cylinder speed caused lower seed damage and observed 0.75 per cent seed damage at a peripheral speed of 1570 fpm (478 m/min).

Arnold (1964) The experiment conducted at National Institute of Agricultural Engineering showed that reduction of damage and its possible elimination depended mainly on the use of lower cylinder speeds. Most of the threshing is done by impact of the beaters on the crop and this caused most of the damage. Hence, any means of reducing the magnitude of number of impacts required could reduce the chances of damage to the grain. It was further noted that cylinder speed was one of the most important factors effecting cylinder losses which progressively decreased with the increasing speeds.

Bainer et al., (1963) reported that with increase in cylinder peripheral speed the seed damage increased while threshing losses were reduced. Tests carried out at California Agricultural Experimental Station indicated that the unthreshed seed loss increased with the increase in total feed rate.

Mark et al, (1962); Henry (1942); Bunnelle et al, (1954); reported that the damage in the threshing of beans occurred mostly due to impact. The peripheral speed of the threshing cylinder was found to be the most critical factor to be considered to minimize seed and grain damage of soybean and other beans.

Lamp et ah, (1961) observed that increased threshing effort required for high moisture harvesting resulted in a reduction in germination. Extensive field work in soybean combine was conducted by Lamp et al, (1961). Tests were done over a period of five years in mostly high moisture crops. Threshing loss and bean damage were reported as function of threshing speed and crop moisture level. It was determined that increasing the cylinder speed for high moisture soybean harvesting resulted in reduced germination and increased splits and cracked seed coats

King and Riddolls (1960) studied the effect of different combination of cylinder speed and concave clearance on damage to wheat and pea seeds at fairly low moisture content. The studies revealed that high cylinder speed was the chief factor in increasing visible damage.

2.3.3 Study of Ergonomic consideration for development of thresher

Rawal and Verma (1982) studied the effect of base and cover angles and the covered length of the feeding chute in relation to the feed rate, physical effort, muscular and mental fatigue. It was suggested the feeding chute with base length of 90 cm, cover length of 45 cm base and cover angles of 5° to be optimum for maximum feed rate against minimum physical effort for spike tooth thresher.

Verma et al, (1980) estimated that every year there was about 1000 thresher accidents in India resulting in either loss of life or disability to the workers. Survey in Punjab revealed that about 73.00 per cent of accidents was due to human factors like carelessness, over work, physical incapability and unskilful ness. About 13.00 per cent of accidents were due to machine factors like improper feeding system. About 5.00 per cent of accidents took place due to crop factors like short crops and about 5.00 per cent due to environmental factors as insufficient light, and hot weather conditions.

Thyagraj and Shrivastava (1980) carried out studies on safety feeding chute and recommended the minimum bottom length as 90 cm and top cover length as 45 cm.They also suggested a tilt angle up to 6° with horizontal for proper feeding of crop materials.

2.4 Synthesis of Mechanism

A mechanism synthesis is constructing and framing out the mechanical linkages in such a constrained manner to get desired motion as work output. Threshing can be achieved by three methods namely rubbing, impact and stripping. Threshing loosens the grains and separates from the stalk. The function can be served mostly by two methods, by impact or by crushing. In impact method an impact is given on crops and the grains are separated. Crushing is one in which the crop mass passes through a gap between drum and concave. Wearing or rubbing action takes place that separates the grains from panicle. In each case rupture of the bond between grains and ears is due to Impact of beaters or spikes over grains and wearing or rubbing action. Research has been carried out to improve the performance characteristic of thresher. Paulsen states that the moisture content of grain is one of the major physical factors for the design and operation of the threshing machine.

Afify *et. al* Developed a simple flax thresher to extract the capsules with minimum stalk damage. His basic design based on three drum shapes (peg-teeth, beaters, and peg-teeth with beaters). The observations showed that the drum with beaters attains different efficiency associated with it as threshing efficiency of 96.52 %, separation efficiency of 98.21 %, cleaning efficiency of 95.79 %, stripping efficiency of 99.35 %, threshing capacity of 1.01 t/h, energy, 2.79 kW.h/ton and less criterion cost of 10.29 L.E / ton under the conditions of drum speed of 5.23 m/s and capsules moisture content of 14.20 %.

El-Nono and Mohammed *et. al*. performed the study on machine power requirement, drum speed, moisture content and grain damage. The research state that machine was directly proportional to the drum speed. Also, the moisture content and grain damage highly affect the power requirement. The experimentation found that the swinging hammer, spike tooth and rasp bas cylinders affect threshing effectiveness and damage of wheat. It has also been seen that the cylinder speed and concave clearance were found to be important variable in unthreshed grain and damage model. Variation in cylinder speed and concave clearance varies the volume of unthreshed grain. The increase in cylinder speed and decrease in clearance increases the power requirement. The overall result of experimentation shows that the swing arm type is less effective than the rasp type.

Mandouh *et. al*. Stated the relation between different threshing parameter like cylinder speed, the concave clearance, feed rate of crops, the number of rows of concave teeth used with spike tooth cylinder, and the type of crop and Threshing effectiveness.

Zaky *et. Al* Recommended that the optimum conditions to reduce the seed damage and total losses of seed with acceptable level of cleaning efficiency were the drum speed ranged from 3.3 to 4.4 m/s, clearance ranged from 2.5 – 3 mm and air velocity of 2 m/s to consumed energy of 25.12 kW.h/ton and criterion cost of 752 L.E/ton. Heretofore, there are no papers published on the design or development of a machine for threshing Soya bean seed capsules. With the availability of reports on the properties of other similar crops and threshing, the objective of this study concerned in development of appropriate threshing machine suits Soya-bean black seed which will reduce the drudgery associated with the traditional methods of threshing Soya-bean seed capsules with high stripping, threshing and cleaning efficiencies in addition to low required energy and cost.

Gol and Nada *et. al*. Concluded that the important factors affecting the efficiency of mechanical pod stripping elements are operation speed and crop conditions. Percentage of stripping pods increased by increasing of peripheral drum speed which ranged from (473 rpm) 0.1m/s to (675 rpm) 3 m/s.

2.5 Analysis and Overview About Crop Strength

In the proposed work an effort has been taken to design and optimize thrasher. The thrasher has to perform the cutting and thrashing action on the crop which if fed through it. The thresher design is thus completely affected by the resistance imparted by crop volume. The volume implies stem leaves and capsule. With a view to design the research is overlooked for physical and mechanical properties of crop. In the research discussed above it have already stated that the moisture content highly affects the strength and threshing characteristic. The findings for the same on the basis of review are discussed as below.

Rafique Polac *et. al*, performed experimentation on soya bean crop in Turky. The moisture content measurement has been made and he found the average moisture content as 6.67 and max limit as 15.3 %. So, he states the physical properties at the given percentage. The sampling has been done on 100 samples properly cleaned and dried for test. The average value requited for optimum design whereas the maximum value required for the maximum strength. Average length, width, thickness, unit mass, geometric mean dia, sphericity, porosity, true and bulk density were 7.1 mm 5.34 mm, 4.30 mm, 121.76 gm, 5.62 mm, 5.75 mm, 75.0, 51.0 ,1062.6 and 108.8 kg m3 respectively. Corresponding value at 15.3 % moisture content were 9.57 mm, 6.75 mm 5.75 mm, 75.0, 51.0, 10626 and 804 kg m3

Liang li *et. al*, Performed the study for stalk shear strength. The work has been performed to provide design parameters for harvesting machinery cutter, and exploring the relationship between shear strength and morphological traits. This strength can be utilized to adjust the shear strength in selecting crop variety process. About seven morphological traits (such as plant height, ear length, ear weight, moisture content and so on) were measured in the crop mature period. The maximum shear force during shearing process, through static test equipment, at the second internode of the basal stalk, was recorded. Based on the experimentation the findings for different mechanical properties are plant height 81.9 cm, Internodes distance 7.9 cm, Internode weight 5.68 gm, cross sectional area 82.77 mm^2, Shear strength 21.7 N, Shear stress 2.62 MPa.

2.6 Traditional Methods of Threshing

2.6.1 Hand beating

Hand threshing is generally done on floor. Threshing is done manually by beating the grain using a flail on a threshing floor One of the simplest systems for threshing of crop is to strike the sheaves of crop spread over threshing floor with a flail or a stick. The threshing-floors on which the sheaves are spread must have a hard, clean surface. **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.

2.6.2 Animal Treading

traditional method is to make donkeys or oxen walk in circles on the grain on a hard surface. Subject to the availability of draught animals, large quantity of crops can be threshed by treading the animals over about 30 cm thick layer of sheaves, technically known as bullock treading. 80 – 110 kg/hr in threshing of grain by treading under the hooves of animals.

2.6.3 Tractor treading

Crop subjected under the tractor in place of animal hooves. This operation, which is also called “treading out” can equally well be accomplished with vehicles (tractor) known as tractor treading. Grain is obtained by running the tractor twice over sheaves of harvested and dried crops that are spread in layers on a circular threshing floor 15-18 m in diameter. The sheaves must be turned over between the two passages of the tractor. It is more efficient than animal treading

2.6.4 Another approach of threshing

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. This method widely adopted in backword village areas.

2.7 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 as 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 from300 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 move spirally between the threshing drum and the circular concave for several complete turns.

2.7.1 Threshing with hand driven machines

Normally a hand-operated machine like Olped thresher, which is basically used for threshing of paddy can also be used for threshing of cut stocks of pigeon pea. By means of the handle or pedal, a big drum fitted with metal rings or teeth is made to rotate. The cut-stocks of pigeon pea is threshed by hand-holding the sheaves and pressing the upper portion of dried plants against the rotating drum. The speed of the threshing drum must be kept at about 300 revolutions per minute (rpm). The hand-held sheaves must all be of the same length with the panicles all laid in the same direction, and the grains must be very ripe and dry. The machine must be continuously and regularly fed, but without introducing excessive quantities of product. Use of these threshing machines may require two or three workers. Depending on the type of machine, the skill of the workers and organization of the work, yields can be estimated at a maximum of 100 kg/h.

2.7.2 Threshing with Motorized threshers

The use of motorized threshers or threshers operated by tractor power has become very common for threshing of pulse crops. The threshers available in the market are basically designed for threshing of cereal crops and no specific thresher is available for threshing of pulse crops. However, by the simple replacement of a few accessories and the appropriate changes in settings threshing elements and design, these machines can be used for threshing of pulse crops as well. Author trying to develop small scale thresher with 1 hp power operating or operated by bullock power for convenience of large no. of marginal and small farmers in Odisha state. these machines often have devices to shake out the straw and to clean the grain. these threshers are often mounted on rubber wheels for easy movement. The use of motorized threshers may require two or three workers. Yields depend on the type of machine, the nature and maturity of the grain, the skill of the workers and organization of the work.

2.8 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 nongrain 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.

2.9 Factors Affecting green gram and black gram Threshing

Threshing of Green gram 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**).

2.10 Factors Affecting green gram and black gram 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.

Chapter : 3

MATERIALS AND METHODS

3.1 Preparation of the test sample

The green gram grains of popular varieties, namely IPM 02-3 and Jyoti were collected in adequate quantity from Centre for Pulse Research (OUAT), Ratanpur, Ganjam. The grain samples were cleaned to remove foreign materials such as dirt, stones, dust, immature grain, broken grains, etc. The initial moisture contents of these samples of two varieties were found out following the standard hot-air oven method using the following formula (**Dutta et al., 1988).**

Samples of green gram used in determining grain properties are collect from seed breeder production firm of odisha. samples were cleaned manually to remove all foreign substance such as dust, dirt, stones and chaff as well as immature, broken grains. The moisture contents of the samples were controlled by standard air oven method. The higher moisture contents of the samples were obtained by rewetting. (**Brusewit, 1975**). Initial moisture content of the grains was determined by hot air oven drying method at 105 ± 1°C for 24 hours (**Dutta etal., 1988**). The initial moisture content of the grains 10.31 % on wet basis for different varieties of green gram. after this, chosen moisture contents (4 mc level) were gained by adding intended amounts of distilled water in the grain samples **Bakane *et al.* (2016).**

By using the following equation, the required quantity of water was added to achieve the desired moisture content.

$$Q = \frac{\mathrm{Wi(Mf-Mi)}}{100-\mathrm{Mf}} \quad \text{.......................................} (1)$$

Where:

Q- Weight of water to be added, gm

Wi- Initial weight of grain, gm

Mi- Initial moisture content of the grain, % (w.b.)

Mf- Desired moisture content of the grain, % (w.b.)

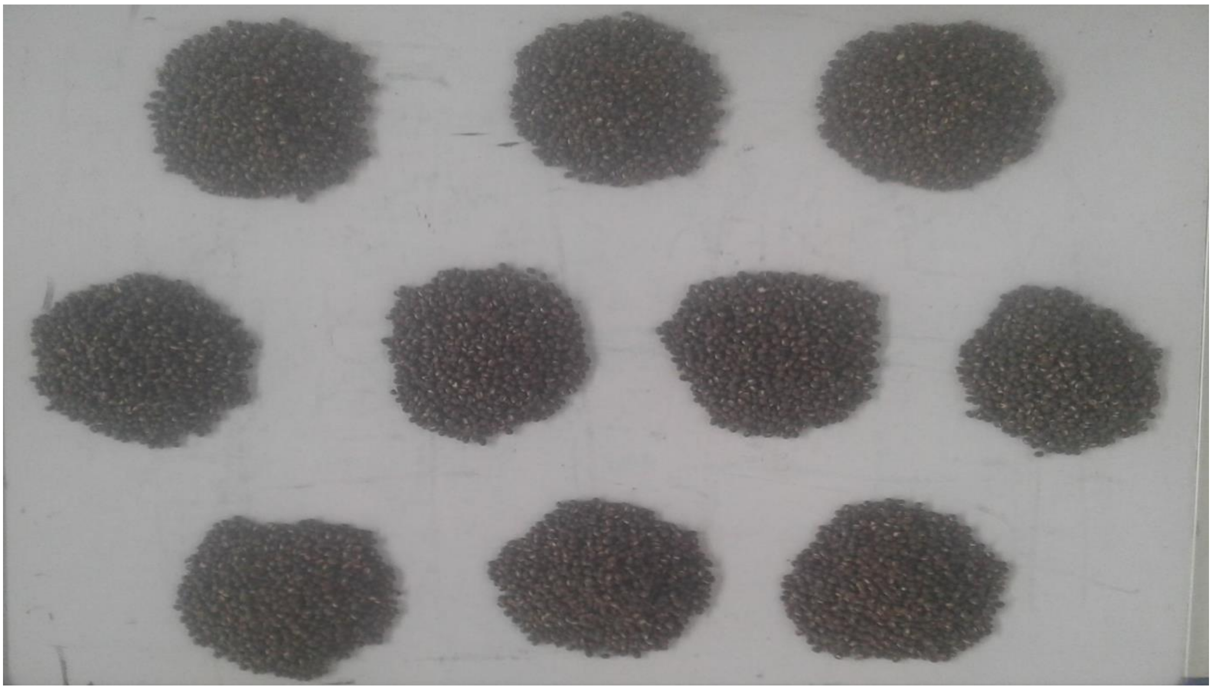

Fig. 3.1 Sampling of grain

Fig. 3.2 Sampling of grain

Then the samples were emptied into separate polyethylene's bags and the bags taped up tightly similar process taken by many researcher's (**Majid Khanali et al. 2017, Siva shankar v and Pandiarajan t 2019**). The samples were kept at 5°C in a refrigerator for a week to enable the moisture to dispense homogeneously throughout the sample. Before starting a test, it is necessary that samples are take out from refrigerator and left for 2 hours. so that samples gained normal room temperature. All properties of the grains were determined at various moisture levels between 8.6 to 26.17% w.b for different varieties of green gram. test was performed with replications of each sample at different MC.

https://www.infonet-biovision.org/PlantHealth/Crops/Green-gram mc storage 12%

http://agritech.tnau.ac.in/agriculture/agri_cropharvesting.html

- The green gram and black gram grain sample of varieties was procured from the research farms of Odisha university of agriculture and technology Bhubaneshwar.
- variety was selected because of its characteristics (high yielding, early maturity and low shattering) and it is the most commonly cultivated by farmers in Odisha.
- 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 (max 50,000 rpm, d=1 rpm) was used for measuring the speed of 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 (Agri search equipment, UN30, Min 5°C, Max 300°C) was used in the
- determination of grain moisture content.
- Other instrument used were tilt table, aluminium, galvanized iron, stainless steel and glass sheet for the determination of the angle of repose and grains coefficient of friction.

3.2 Determination of Physical Properties of green gram and black gram

3.2.1 Linear Dimensions

To determine the average size of the grain, 100 grains were randomly picked by hand and their three axial dimensions viz, length L, width W, and thickness T were measured using a calliper with 0.01 mm sensitivity. The measurements were taken at room temperature (**Thonga, P. T. et al. 2010, Chowdhury, M.M.I. 2001and Deshpande, S.D. 1993).**

Fig. 3.3 Measurement of grain dimension

Fig. 3.4 Measurement of grain dimension

3.2.2 Grain size (AMD, GMD, SMD and EQD)

The average diameter of grain was calculated by using the arithmetic mean and geometric mean of the three axial dimensions. The arithmetic mean diameter (D_a), geometric mean diameter (D_g), square mean diameter (D_s) and equivalent diameter (D_e) of the grains were calculated by using the following relationships (**Unal et al. 2006, Baümler et al. 2006, Chowdhury et al. 2001 and Mohsenin, 1986**).

$$D_a = \frac{(L+W+T)}{3} \quad \ldots (2)$$

$$D_g = (LWT)^{1/3} \quad \ldots (3)$$

$$D_s = (LW + WT + TL)^{1/2} \quad \ldots (4)$$

$$D_e = \frac{\text{AMD+GMD+EQD}}{3} \quad \ldots (5)$$

3.2.3 Test Weight W_{1000}

Test weight is the weight of 1000 grain which is randomly chosen from bulk. In this process mass of 1000 grain was determined by counting 1000 grains and weighing them in an electric weight balance with precision of 0.1 g (**Bakane *et al.*2016**). Many of researchers taking test weight by weighing of 100 seed and then multiplied with 10. (**Monirul Islam Chowdhury et al.2001**).

3.2.4 Sphericity and Aspect ratio

The standards used to define the shape of the grain are in terms of sphericity and aspect ratio. Thus, sphericity and aspect ratio were calculated based on the three linear dimensions (**Mohsenin, 1970**). The degree of sphericity S_p can be expressed as follows:

$$S_p = \frac{Dg}{L} \quad \text{...} \quad (6)$$

The aspect ratio (R_a) of grains was calculated by using the following equation (**Owolarafe et al., 2007, Maduako & Faborode, 1990).**

$$R_a = \frac{W}{L} \quad \text{...} \quad (7)$$

3.2.5 Surface area

The surface area (A_s) was calculated using the relationship (**McCabe et al., 1986, Arthur (2009).**

$$A_s = \pi\,(D_g)^2 \quad \text{...} \quad (8)$$

3.2.6 Volume (V_{grain})

The seed volume, V_{grain} and grain surface area, S was calculated by the following formulae (**Baryeh and Mangope**,).

$$V_{grain} = \frac{\pi B^2 L^2}{6(2L-B)} \quad \text{...} \quad (9)$$

Where: B = $(WT)^{1/2}$

3.2.7 Bulk density

Bulk density (ρ_b) is the ratio of the weight of the material to its total (bulk) volume (including the intergranular air space between grains). This is determined with the help of the test weight apparatus. A 500 mL cylinder was filled with grains from a height of 15 cm. The excess grains were removed by sweeping the surface of the cylinder and the grains were not compressed. Bulk density was then calculated as the ratio between the grain weight and the volume of the cylinder (**Desphande et al., 1993**). The bulk density for each replication was calculated from the following equation:

$$\rho_b = \frac{M(mass\ of\ grain\ in\ container)}{V(total\ volume\ of\ grain\ or\ container)} \quad \text{...} \quad (10)$$

Where: ρ_b = Bulk density, kg.m^{-3}; M = Mass of sample, kg; and V = Volume of container, m^3. True density (ρ_t) is the ratio mass of the green gram to its true volume (not including the intergranular air space between grains).

Fig. 3.5 Measurement of Bulk Density Without grain

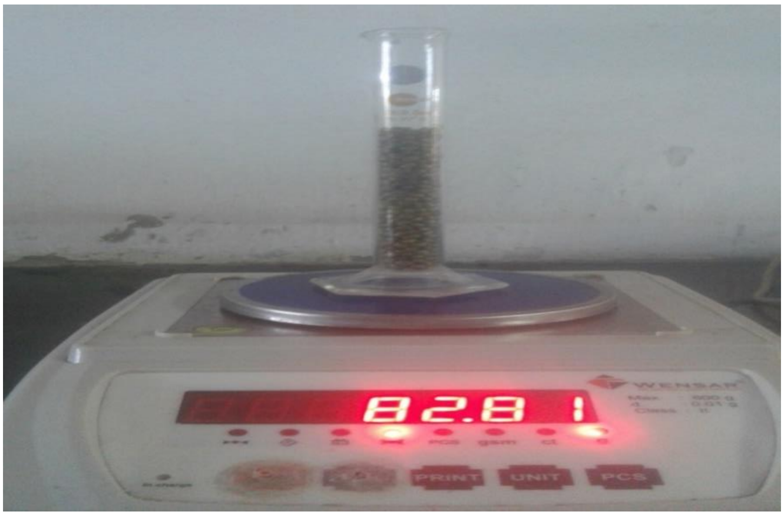

Fig. 3.6 Measurement of Bulk Density With grain

3.2.8 True density

True density (ρ_t) was determined using the toluene displacement method (**Mohsenin 1986; Singh and Goswami 1996**). Toluene (40 ml) was filled in 100ml graduated measuring cylinder and 50g of grains were poured in it. The amount of toluene displaced was recorded. The true density was estimated as the ratio of sample mass to the volume of displaced toluene (**Suthar, S.H. et al. 1996, Teotia, M.S. et al. 1989, Fraser, B.M. et al. 1978).**

$$\rho_t = \frac{M(\,known\,mass\,of\,\,grain\,)}{\text{Vtoluene}(\,volume\,of\,\,toluene\,displaced\,by\,grain\,)} \quad \ldots\ldots (11)$$

Where: ρ_b = Bulk density, kg. m^{-3},

M = Mass of sample, kg; and $V_{toluene}$ = Volume of container, m^3.

3.2.9 Density ratio

The density ratio (R_d) is the ratio of bulk density to true density expressed in a percentage or decimal as follows:

$$D_r = \frac{\rho_b}{\rho_t} \times 100 \quad (12)$$

3.2.10 Porosity

Porosity (ε) is defined as the percentage of void space in the bulk grain which is not occupied by the grain. Or is a fraction of the volume of voids over the total volume (**Mohsenin, 1986**). Also, the porosity bulk seed was computed from the values of true density and bulk density using the following relation (**Thompson and Isaacs, 1967**)

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (13)$$

Where:

ε = Porosity (%)

ρ_b = Bulk density, kg. m^{-3},

ρ_t = True density, kg-m

3.3 Determination of frictional properties

3.3.1 Angle of repose

The angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using the apparatus consisting of a plywood box of 140 x 160 x 35 mm and plates fixed and adjustable. The box was filled with the sample from constant height (15 cm), and then the adjustable plate was inclined gradually allowing the grains to fall freely and assume a natural slope, this was measured as the emptying angle of repose (**Sacilik K. et al. 2003 and Sahoo, P.K. et al. 2002**). The angle of repose was determined using the following relationship:

$$\boldsymbol{\theta_r} = \tan^{-1}\left[\frac{2H}{D}\right] \quad (14)$$

Where, $\boldsymbol{\theta_r}$ = Angle of repose, degree; H = Height of heap, mm and D = Diameter of base of heap, mm

3.3.2 Static coefficient of friction (μ)

The coefficient of static friction of samples of sorghum grain was determined with respect to four surface materials including plywood, glass, galvanized iron and mild steel to study the flowability of the samples through the hopper with reduced friction (**Shashikumar, G., et al., 2018**). The Co-efficient of friction for sorghum grains was determined by placing a bottomless plastic cup over plywood/glass / mild steel (MS) / galvanized iron sheets and filled the cup with a known weight of samples. Then, the cup was connected to the loading pan through a strong thread and the thread was made to move over a frictionless pulley. Weight was added gradually until the cup started moving/ dragging. Now, the weight added to the pan was noted (**Mohsenin, 1986**). The experiment was repeated five times with different sheets *viz.*, plywood/glass / mild steel (MS) / galvanized iron sheets and the values were noted for necessary calculations (**Amin, M.N. et al. 2005 and Nimkar, P.M. et al. 2001**). The Co-efficient of friction was calculated from the equation,

$\mu = F/N$ ……………………..…..................................…………………………………..……. (15)

Where,

μ = Co-efficient of friction

F = Lateral force (weight on the pan), gm

N = Normal force (weight of the sample), gm

3.4 Determination of aerodynamic properties

3.4.1 Terminal velocity

The terminal velocity of agricultural grains can be measured by using vertical wind column apparatus. (**Unal et al. 2006, Singh and Goswami, 2006 and Suthar and Das, 1996**). A vertical air tunnel was used to determine the experimental terminal velocity of grains. 25 g of sorghum seeds at different moisture content levels were randomly selected for measurement terminal velocity. The seed sample was placed on a mesh screen in a vertical tube. The air velocity was adjusted by increasing the speed of the motor until the seed began to float. The air velocity near where the seed became suspended was measured with an anemometer with 0.1m/s accuracy.

3.5 Design of machine

A Pulse thresher is proposed to be developed on the principle of impact and shear forces. the physical properties of the green gram and black gram are to be studied to design feeding chute, threshing element, sieves, concave clearance at chaff outlet, rpm etc. The linear dimensions, roundness, AMD, GMD, sphericity and bulk density of grain are to decide the sieve opening size, cleaning and separation unit while mechanical properties help in force analysis. Aerodynamic properties of agricultural products are important and required for design of air conveying systems and the separation equipment. Angle of repose and coefficient of friction are deciding factors for the slope of the sieve. The threshing drum would be fitted with two types of threshing elements of studs and blades in alternate arrangement for effective threshing. the concave is proposed with MS square bars and a blower/aspirator to be designed for cleaning of threshed grain.

3.5.1 Design consideration

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

i) The thresher was operated using bullock power(1.0hp) in rotary mode. This was chosen based on the requirement of the majority (91%) of marginal and small land holdings of Odisha state and availability of electricity in village area of state.

ii) The speed of 600 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^{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 7-9 m/s was used as reported by **Vijasit and Salokhe**,

From the above said interactions between machine parameters, the optimum range could be selected as follows:

a. When the moisture content of the crop at 12.00 per cent

i. Peripheral speed = 7-9 m/s

ii. Crop feeding height = 1.5-2 m

iii. Crop feeding angle =10°

b. When the moisture content of the crop at 9.00 per cent

i. Peripheral speed = 7-9 m/s

ii. Crop feeding height = 1.5-2 m

iii. Crop feeding angle =10°

c. When the moisture content of the crop at 6.00 per cent

i. Peripheral speed = 7 m/s
ii. Crop feeding height = 1.5 m
iii. Crop feeding angle =10-15°

3.5.2 Mathematical Design calculations and analysis of machine

3.5.2.1 Feed rate of thresher

$$m = \frac{75(1-\mu)P}{(v)^2}$$ (D.N. SHARMA, Design of Farm Machinery)

Where:

m = Feeding rate (kg/s)

μ =Coefficient of friction between straw and thresher material (0.6)

P = horse power (1hp, Bullocks power)

Actual power generates by bullocks

Note: power generate by bullocks

- **(0.65 to 0.70 hp) in rotary mode and**
- **(0.70 to 0.80 hp) in straight mode**

$= 0.70 \times 1$ hp

$= 0.70$ hp

Mechanical efficiency of rotary system = 60 to 70 %
(Practically determined on rotary system at CAET, OUAT, BHUBANESHWER)

Actual working power at thresher = Mechanical efficiency of rotary system (0.70) × Actual power generate by bullocks (0.70 hp)

$= 0.70 \times 0.70$ hp

$= 0.49$ hp

V= velocity (8.5m/s),

(For most effective working velocity should be between 7m/s to 10 m/s)

$$m = \frac{75(1-0.6)0.49}{(8.5)^2}$$

m = 0.203 kg/s (maximum)

m= 7.32 q/hr (maximum)

3.5.2.2 Determination of thresher cylinder diameter (D)

Diameter was determined using the expression of belt speed established by Hannah and Stephen (1984) thus:

$$v = \frac{\pi N D}{60} \text{ (m/s)}$$

Where:

D= Diameter of cylinder (m)

N= Revolution of cylinder per minute (600RPM)

v= Peripheral velocity (8.5m/s)

$$D = \frac{60}{\pi N} v \text{ (m)}$$

$$D = \frac{60}{\pi\ 600} 8.5 \text{ (m)}$$

$$D = 0.27056 \text{ m}$$

$$\mathbf{D = 270.56\ mm}$$

3.5.2.3 Determination of cylinder length (m)

$$L = \frac{m(1+m')}{0.25 \times n \times N \times K}$$ (D.N. SHARMA, Design of Farm Machinery)

Where:

L = Cylinder length (m)

m = Feed rate (kg/s)

n =Number of bars

N=Revolution of cylinder per second

K= 0.03-0.17 kg/m length of cylinder

$m' = \frac{1}{\delta}$, δ = Straw grain ratio (3)

$$m' = \frac{1}{3}$$

$$m' = 0.333$$

$$L = \frac{0.203(1+0.33)}{0.25 \times 6 \times 10 \times 0.03}$$

$L = 0.5290$ m(maximum)

$L = 529.0$ mm (maximum)

3.5.2.4 Determination of pulley size

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

$$N_aD_a = N_bD_b$$

Where:

N_a = RPM on drive pulley

N_b = RPM on driven pulley

D_a = Diameter of drive pulley

D_b = Diameter of driven pulley

3.5.2.4.1 Determination of pulley size mounted on cylinder shaft

$$N_1D_1 = N_2D_2$$

Where:

N_1 = RPM on main pulley (drive) 300

N_2 = RPM on cylinder shaft pulley (driven) 600

D_1 = Diameter of main pulley (drive) 150 mm

D_2 = Diameter of cylinder shaft pulley (driven)??

$$150 \times 300 = 600 \times D_2$$

$D_2 = 75$ mm

3.5.2.4.2 Determination of pulley size mounted on shaker arm

$$N_3D_3 = N_4D_4$$

Where:

N_3 = RPM on cylinder shaft pulley (drive) 600

N_4 = RPM on shaker pulley (driven) 240

D_3 = Diameter of cylinder shaft pulley (drive) 75 mm

D_4 = Diameter of shaker arm pulley (driven)??

$$75 \times 600 = 240 \times D_4$$

$$\mathbf{D_4 = 187.5\ mm}$$

3.5.2.4.3 Determination of pulley size mounted on fan shaft

$$N_5D_5 = N_6D_6$$

Where:

N_5 = RPM on cylinder shaft pulley (drive) 600

N_6 = RPM on fan pulley (driven) 477

D_5 = Diameter of cylinder shaft pulley (drive) 75 mm

D_6 = Diameter of fan pulley (driven)??

$$75 \times 600 = 477 \times D_6$$

$$\mathbf{D_6 = 94\ mm}$$

3.5.2.5 Determination of belt length

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

$$L_{cross/open} = \frac{\pi}{2}(D + d) + 2C + \frac{(D \pm d)^2}{4C}$$

3.5.2.5.1 Belt size for cylinder shaft pulley

$$L_{open} = \frac{\pi}{2}(D + d) + 2C + \frac{(D \pm d)^2}{4C}$$

Where

D= Diameter of large pulley 150mm

d = diameter of small pulley 75mm

C = Distance between centre of large and small pulley 1665mm

$$L_{open} = \frac{\pi}{2}(150 + 75) + 2 \times 1665 + \frac{(150 - 75)^2}{4 \times 1665}$$

$$\mathbf{L_{open} = 3684.26\ mm}$$

3.5.2.5.2 Belt size for shaker arm pulley

$$L_{cross} = \frac{\pi}{2}(D + d) + 2C + \frac{(D + d)^2}{4C}$$

Where

D= Diameter of large pulley 175mm

d = Diameter of small pulley 75mm

C = Distance between center of large and small pulley 310 mm

$$L_{cross} = \frac{\pi}{2}(175 + 75) + 2 \times 310 + \frac{(175 + 75)^2}{4 \times 310}$$

$$\mathbf{L_{cross} = 1062.90\ mm}$$

3.5.2.6 Determination lap angle of belt on pulley ($\boldsymbol{\theta}$)

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

$$\theta = \frac{\pi}{180}(180 - 2\alpha)$$

$$\alpha = \sin\frac{(D - d)}{2C} \text{ For open belt}$$

$$\alpha = \sin\frac{(D + d)}{2C} \text{ For cross belt}$$

α = Coefficient of increase of the belt length per unit force

$$\alpha = \sin\frac{(D - d)}{2C} \text{ For open belt}$$

C = distance between center of two pully 1665mm

D= Diameter of large pulley 150mm

d = Diameter of small pulley 75mm

$$\alpha = \sin\frac{(150 - 75)}{2 \times 1665}$$

$$\boldsymbol{\alpha = 0.000393}$$

$$\theta = \frac{\pi}{180}(180 - 2 \times 0.000393)$$

$$\boldsymbol{\theta = 179.99°}$$

$$\boldsymbol{\theta = 3.14\ radian}$$

$$\alpha = \sin\frac{(D+d)}{2C} \text{ For cross belt}$$

Where

$C =$ distance between centre of two pulley 310mm

D= Diameter of large pulley 175mm

d = Diameter of small pulley 75mm

$$\alpha = \sin\frac{(175\ +75)}{2\ \times 310}$$

$$\boldsymbol{\alpha = 0.00698}$$

$$\theta = \frac{\pi}{180}(180 - 2 \times 0.00698)$$

$$\boldsymbol{\theta = 179.98°}$$

$$\boldsymbol{\theta = 3.141\ radian}$$

3.5.2.7 Determination of belt speed

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

$$V_b = \frac{\pi ND}{60} \text{ (m/s)}$$

Where:

N= drive speed (300RPM)

D = diameter of drive pulley (0.15m)

V_b = belt speed (m/s)

$$V_b = \frac{\pi \times 300 \times 0.15}{60} \text{ (m/s)}$$

$$V_b = 2.35 \text{ m/s}$$

3.5.2.8 Determination of fan parameters

3.5.2.8.1 Determination of weight of fan

The weight of fan blades (W) was determined using the expression outlined by

(Mohammed, 2009);

$$w = \rho g V_T$$

Where

W = Weight (N)

ρ = Density of blade material of fan (For mild steel 7850 kg/m^3)

g = Gravitational acceleration (9.8 m/s^2)

V_T= Volume of fan material

$$v = \text{Length (700)} \times \text{Width (80)} \times \text{Thickness (2)}\ mm^3$$

$$\mathbf{v = 1.120 \times 10^{-4}\ m^3}$$

Number of blades = 04

Total volume of fan material (**V_T**)

$$\mathbf{V_T} = 1.12 \times 10^{-4} \times 04$$

$$\mathbf{V_T = 4.48 \times 10^{-3}}$$

Thus, weight of fan

$$W = 7850 \times 9.81 \times 4.48 \times 10^{-4}$$

$$\mathbf{W = 34.45\ N}$$

3.5.2.8.2 Rpm required for fan

$$V_F = \frac{\pi ND}{60}$$

Where:

D_F= Diameter of fan (m), (80 + 20 + 30 + 20 + 80 ± 10) mm

(Measured of threshers at **CAET, OUAT, BHUBANESHWER)**
= 240 mm

N= Revolution of cylinder per minute

V_F= Peripheral velocity (6 m/s), **peripheral velocity of fan peripheral velocity of fan should be less than terminal velocity (about 7-9 m/s) of grain and more than carrying velocity of chaff pieces (5-6 m/s)**

thus, peripheral velocity of fan = 6 m/s

$$6.0 = \frac{\pi \times N \times 0.240}{60}$$

$$\mathbf{N = 477\ RPM}$$

3.5.2.8.3 Power required for fan

Power required for fan = weight of fan × peripheral velocity of fan

$$P_F = W \times V_F$$

$$= 34.45 \text{ N} \times 6 \text{ ms}^{-1}$$

$$= 206.7 \text{ Nms}^{-1}$$

$$\mathbf{P_F = 206.7 \text{ watt}}$$

$$\mathbf{P_F = 0.276 \text{ hp}}$$

3.5.2.8.4 Determination of air discharge rate of fan

According to joshi (1981), air discharge rate of aspirator

$$Q = v \times D \times w$$

Where:

Q = air discharge rate m^3s^{-1}

v= Air velocity 5.0 ms^{-1}

D = Depth of flow above the reference point 0.35 m

w = Width over which air is required 0.55 m

$$Q = 5.0 \times 0.35 \times 0.55$$

$$\mathbf{Q = 0.962.5 \text{ m}^3\text{s}^{-1}}$$

3.5.2.9 Shaft design for cylinder (D.N. SHARMA, Design of Farm Machinery)

We know that

$$Hp = \frac{2\pi NT}{4500}$$

Hp = horse power hp

T= Torque in kg-m

$$T = (T_1 - T_2) R$$

N= RPM of cylinder

$$0.7 = \frac{2 \times \pi \times 600 \times T}{4500}$$

$$\mathbf{T = 0.8356 \text{ kg-m}}$$

3.5.2.10 Determination of belt tension

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

T_1 and T_2 are the tensions on the tight and slack side respectively and R is the radius of driven pully.

$$T = (T_1 - T_2) \times R$$

Also, we know that

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

μ = coefficient of friction between belt and pully (0.30)

ϴ = angle of lap, radians (π)

Therefore

$$\frac{T_1}{T_2} = e^{0.3 \times \pi}$$

$$T_1 = 2.56T_2$$

$$T = (T_1 - T_2) \times R$$

$$0.835 = (2.56T_2 - T_2) \times 0.04$$

$$\mathbf{T_2 = 13.38\ Kg\text{-}m}$$

$$T_1 = 2.56T_2$$

$$T_1 = 2.56 \times 13.38$$

$$\mathbf{T_1 = 34.25\ Kg\text{-}m}$$

3.5.2.11 Determination of power transmitted by belt

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

$$P_b = (T_1 - T_2) \times V_b$$

Where:

P_b = power transmitted by the belt (W)

V_b = velocity of the belt (m/s)

T_1 = tension on the tight side (N)

T_2 = tension on the slack side (N)

3.5.2.12 Bending moment (M) acting on shaft is given by

$$M = (T_1+T_2 + W) \times \text{overhang of pully}$$

Assume distance of overhang of pully (15 cm)

M= bending moment in shaft, Kg-cm

T_1 = tension in tight side of belt, 34.25 Kg

T_2= tension in slack side of belt, 13.38

W = weight of driven pully, 2.5 Kg

$$M = (T_1+T_2 + W) \times \text{overhang of pully}$$

$$M = (34.25+13.38+ 2.5) \times 15$$

$$\mathbf{M = 751.95\ Kg\text{-}cm}$$

Since the thresher shaft loading in bending and torsion, so equivalent torque (T_e) is given by

$$T_e = \{(K_m \times M)^2 + (K_t \times T)^2\}^{0.5}$$

K_m =combined shock and fatigue for bending in gradually applied load (1.5),

K_t =combined shock and fatigue for torsion in gradually applied load (1.0)

$$T_e = \{(K_m \times M)^2 + (K_t \times T)^2\}^{0.5}$$

$$T_e = \{(1.5 \times 751.95)^2 + (1.0 \times .835)^2\}^{0.5}$$

$$\mathbf{T_e = 1127.92\ Kg\text{-}cm}$$

3.5.2.13 Determination of shafts diameters

The shafts sizes were selected using the relationship given by **Hall and Hollowenko, (1982)** 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.

$$d_s^3 = \frac{16}{\pi\, fs} \{(K_m \times M)^2 + (K_t \times T)^2\}^{0.5}$$

$$d_s^3 = \frac{16}{\pi\, fs} T_e$$

F_s = Allowable shear stress for mild steel shaft,350 kg/cm^2

d_s = shaft diameter, cm

$$d_s^3 = \frac{16}{\pi \times 350} 1127.92$$

OR

$$T_e = \frac{\pi}{16} f_s . d_s^3$$

$$1127.92 = \frac{\pi}{16} \times 350 \times d_s^3$$

d_s = 2.55 cm

Consider factor of safety as (1.20)

d_s = 2.55 cm × 1.20

d_s = 3.0 cm

d_s = 30 mm

3.5.2.14 Determination of reaction on shaft mounting bearings

Weight of threshing drum = (450 N, assume)

Drum length = 500 mm

Bearing mounting distance from drum = 125 mm

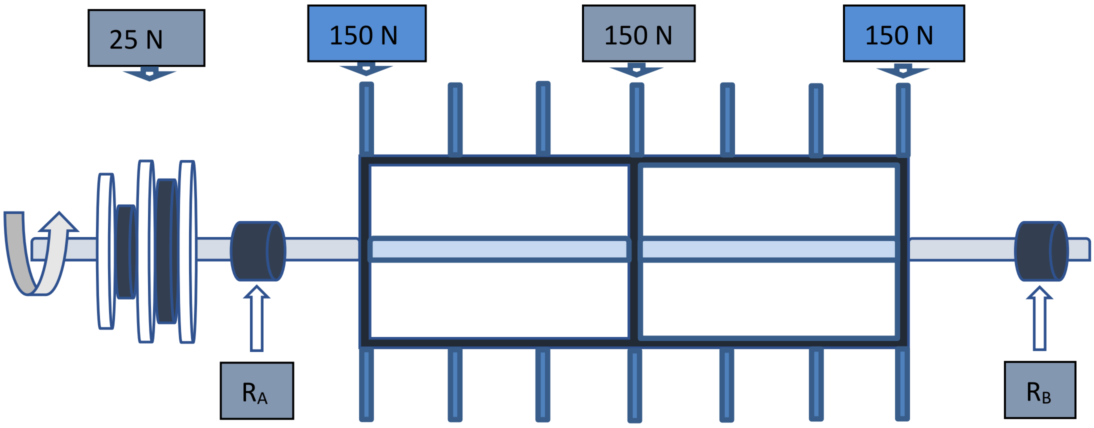

Fig. 3.7 Sketch diagram of Shaft and Cylinder

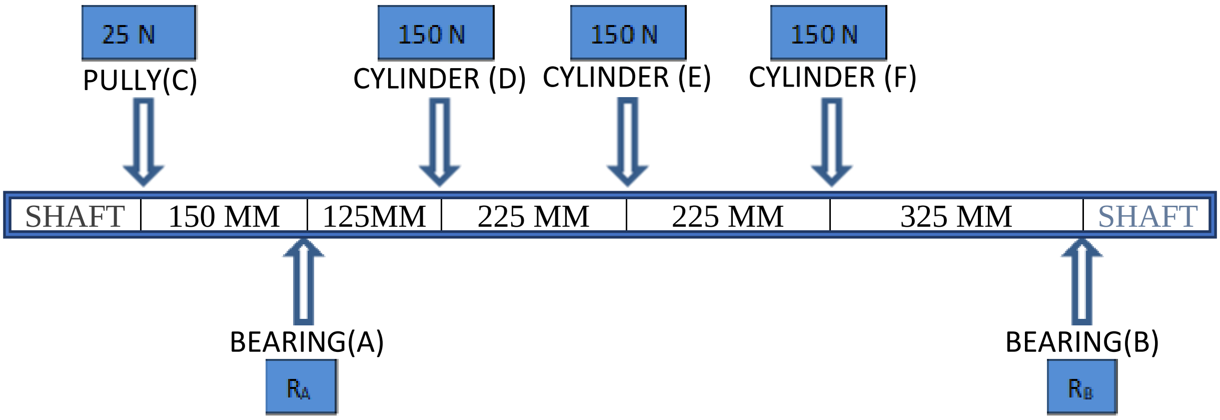

Fig. 3.8 Sketch diagram of Shaft

by taking moment at point A, we have

$R_B \times 0.90\ m + 25\ N \times 0.15\ m = 150\ N \times (0.125\ m + 0.35\ m + 0.575\ m)$

$\mathbf{R_B = 170.83\ N}$

R_A = Total load – R_B

$R_A = 475\ N - 170.83\ N$

$\mathbf{R_A = 304.17\ N}$

3.5.2.15 Shear force diagram

S.F. at C = -25 N

S.F. Between C and A remains = -25 N

S.F. at A = 304.17 - 25 N

= 279.17 N

S.F. Between A and D remains = 279.17 N

S.F. at D = 279.17 – 150 N

= 129.17 N

S.F. Between D and E remains = 129.17 N

S.F. at E = 129.17 N – 150 N

= -20.83 N

S.F. Between E and F remains = -20.83 N

S.F. at F = -150 N – 20.83 N

= -170.83 N

S.F. Between F and B remains = -170.83 N

S.F. at B = -170.83 N

3.5.2.16 Bending moment diagram

B.M. at C = 0 N-m

B.M. at A = -25 N× 0.150 m

= -3.75 N-m

B.M. at D = -25 N× (0.15 m + 0.125 m) +R_A× 0.125 m

= -25 N× 0.225 m +304.17 N × 0.125 m

= 43.64 N-m

B.M. at E = -25 N× (0.15 m + 0.125 m + 0.225 m) + R_A × (0.125 m+0.225 m)

- 150 N× 0.225 m

= -25 N × 0.450 m + 304.17 N × 0.35 m – 150 N× 0.225 m

= 61.46 N-m

B.M. at F = -25 N× (0.15 m + 0.125 m + 0.225 m + 0.225 m)

+ R_A × (0.125 m+0.225 m + 0.225 m) – 150 N× (0.225 m + 0.225 m)

- 150 N× 0.225 m

= -25 N × 0.675 m + 304.17 × 0.575 m – 150 N× 0.450 m – 150 N× 0.225 m

= 56.77 N

OR = 170.83 N× 0.325 m

= 55.52 N-m

B.M. at B = **0 N-m**

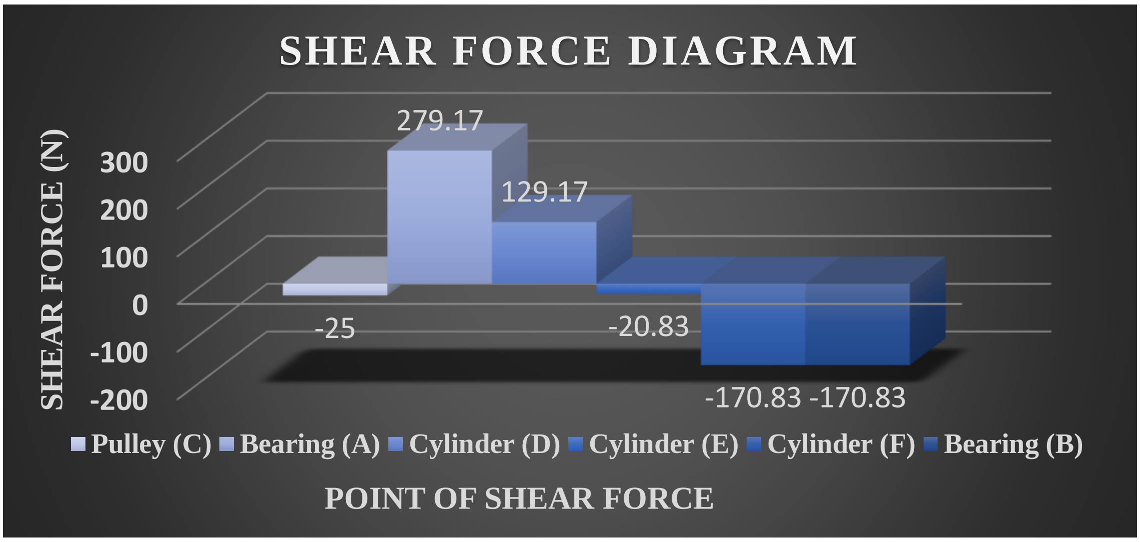

Fig. 3.9 Shear Force Diagram

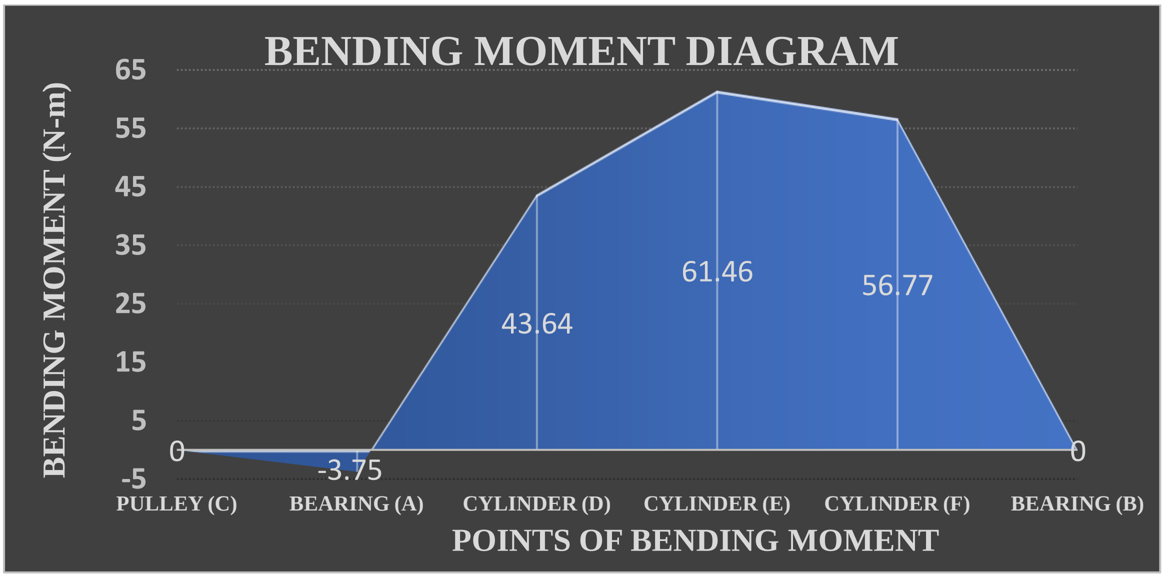

Fig. 3.10 Bending Moment Diagram

3.6 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, (%)

3.6.1Output capacity

The thresher capacity was determined using the relationship as determined by Ndirika

(1994):

$C = \frac{Q}{t}$

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

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

t = threshing time (hr)

3.6.2 Threshing efficiency

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

$T_E = 100 - (\frac{A}{Tg})$x 100

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)

3.6.3 Cleaning efficiency

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

$C_E = \frac{B}{D} \times 100$

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)

3.6.4 Scatter loss

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

$L_S = 100 - (\frac{E}{Tg}) \times 100$

Where: Ls = scatter loss (%)

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

T_g= total grain input per unit time (kg)

3.6.5 Grain Damage

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

$D_g = \frac{G}{100} \times 100$

Where: D_g= damaged grain (%)

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

3.6.6 Experimental procedure Experimental design and layout

The Green gram variety used was collected from villages of Odisha state. For the development of this threshing machine, the existing Green gram threshing machine developed earlier was studied for its performance and identification of its weakness and faults. The properties of aforementioned variety of Green gram 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 analysed eventually. Finally, the performance of the existing machine and that of the modified one were compared to assess their differences.

3.6.7 Experimental design and layout

The machine was subjected to three experimental factors, thus:

i. Concave clearance (C), at 3 levels (C1 = 10mm, C2 = 13mm and C3 = 15mm)

ii. Feed rate (F), at 3 levels. (F1 = 2 kg/min, F2 = 2.5 kg/min, and F3 = 3 kg/min)

iii. Cylinder speed (S), at 3 levels. (S1 =600 rpm, S2 = 700 rpm, S3 = 800 rpm).

The layout of the factorial experiment and the outline of the ANOVA are shown in Appendices A1 and A2. Complete Randomized Design (CRD). Four different levels of cylinder peripheral speeds; (600, 700 and 800 rpm) while three levels each of feed rates (2, 2.5, and 3 kg/min) and concave to cylinder clearances (10, 13and 15 mm) with three replications were considered for the evaluation of the developed machine using Green gram.

C1S1F1 C1S2F2 C1S3F3 C2S1F1 C2S2F2 C2S3F3 C3S1F1 C3S2F2 C3S3F3
C1S2F2 C1S3F3 C1S4F3 C2S2F2 C2S3F3 C2S4F3 C3S2F2 C3S3F3 C3S4F3
C1S3F3 C1S4F2 C1S1F1 C2S3F3 C2S4F2 C2S1F1 C3S3F3 C3S4F2 C3S1F1
RI
C1S1F1 C1S2F2 C1S3F3 C2S1F1 C2S2F2 C2S3F3 C3S1F1 C3S2F2 C3S3F3
C1S2F2 C1S3F3 C1S4F3 C2S2F2 C2S3F3 C2S4F3 C3S2F2 C3S3F3 C3S4F3
C1S3F3 C1S4F2 C1S1F1 C2S3F3 C2S4F2 C2S1F1 C3S3F3 C3S4F2 C3S1F1
RII
C1S1F1 C1S2F2 C1S3F3 C2S1F1 C2S2F2 C2S3F3 C3S1F1 C3S2F2 C3S3F3
C1S2F2 C1S3F3 C1S4F3 C2S2F2 C2S3F3 C2S4F3 C3S2F2 C3S3F3 C3S4F3
C1S3F3 C1S4F2 C1S1F1 C2S3F3 C2S4F2 C2S1F1 C3S3F3 C3S4F2 C3S1F1
RIII

Chapter : 4

RESULTS AND DISCUSSION

This chapter deals with the results on experiments on properties of green gram grain at different moisture contents and performance evaluation of the thresher. The results on the cost economics of use of the developed thresher along with the other methods have been discussed.

4.1 PROPERTIES OF GREEN GRAM

4.1.1 DIMENSIONS OF GRAINS

The linear dimensions of green gram seed were measured and presented in terms of maximum, minimum, mean and standard deviation at 5 level of moisture content (w.b.) (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3). Result shows that mean value of length, thickness and width were increase from 4.42 mm to 4.89 mm, 3.13 mm to 3.65 mm and 3.03 mm to 3.47 mm respectively with increase in grain moisture content presented in [Table-01]. Increase in grains dimensions possibly will be connected to the grain expansion which is due to the absorption of water content by the grain's intercellular gaps. And [Fig. 01] present the variation in principle dimensions of green gram variety with respect to moisture content in graphical form. It is purely showing from the Figures that the dimensions of green gram increase with increase in moisture content**.**

Table-4.1 Effect of properties of green gram grains at 5 level of moisture content.

MC (w.b.)	Length	Width	Thickness	AMD	GMD	SMD	EQD
10.31	4.42	3.13	3.03	3.41	3.47	5.66	4.22
14.35	4.48	3.20	3.09	3.48	3.54	5.76	4.29
18.3	4.60	3.35	3.22	3.62	3.67	5.98	4.46
22.53	4.74	3.49	3.34	3.74	3.81	6.18	4.61
26.17	4.89	3.65	3.47	3.89	3.96	6.42	4.79
$C.D._{(0.05\%)}$	0.05	0.03	0.024	0.02	0.02	0.063	0.03
SE(m)	0.01	0.01	0.008	0.01	0.01	0.02	0.01

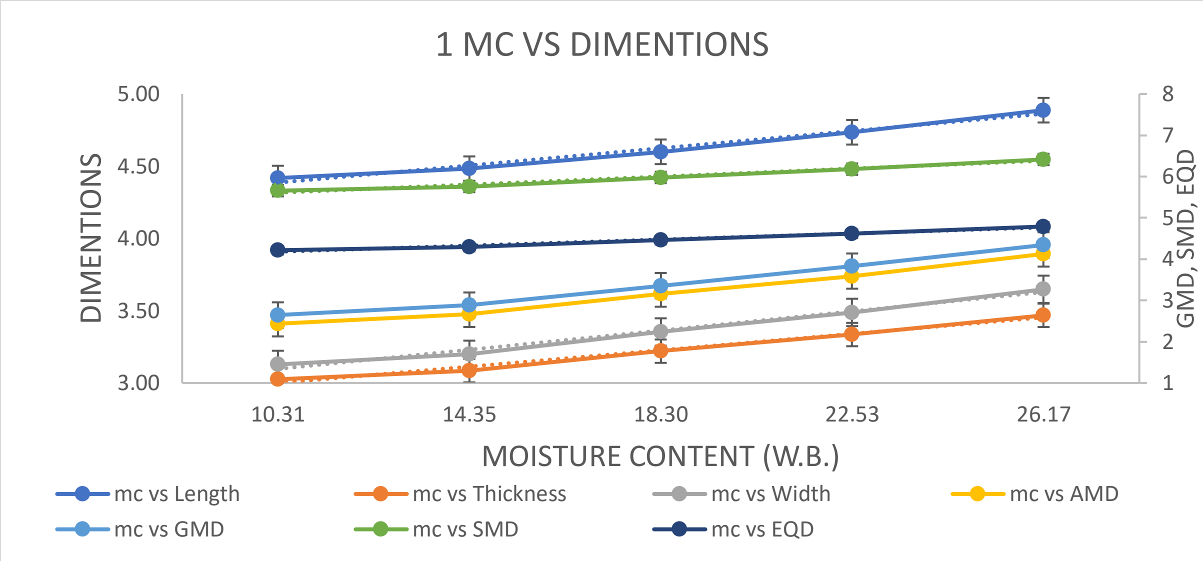

Fig: -4.1 Graphical presentation of dimensions of IPM 02-3 variety influence with Mc (w.b)

4.1.2 Arithmetic mean diameter (D_a) and Geometric mean diameter (D_g), Square mean diameter (D_s) and Equivalent diameter (D_e)

Arithmetic mean diameter D_a and geometric mean diameter D_g of the green gram grains were increased with increase in moisture content (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3). Also, square mean diameter (D_s) and equivalent diameter (D_e) of the grains were increased with increase in moisture content which is presented in [Table-1]. is due to the increased principle dimensions of the grains. and [Fig 01] shows the effect of moisture content on AMD, GMD, SMD and EQD of green gram with standard error bar. Also, regression analysis was taken for prediction of effect of moisture content.
Following regression equations create for predicting the variation in grain dimensions which are function of moisture content.

$L = 0.0298Mc + 4.0781, R^2 = 0.9776$
$W = 0.0333Mc + 2.7528, R^2 = 0.9835$
$T = 0.0284Mc + 2.7054, R^2 = 0.9847$
$D_a = 0.0308Mc + 3.0619, R^2 = 0.9821$
$D_g = 0.031Mc + 3.1198, R^2 = 0.9838$
$D_s = 0.1934Mc + 5.418, R^2 = 0.9852$
$D_e = 0.147Mc + 4.0328, R^2 = 0.9855$

4.1.3 Sphericity (S_P), Aspect ratio (R_A) and Volume (V_{grain})

Sphericity of green gram increased with increase in moisture content 5 levels (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3) and (9.30%, 13.70%, 18.30%, 21.90% and 25.10% for JYOTI) on (w.b.). and change from 0.708 to 0.746. aspect ratio is also representing the shape of the grain and varied from 0.786 to 0.809 presented in [Table-02]. Sphericity and aspect ratio both are not influence much on variation of moisture content. Also, volume of grain increases from 8.12 mm^3 to 11.87 mm^3 with increase in moisture of grains presented in [Table-03]. Increase in sphericity, aspect ratio and volume of green gram was presented below by the regression (R^2) equation:

$S_P = 0.0015Mc + 0.7697, R^2 = 0.9747$
$R_a = 0.0025Mc + 0.681, R^2 = 0.9775$

4.1.4 Bulk density, True density

Bulk density and true density of green gram found experimentally at 5 moisture levels (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3) (wet basis) from 754.08 $kg.m^3$ to 713.55 $kg.m^{-3}$, and 1335.38 $kg.m^{-3}$ to 1300.08 $kg.m^{-3}$ respectively. The bulk density was found lower than true density at the same moisture content. The following regression equations were created for examination of bulk density and true density. And [Fig: 02] shows variation in bulk density and true density test were also showing that decreasing in bulk and true density of green gram is the function of increasing in principle dimensions.

$\rho b = -9.995Mc + 763.2, R^2 = 0.9979$
$\rho t = -8.7425Mc + 1342.2, R^2 = 0.9867$

Table-4.2 Effect of properties of green gram grains at 5 level of moisture content.

MC(w.b.)	Aspect ratio	Surface area	Sphericity	Test weight	True density	Bulk density	Density Ratio	Porosity
10.31	0.708	37.83	0.786	35.51	1335.38	754.08	0.57	43.53
14.35	0.713	39.29	0.789	37.23	1323.40	742.13	0.56	43.92
18.3	0.729	42.44	0.799	38.96	1314.58	733.10	0.56	44.23
22.53	0.736	45.48	0.803	41.14	1306.58	723.23	0.55	44.64
26.17	0.746	49.45	0.809	43.37	1300.08	713.55	0.55	45.12
$C.D._{(0.05\%)}$	0.007	0.556	0.006	0.16	1.15	1.25	0.001	0.088
SE(m)	0.002	0.179	0.002	0.05	0.37	0.40	0	0.028

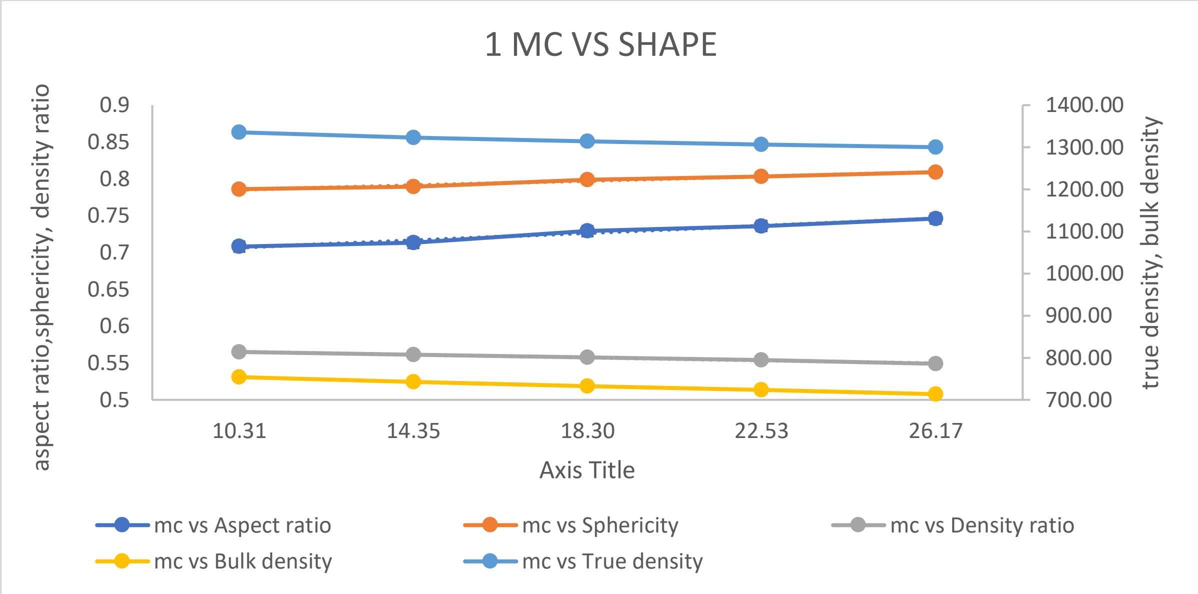

Fig: -4.2 Graphical presentation of properties of IPM 02-3 variety influence with Mc (w.b.)

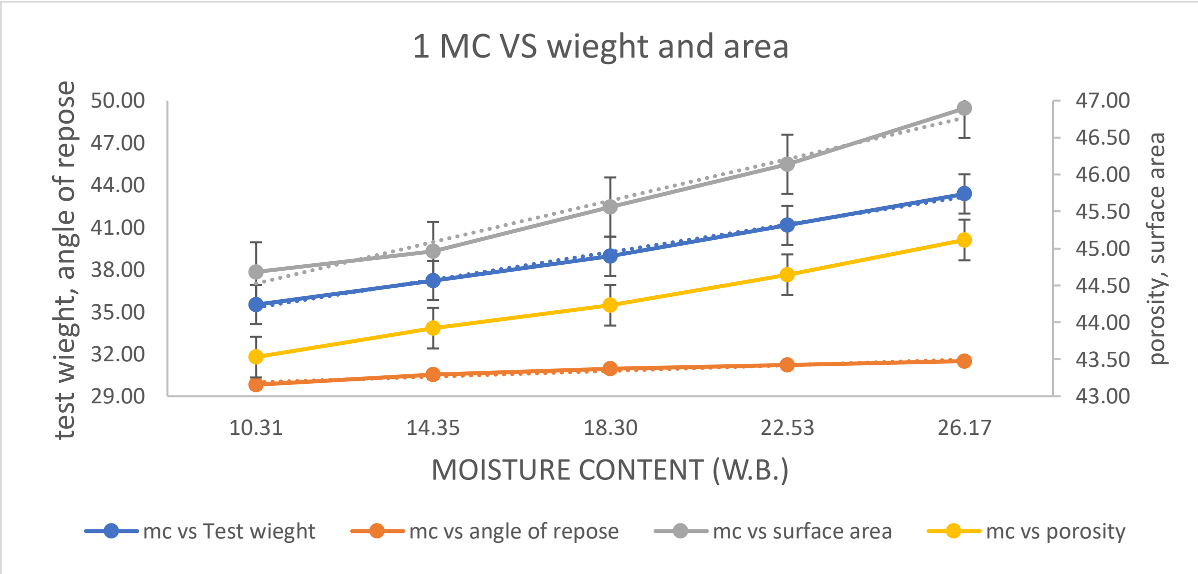

Fig: -4.3 Graphical presentation of properties of IPM 02-3 variety influence with Mc (w.b.)

4.1.5 Density ratio (R_d)

Density ratio also calculated by using the values of the bulk density and true density. Is the ratio of bulk density and true density, ratio was not much influence but decrease from 0.57 to 0.55 with increase in moisture content variation shows in [Table-02] is the function of bulk density and true density. regression equations presented the variation in density ratio as follow: $R_d = -0.0039Mc + 0.5691$, $R^2 = 0.9928$

4.1.6 Porosity

porosity was found by using the values of the bulk density and true density. the porosity was increased from 43.53% to 45.12% with respect to 5 moisture content levels from 9.30% to 26.17% (w.b.) [Fig: 03] shows variation in porosity. by developing the equation porosity was observed increase with varying moisture content which is due to the elongation in the length of the grains. The relationship of the moisture and porosity of the green gram was shows below, has regression equation:

$\epsilon = 0.3889Mc + 43.123$, $R^2 = 0.995$

4.1.7 Test weight W_{1000}

Test weight is the weight of green gram varieties at different moisture (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3) varied from 35.51g to 43.37 g. as the moisture content increased from 9.30% to 26.17% w.b. [Fig: 03]. The increase in thousand grain weight with increase in moisture content might be due to increase in water content of green gram. Similar results have been shows for soybean (Deshpande et al. 1993), black gram (Munde et al. 1999) and paddy (**Ravi and Venkatachalam 2014**). The equation with R^2 values shows the relationship of moisture content with test weight is as follows:

$W_{1000} = 0.4918Mc + 30.225$, $R^2 = 0.9942$

4.1.8 Surface area (A_S)

Surface area of the green gram were increased linearly with increase in moisture content as shown in [Figures- 03] for different varieties. Variation in values of the surface area at the moisture content of (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3) is from 37.83 to 49.45 mm^2. increase in surface area with respect to moisture is due the absorption of moisture content by the grains which contributes by the small increase in grain length. Many of the researcher shows same leaning discussed earlier. The bond of surface area, as of green gram varieties with moisture content can be expressed by the following linear equation with regression equation

$A_S = 0.7357Mc + 29.41$, $R^2 = 0.975$

Table-4.3 Effect of properties of green gram grains at 5 level of moisture content.

MC(w.b.)	volume	Angle of repose	Stainless steel	Galvanized iron	Wood	Aluminium	Terminal velocity
10.31	8.12	29.83	0.255	0.295	0.305	0.266	7.24
14.35	8.58	30.53	0.294	0.345	0.356	0.314	7.40
18.3	9.58	30.95	0.316	0.380	0.384	0.333	7.56
22.53	10.60	31.23	0.336	0.371	0.401	0.354	7.70
26.17	11.87	31.50	0.353	0.398	0.465	0.366	7.84
C.D.$_{(0.05\%)}$	0.203	0.070	0.002	0.025	0.027	0	0.024
SE(m)	0.065	0.022	0.001	0.008	0.009	0	0.008

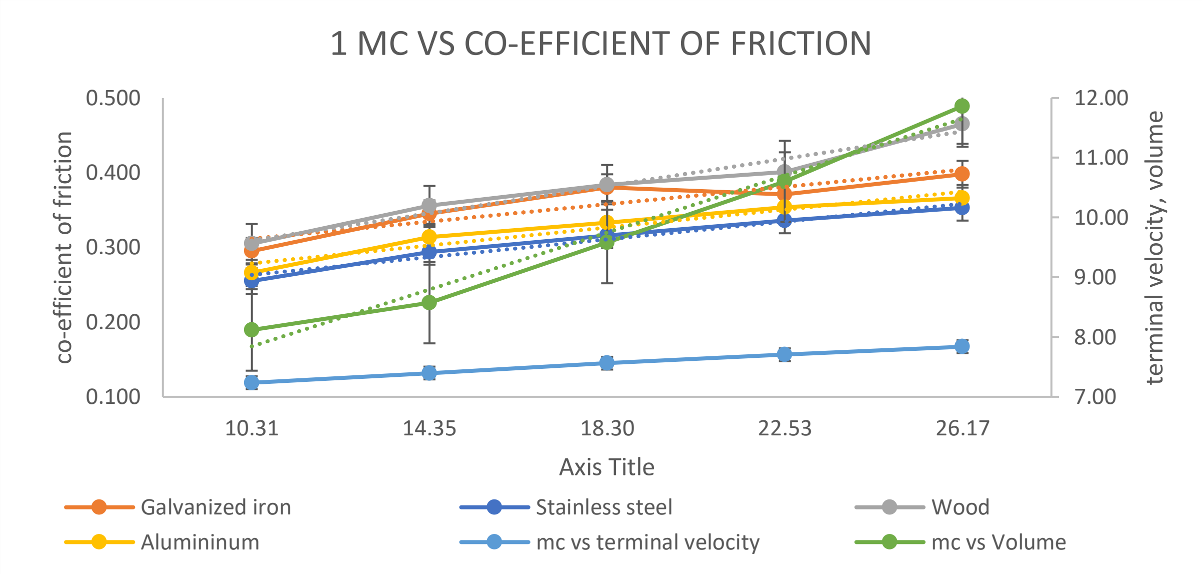

Fig: -4.4 Graphical presentation of properties of IPM 02-3 variety influence with Mc (w.b.)

4.1.9 Angle of repose (θr)

Angle of repose θ of green gram increase with increase in 5 moisture content levels (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3) ranged from 29.83º to 31.50º is presented below in graphical form [Fig: 03]. and the regression(R^2) equation also developed for checking of variation in angle of repose of green gram variety:

θr = 0.1016Mc + 28.942, R^2 = 0.9564

4.1.10 Coefficient of friction (μ)

Coefficient of static friction of green gram effected by moisture content against various experimental surfaces (stainless steel, galvanized iron, wood and aluminium) is shows in [Fig: 04]. Figure shows that mean of the static coefficient of friction of green gram increased with increase in 5 moisture content level from 10.31% to 26.17%(w.b.), also function of surface material as. for change in moisture contents respectively. Wood surface create maximum friction, followed by galvanized iron, aluminium and stainless steel. This variation is due to roughness of surface material and cohesive force between grains and test surfaces like wood which has more static friction as compared to other 3 surface. variations in coefficient of friction due to change in moisture content of green gram on different surface are predicted by regression equations as:

μ_{wood} = 0.0091Mc + 0.2151, R^2 = 0.9545

μ_{GI} = 0.0058Mc + 0.2514, R^2 = 0.8398

μ_{Al} = 0.006Mc + 0.2161, R^2 = 0.9369

μ_{St} = 0.006Mc + 0.2013, R^2 = 0.9724

4.1.11 Terminal velocity (V_t)

Terminal velocity V_t increase with increase at 5 moisture content level (10.31%, 14.35%, 18.30%, 22.53% and 26.17% for IPM 02-3) (wet basis) varied from 7.24 to 7.84 ms^{-1} is presented in [Fig: 04]. Which shows that terminal velocity is the function of moisture content because of grains getting weight while gaining moisture. Regression(R^2) equation was also developed for predicting variation in terminal velocity.

$Vt = 0.0379Mc + 6.8532, R^2 = 0.9982$

4.2. Effects of variable factors on the machine performance

Table-4.4 Performance of thresher in rotary mode at no load condition

	Parameters	Duration (hrs)							Mean
SI No.		Initial	0.50	1.00	1.50	2.00	2.50	3.00	
1	Draft (N)	-	218.00	220.00	225.00	226.00	235.00	236.00	226.67
2	Speed (Kmh^{-1})	-	3.11	2.99	2.87	2.73	2.45	2.38	2.76
3	RPM of Thresher	600	600.00	600.00	600.00	600.00	600.00	600.00	600.00
4	Power output	-	0.25	0.25	0.23	0.22	0.22	0.20	0.23

Table-4.5 Performance of thresher in rotary mode at load condition

	Parameters	Duration (hrs)							Mean
SI No.		Initial	0.50	1.00	1.50	2.00	2.50	3.00	
1	Draft (N)	-	522.00	515.00	510.00	498.00	490.00	485.00	503.33
2	Speed (Kmh^{-1})	-	2.59	2.45	2.35	2.32	2.33	2.30	2.39
3	RPM of Thresher	-	565.00	555.00	545.00	550.00	560.00	550.00	554.17
4	Peripheral Velocity (ms^{-1})	-	7.09	7.13	7.20	7.21	7.25	7.05	7.16
5	Power output	-	0.49	0.49	0.50	0.48	0.47	0.46	0.48

4.2.1 Study on 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 8.3 m/s (700 rpm) and a feed rate of 2.5 kg/min while the maximum was also at a speed of 8.0 m/s and a feed rate of 2 kg/min (Appendix C2). 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; 6.0 and 7.0 m/s are statistically equal but speed level 8.3 m/s are greater. The feed rates level; 2 and 3kg/min were statistically not equal, with feed rate 3kg/min having contributed least to the threshing efficiency. Similarly, concave clearance 15mm and 13mm were statistically equal but greater than that of 10mm. A combination of speed level of 8.3m/s and 3kg/min feed rate were ranked the best interaction and may be the best treatment combination for the thresher.

Feed rate	2 Kg/min	2.5 Kg/min	3.0 Kg/min
RPM			
600	93.00	94.00	96.00
700	96.00	95.00	97.00
800	97.00	96.00	96.00

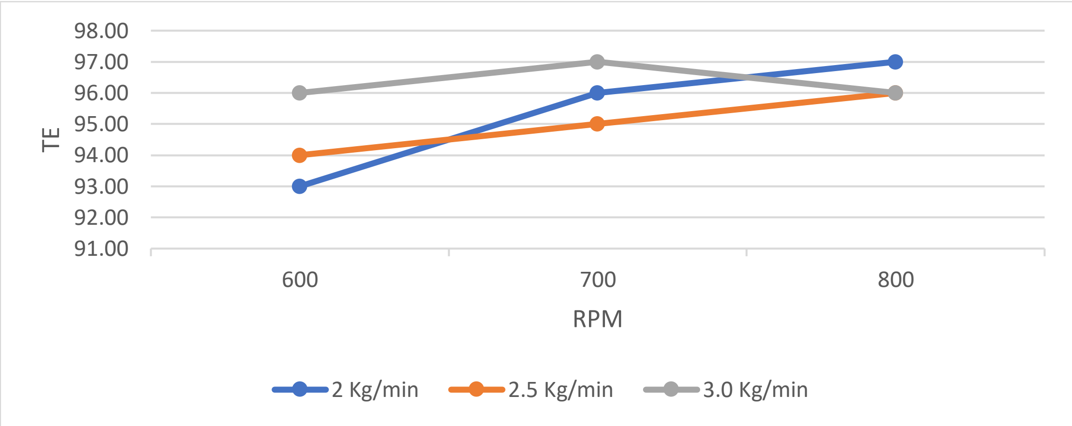

Fig. 4.5 Effects of cylinder speed on threshing efficiency at three feed rates

Table 4. 6: Analysis of Variance for the Green gram Threshing Efficiency

SV	DF	SS	MSS	Fcal	Ftab 5%	Ftab 1%
Replication	3	0.45	0.22	1175.93	3.13	4.92
Speed	3	3.28	1.093	5754.39	2.74	4.08
Feed rate	3	34.918	17.455	91889.38	3.13	4.92
Clearance	3	6.485	3.242	17064.81	3.31	4.92
S × F	3	14.287	2.381	12532.65	2.23	3.07
S×C	3	12.772	2.129	11203.22	2.23	3.07
F×C	3	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	.00019			
Total	107	109.139				

4.2.2 Study on effects of cylinder speed on threshing efficiency at three concave clearances

The threshing efficiency shows an increasing pattern with increase in concave clearance (appendix C2). It was also observed that 13mm concave clearance gave a greater threshing efficiency than 10 and 15 mm in the overall threshing efficiency of the machine. because efficiency in 10 mm clearance grain damage percent is higher due to inconvenience of threshing and at 15 mm clearance grains are remain unthreshed so why this 13 mm clearance is well efficient. 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 8.3 (700) m/s and 13 mm concave.

Concave Clearance	10MM CLC	13MM CLC	15MM CLC
RPM			
600	94.00	96.00	94.00
700	95.00	97.00	94.00
800	96.00	97.00	95.00

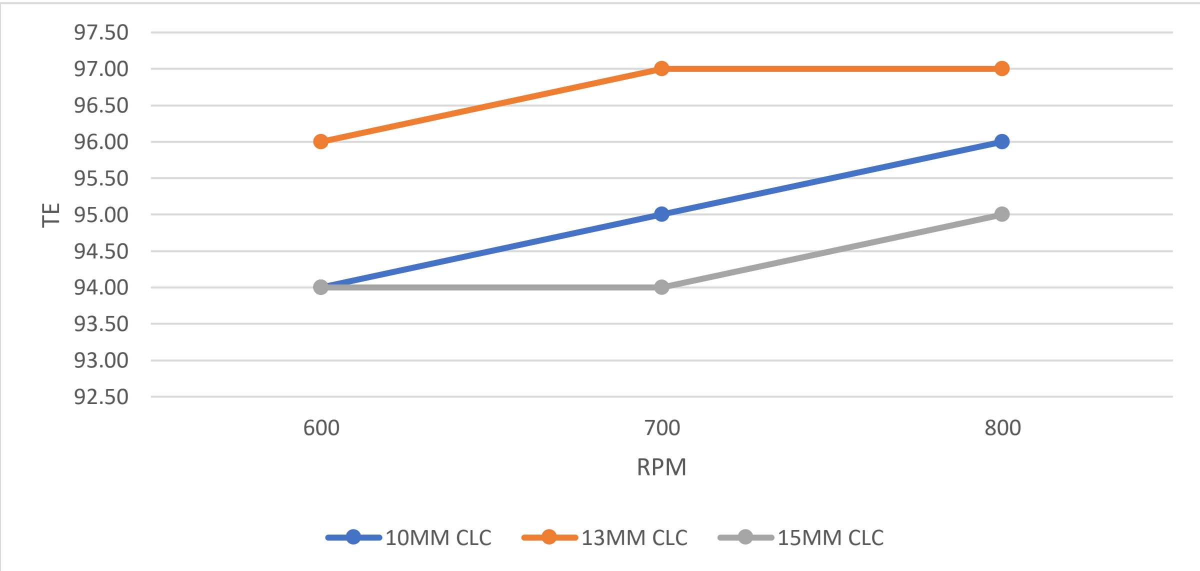

Fig:4.6 Effects of cylinder speed on threshing efficiency at three concave clearances

4.2.3 Study on 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 6.5 m/s (500 rpm) and 9 m/s (800 rpm) respectively. The minimum cleaning efficiency was obtained at a feed rate of 2.5 kg/min while the maximum was at 3 kg/min (Appendix C2). 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 9 m/s has the highest effect and was ranked the best followed by 8 m/s and so on. Likewise, the feed rates levels exhibit the same that 2 and 3kg/min, 3 and 4 kg/min were statistically equal though 3 kg/min was greater than 2.5 kg/min (Appendix D). The interaction between the speed and the feed rates further indicated that the combination of speed level 8.3 m/s and a feed rate level of 3kg/min gives the best cleaning efficiency for the threshing process.

Feed rate	2 Kg/min	2.5 Kg/min	3.0 Kg/min
RPM			
600	95.00	95.00	96.00
700	96.00	95.00	97.00
800	96.00	95.00	96.00

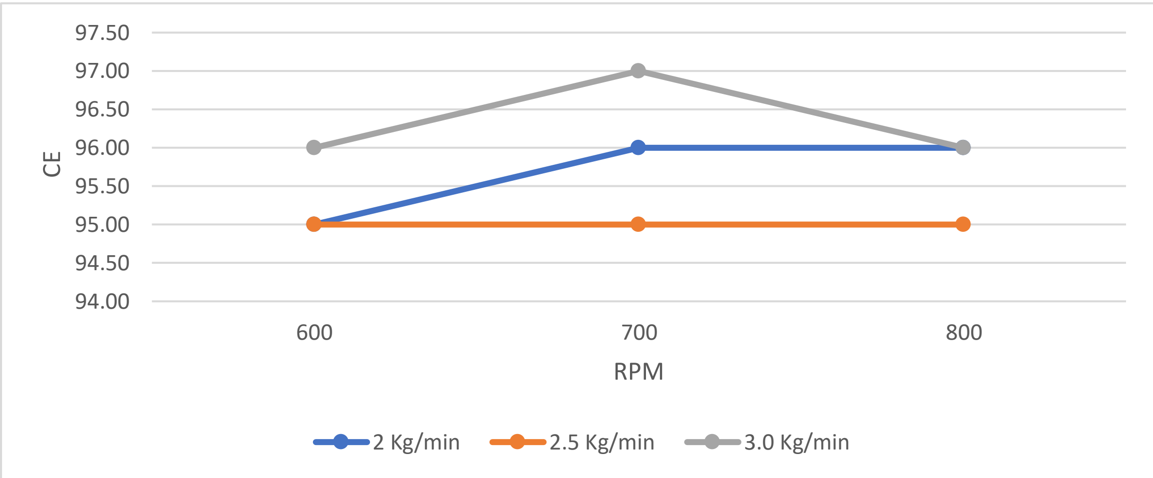

Fig. 4.7 Effects of cylinder speed on Cleaning efficiency at three feed rates

Table 4. 7: Analysis of Variance for the Green gram Cleaning Efficiency

SV	DF	SS	MSS	Fcal	Ftab5%	Ftab1%
Replication	3	10.85	5.43	0.66NS	3.13	4.92
Speed	3	469.476	156.492	18.93	2.74	4.08
Feedrate	3	220.954	110.477	13.36	3.13	4.92
Clearance	3	4.954	7.477	0.90NS	3.13	4.92
S × F	3	220.048	37.008	4.48	2.23	3.07
S×C	3	70.052	11.675	1.41NS	2.23	3.07
F×C	3	41.100	10.275	1.24NS	2.5	3.6
S×F×C	12	419.703	34.975	4.23	1.89	2.45
Error	70	578.679	8.266			
Total	107	2047.820				

4.2.4 Study on 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 result 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).

Concave Clearance	10MM CLC	13MM CLC	15MM CLC
RPM			
600	93.00	95.00	93.00
700	93.00	97.00	95.00
800	95.00	96.00	94.00

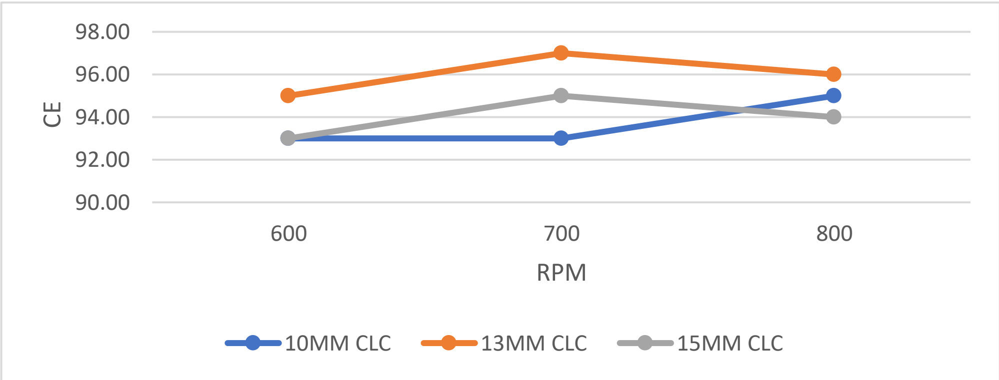

Fig. 4.8Effects of cylinder speed on Cleaning efficiency at three concave clearances

4.2.5 Study on effects 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 6.5 m/s and feed rate level of 2.5 kg/min and speed level 7 m/s and feed rate level 3 kg/min, while the maximum occurs at a speed level of 8 m/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).

Feed rate	2 Kg/min	2.5 Kg/min	3.0 Kg/min
RPM			
600	0.80	1.00	1.05
700	1.20	1.10	1.10
800	1.50	1.25	1.30

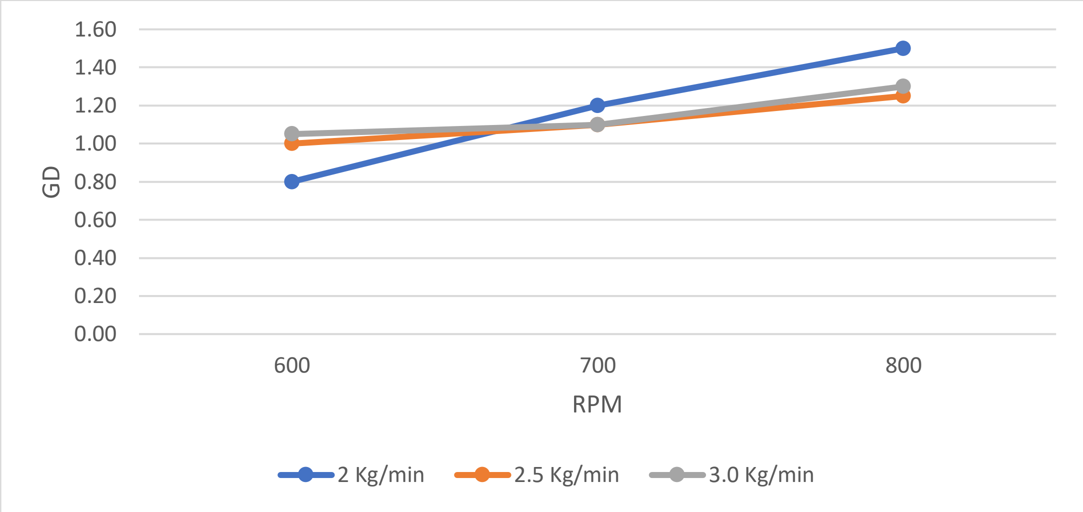

Fig. 4.9Effects of cylinder speed on Grain damage at three feed rates

Table 4. 8: Analysis of Variance for the Green gram Grain Damage

SV	DS	SS	MSS	Fcal	Ftab5%	Ftab1%
Replication	3	0.10	0.05	0.07NS	3.13	4.92
Speed	3	5.074	1.691	2.25NS	2.74	4.08
Feedrate	3	3.034	1.517	2.02NS	3.13	4.92
Clearance	3	4.410	2.205	2.94NS	3.13	4.92
S×F	3	5.518	0.920	1.23NS	2.23	3.07
S×C	3	41.749	6.958	9.27	2.23	3.07
F×C	3	6.064	1.516	2.02NS	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 15-mm cylinder to concave clearances (appendix C2), 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 is statistically not equal with a combination of speed level 6.5 m/s and cylinder concave clearance 10mm may be the best in terms of contributing least to grain damage for the threshing process.

Concave Clearance	10MM CLC	13MM CLC	15MM CLC
RPM			
600	1.10	1.00	1.10
700	1.05	0.80	0.90
800	1.20	0.90	1.00

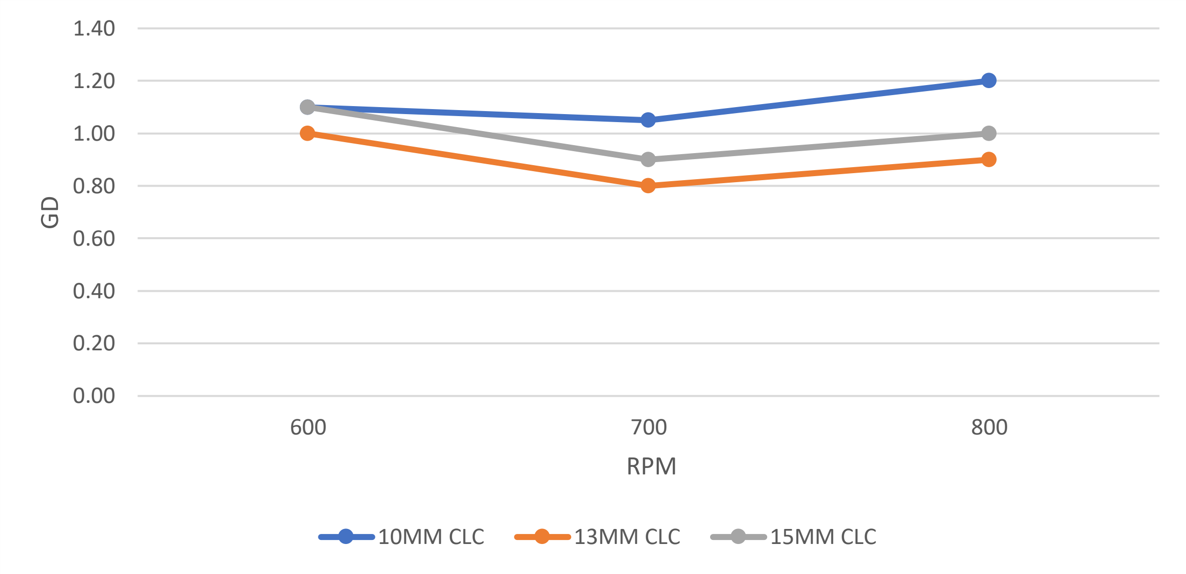

Fig. 4.10 Effect of cylinder speed on grain damage at the three concave clearances

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

A maximum scattered loss of 2.9 % was obtained at a speed of 9 m/s (800rpm) with a feed rate of 2kg/min while a minimum of 0.36 % was obtained at the same speed of 9 m/s and feed rate of 3kg/min (Appendix C2). 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 9 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. However, this signifies that a speed level of 7 m/s and feed rate of 5 kg/min could give the best in terms of minimum scattered losses.

Table 4. 9: Analysis of Variance for the Green gram Scatter Loss

SV	DS	SS	MSS	Fcal	Ftab5%	Ftab1%
Replication	3	0.31	0.15	2.15NS	3.13	4.92
Speed	3	2.089	0.695	9.72	2.74	4.08
Feedrate	3	3.717	1.858	25.97	3.13	4.92
Clearance	3	0.560	0.280	3.91	3.31	4.92
S × F	3	4.422	0.737	10.30	2.23	3.07
S×C	3	1.292	0.251	3.01	2.23	3.07
F×C	3	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				

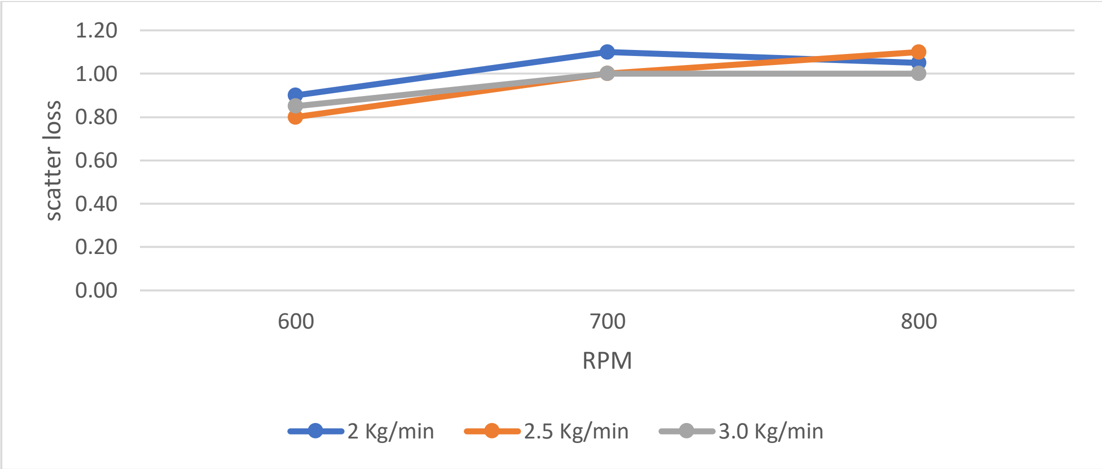

Fig. 4.11Effect of cylinder speed on Scatter loss at the three-feed rate.

Feed rate	2 Kg/min	2.5 Kg/min	3.0 Kg/min
RPM			
600	0.90	0.80	0.85
700	1.10	1.00	1.00
800	1.05	1.10	1.00

4.2.8 Study on effects 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 15mm 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 C2). 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 15 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 15 mm were statistically equal though 10 mm was greater than 15 mm in terms of higher losses. However, it implies that 15mm clearance could be the best in terms of minimum scatter loss. The analysis also showed that a combination of speed level 6.5 m/s and the cylinder concave clearance of 13mm gives the best in terms of minimum scatter loss.

Concave Clearance	10MM CLC	13MM CLC	15MM CLC
RPM			
600	1.10	0.90	0.90
700	0.98	0.80	0.95
800	1.00	0.90	1.00

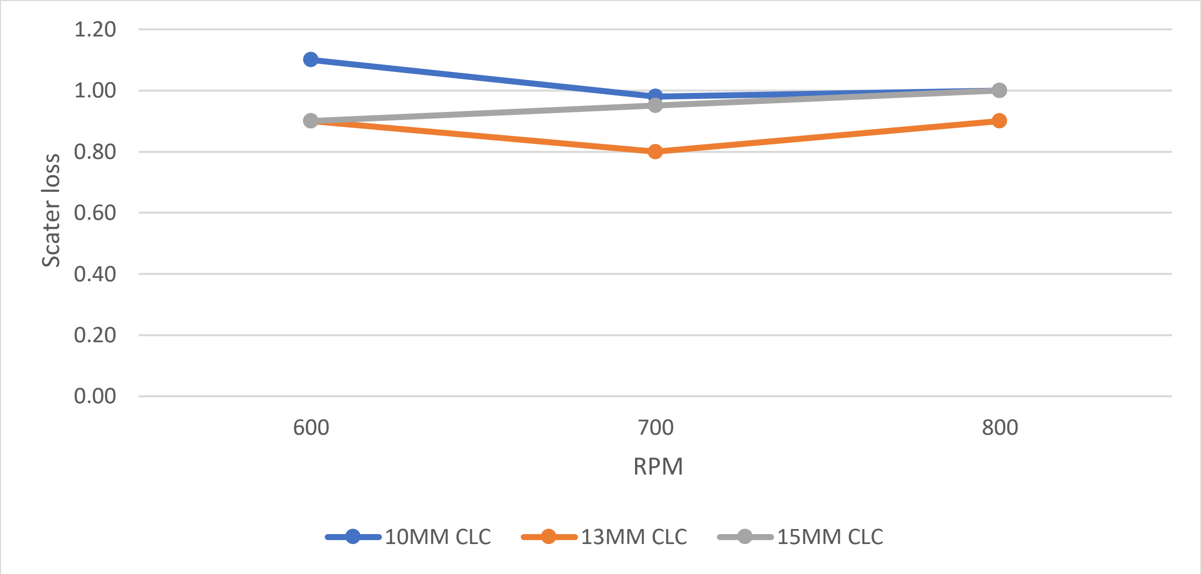

Fig. 4.12 Effect of cylinder speed on Scatter loss at the three-concave clearances

4.2.9 Study on effects 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 8 m/s (700 rpm) and a feed rate of 3 kg/min while a minimum of 30.92 kg/hr was obtained at a speed of 6.5 m/s (500 rpm) with a feed rate of 2 kg/min (Appendix C2). 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 analysed, the speed levels; 6.5 and 7 m/s were statistically equal, while 9 and 7.5 m/s were statistically not equal. Likewise, feed rate level 2 and 3kg/min were statistically equal, with 3 kg/min being greater. The interaction between the speed and the feed rate indicated that speed level 9 m/s and feed rate level 3 kg/min gave the best output capacity.

Feed rate	2 Kg/min	2.5 Kg/min	3.0 Kg/min
RPM			
600	30.00	50.00	65.00
700	35.00	55.00	68.00
800	32.00	55.00	70.00

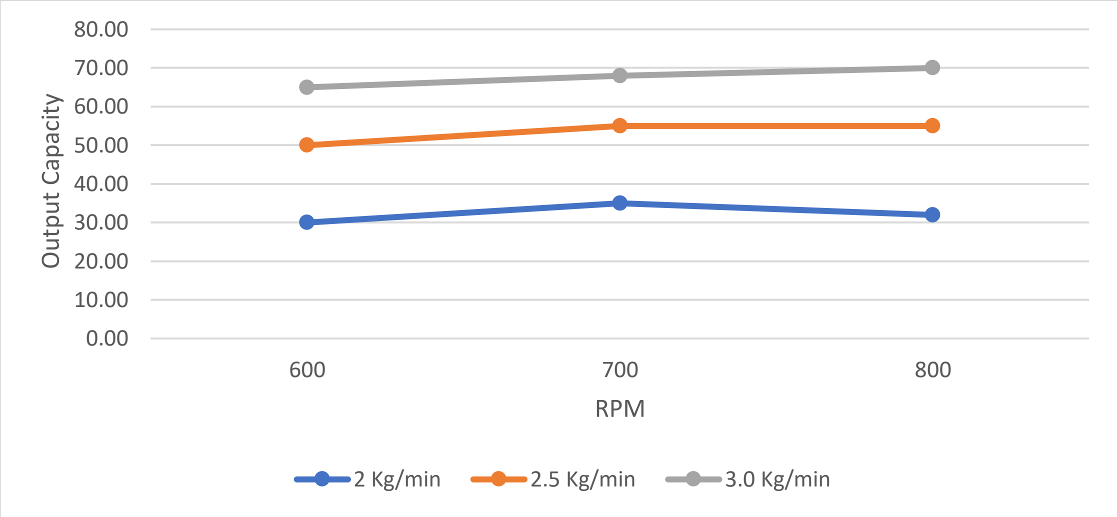

Fig. 4.13 Effect of cylinder speed on Output Capacity at the three-feed rate

Table 4. 10: Analysis of Variance for the Green gram Output Capacity

SV	DF	SS	MSS	Fcal	Ftab5%	Ftab1%
Replication	3	1496.62	748.21	16.42	3.13	4.92
Speed	3	22704.394	7568.131	166.06	2.74	4.08
Feedrate	3	2613.886	1306.943	28.68	3.13	4.92
Clearance	3	1074.361	537.18	11.79	3.13	4.93
S × F	3	2756.361	459.398	10.08	2.23	3.07
S × C	3	2655.870	442.645	9.71	2.23	3.07
F × C	3	998.333	249.583	5.48	2.5	3.6
S×F×C	12	10087.37	840.613	18.44	1.89	2.45
Error	70	3190.308	45.57583			
Total 8	107	47577.318				

4.2.10 Study on effects of cylinder speed on output capacity at the three concave clearances

The output capacity shows an increased with increase in concave clearance. This could be related to the actual crop requirement that the 15 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, 15 and 10mm clearance were statistically equal, with 15mm being greater. Combination of speed level 9 m/s and concave clearance 15 also gave the best output capacity for the threshing operation.

Concave Clearance	10MM CLC	13MM CLC	15MM CLC
RPM			
600	31.00	52.00	68.00
700	34.00	58.00	70.00
800	30.00	55.00	65.00

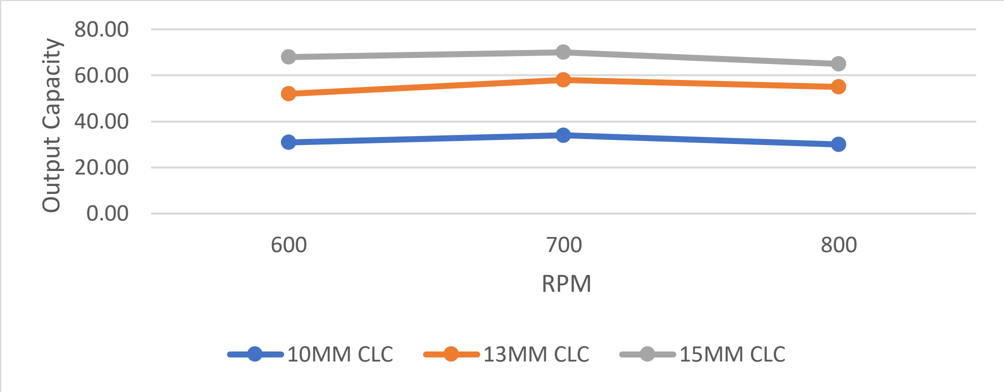

Fig. 4.14Effect of cylinder speed on Output Capacity at the three-concave clearance

4.3 Economic evaluation of thresher

The economic evaluation of the developed thresher was done with comparison to the traditional method to make acceptable by the farmers. The machine cost was calculated as Rs 40000 without motor. And the total operating cost of the machine operated in rotary mode was calculated as Rs 150/ h and operating cost for threshing of one Kg of pulse (green gram/ black gram) by the developed pulse thresher was Rs 1.54 /Kg. when operated with the help of single phase 1 hp motor the total operating cost of machine was Rs 80.50/h and 0.90/Kg of grain. In case of traditional method, it was coming around Rs 30.40/h and Rs 5.50/Kg for hand beating method but in case of foot trampling method it was about Rs 4.80 which is costlier as compare to the developed pulse thresher. There was a saving of 60-70 %of operational cost through the developed pulse thresher with compare to local method of threshing and the comparison between different types of threshing was shown in fig 4.7

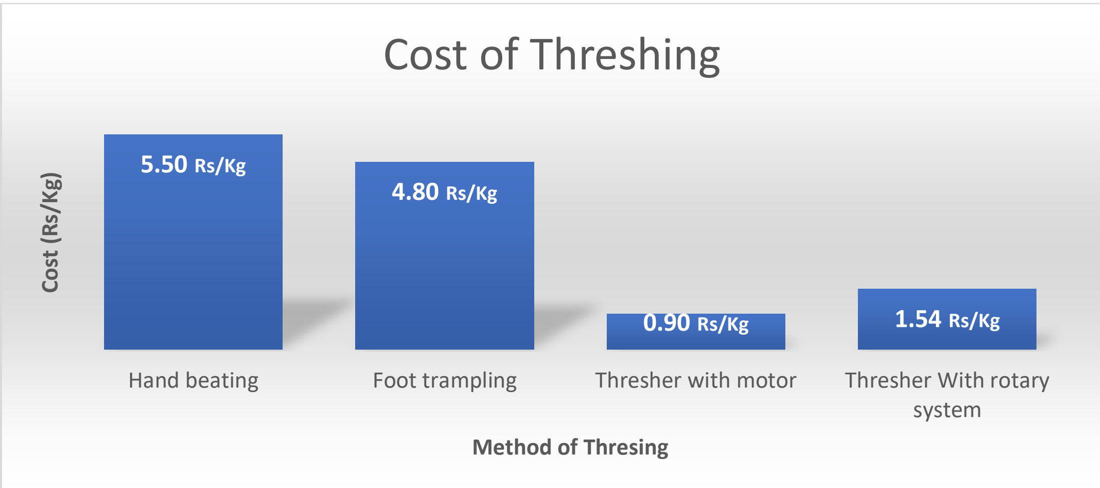

Fig: -4.15 Costing of Threshing of different methods

Chapter : 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Green gram is scientifically known as *Vigna radiata* and it is commonly known as *Mung or mungbean* in India, and believed to be originated from India. It is commonly known as Mung in India. It is a short duration legume crop grown mostly as a fallow crop in rotation with rice. Similar to the leguminous pulses, green gram, enriches soil nitrogen content. It is grown mostly in Asian region traditionally while its cultivation has spread to Africa and Americas relatively in the recent times. More than 70% of world's green gram production comes from India is excellent source of high-quality protein. similar to other pulses, mung is grown primarily for its protein rich seeds. Mung contains 20-25% protein. Moong is consumed as whole grains, sprouted form as well as dhal in a variety of ways in homes. Mungbam is a leguminous crop. It has the capacity to fix atmospheric nitrogen through symbiotic nitrogen fixation, being a short duration crop it make available an excellent green fodder to the animals. also used as green manuring crop. Improved variety resistance to pod shattering and to maintain the level of all other trait's 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 crop were determined at various moisture contents. The average length, width and thickness of Green gram grains ranged from (length: 4.42 – 4.89 mm, width:3.13 – 3.63 mm, thickness:.03 – 3.47 mm as the moisture content increased from 10.31 to 26.17%. respectively. The geometric mean diameter increased from AMD: 3.41 – 3.89 mm, GMD: 3.47 – 3.96 mm, SMD: 5.66 – 6.42 mm, EQD: 4.22 – 4.79 mm, test weight: 35.51- 43.37 gm, volume: 8.12 mm^3 - 11.87 mm^3, surface area37.83 - 49.45 mm^2. angle of repose: 29.83º- 31.50º, porosity: 43.53- 45.12%, co-efficient of friction on - (stainless steel: 0.255-0.353, galvanized iron: 0.295- 0.398, wood: 0.305- 0.465, aluminium: 0.266-0.366) and terminal velocity: 7.24-7.84 ms^{-1}Respectively. But the true density, bulk density and density ratio decreased with increase in moisture content in the range of (true density: 1335.38- 1300.08 $Kg.m^{-3}$ and bulk density: 754.08- 713.55 $Kg.m^{-3}$ and density ratio: 0.57-0.55). And sphericity and aspect ratio not influence at greater level which were presented later, while ranged in (sphericity: 0.786- 0.809 and aspect ratio: 0.708- 0.746). study shows that co-efficient of friction is also the function of surface area, texture of grain and varied with material of sliding surface. And porosity of fine(heavy) texture (small sized seed) is higher than light texture (large sized seed) also finds in experiment tests. This study presented with a view of trying to show variation in properties of green gram which is dependent parameters of this study by the effect of independent parameters moisture and variety of green gram.

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 3 kg/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, frictional and aerodynamic property like length, thickness, width, aspect ratio, arithmetic mean diameter(AMD), geometric mean diameter(GMD), square mean diameter (SMD) and equivalent diameter (EQD) surface area, sphericity, test weight, true density, bulk density, density ratio, volume, porosity, angle of repose, co-efficient of friction and terminal velocity of variety (independent) of green gram were studied.

2) A Green gram thresher was designed, constructed and evaluated using the locally available materials. The best performance of the developed thresher was obtained at a speed of 7.5 m/s (600 rpm) at a feed rate level of 2.5 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 55.96 kg/hr respectively.

3) In comparison with the Green gram thresher developed in past, 99.0 %, 95 %, 1.01 %, 2.7 % and 25.5 kg/h), it showed that the overall performance of the this machine (99.97 %, 97.64 %, 0.86 %, 1.0 % and 55.96 kg/h) is better than that of the existing machine in case of rotary system and good for marginal and small farmer of the Odisha state. therefore, an improvement has been achieved in CAET, OUAT Bhubaneswar 751003.

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 the volume of air to blow off the chaffs and hence improving the cleaning efficiency.

3) Further studies to evaluate the machine using others Green gram varieties should be conducted.

4) An on-farm trail of the improved thresher should be carried out by the farmers for 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 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 B: Data for the Evaluation of the Green gram Thresher

Appendix B1: Average Experimental Data for the Evaluation of the Green gramThresher

S/N	TRTM	CRC (mm)	SPD (RPM)	FDRT (kg)	T (s)	D (kg)	A (kg)	B (kg)	LS (kg)	G (g)
1	S1F1C1	10	600	2.0	40.00	0.62	0.15	0.15	0.60	15
2	S1F2C1	10	600	2.5	50.00	0.72	0.20	0.20	0.75	13
3	S1F3C1	10	600	3.0	60.00	1.2	0.20	0.20	0.80	14
4	S2F1C1	10	700	2.0	35.00	0.7	0.180	0.180	0.63	15
5	S2F2C1	10	700	2.5	40.00	0.75	0.19	0.19	0.75	16
6	S2F3C1	10	700	3.0	60.00	1.20	0.19	0.19	0.80	14
7	S3F1C1	10	800	2.0	30.00	0.87	0.19	0.19	0.85	10
8	S3F2C1	10	800	2.5	40.00	0.60	0.15	0.15	0.90	12
9	S3F3C1	10	800	3.0	50.00	1.72	0.21	0.21	0.95	16
10	S1F1C2	13	600	2.0	42.00	0.80	0.20	0.20	0.65	14
11	S1F2C2	13	600	2.5	60.00	1.25	0.180	0.82	0.70	14
12	S1F3C2	13	600	3.0	65.00	1.10	0.19	1.10	0.85	15
13	S2F1C2	13	700	2.0	40.00	0.83	0.180	0.15	0.60	15
14	S2F2C2	13	700	2.5	55.00	1.50	0.15	0.20	0.75	13
15	S2F3C2	13	700	3.0	60.00	1.48	0.20	0.20	0.80	12
16	S3F1C2	13	800	2.0	70.00	0.90	0.20	0.180	0.63	15
17	S3F2C2	13	800	2.5	40.00	1.23	0.180	0.19	0.75	15
18	S3F3C2	13	800	3.0	54.00	1.67	0.19	0.19	0.80	17
19	S1F1C3	15	600	2.0	40.00	070	0.19	0.19	0.85	18
20	S1F2C3	15	600	2.5	40.00	0.80	0.19	0.15	0.90	14
21	S1F3C3	15	600	3.0	65.00	1.10	0.15	0.21	0.95	13
22	S2F1C3	15	700	2.0	40.00	0.70	0.21	0.20	0.65	14
23	S2F2C3	15	700	2.5	62.00	0.75	0.20	0.180	0.70	14
24	S2F3C3	15	700	3.0	70.00	1.2	0.180	1.2	0.85	12
25	S3F1C3	15	800	2.0	45.00	0.87	0.195	0.54	0.60	13
26	S3F2C3	15	800	2.5	50.00	0.60	0.180	0.85	0.70	10
27	S3F3C3	15	800	3.0	70.00	1.72	0.170	1.10	0.80	09

Appendix B2: Average Calculated Data for the Evaluation of the Green gram Thresher

S/N	TRTM	CRC (mm)	SPD (RPM)	FDRT (kg)	TE (%)	CE (%)	SL (%)	GD (%)	BL (%)	CP (%)
1	S1F1C1	10	600	2.0	95	87	0.60	0.15	0.60	42.3
2	S1F2C1	10	600	2.5	94.53	90	0.65	.20	0.75	50.0
3	S1F3C1	10	600	3.0	95	92	1.100	0.20	0.80	50.2
4	S2F1C1	10	700	2.0	94.50	94	0.65	0.180	0.63	53.2
5	S2F2C1	10	700	2.5	95	92	0.75	0.19	0.75	33.1
6	S2F3C1	10	700	3.0	96	90	0.80	0.19	0.80	60.2
7	S3F1C1	10	800	2.0	93	93	0.85	0.19	0.85	45.50
8	S3F2C1	10	800	2.5	96	90	0.85	0.15	0.90	55.1
9	S3F3C1	10	800	3.0	96	90	0.90	0.21	0.95	50.0
10	S1F1C2	13	600	2.0	94	91	1.07	0.20	0.65	55.0
11	S1F2C2	13	600	2.5	96	92	0.65	0.82	0.70	45.0
12	S1F3C2	13	600	3.0	97	93	0.70	1.10	0.85	55.0
13	S2F1C2	13	700	2.0	95	91	0.85	0.15	0.60	40.0
14	S2F2C2	13	700	2.5	95	94	0.60	0.20	0.75	45.0
15	S2F3C2	13	700	3.0	99	94	0.75	0.20	0.80	55.0
16	S3F1C2	13	800	2.0	96	95	0.80	0.180	0.63	38.0
17	S3F2C2	13	800	2.5	97	93	0.63	0.19	0.75	42.0
18	S3F3C2	13	800	3.0	96	94	0.75	0.19	0.80	55.5
19	S1F1C3	15	600	2.0	96	93	0.80	0.19	0.85	45.50
20	S1F2C3	15	600	2.5	95	90	0.85	0.15	0.90	48.5
21	S1F3C3	15	600	3.0	96	89	1.10	0.21	0.95	50.0
22	S2F1C3	15	700	2.0	97	89	1.05	0.20	0.65	40.0
23	S2F2C3	15	700	2.5	96	88	0.65	0.180	0.70	45.0
24	S2F3C3	15	700	3.0	95	90	0.70	1.2	0.85	55.0
25	S3F1C3	15	800	2.0	95	91	0.85	0.54	0.60	40.0
26	S3F2C3	15	800	2.5	96	92	0.60	0.85	0.70	48.0
27	S3F3C3	15	800	3.0	94	91	0.70	1.10	0.80	55.0

Appendix C: Cost Calculation of Developed Pulse Thresher

Appendix C-1Calculation of cost of operation of thresher with rotary unit

Cost of operation per hour was calculated for the thresher individually as well as with rotary mode using the standard market prices.

Cost of operation of rotary unit

Assumptions:

- Annual hours of usage =1100h
- Cost of rotary unit =Rs.78,000
- Salvage or junk value =10%
- Operational hours per day =8h
- Life span =10 yrs

Calculation of Fixed Cost

Salvage value for the rotary unit = Rs.78,000 ×(10/100)= Rs. 7,800

Depreciation cost = (Rs.78,000 – Rs.7,800)/10= Rs. 7,020

Depreciation cost per hour = Rs.7020/1100= Rs. 6.38

Interest @13%= $\frac{Rs.78{,}000+Rs.7{,}800}{2} \times \frac{13}{100}$= Rs. 5,577

Interest per hour =Rs. 5,577/1100= Rs. 5.07

Insurance= $\frac{Rs.78{,}000+Rs.7{,}800}{2} \times \frac{2}{100}$= Rs.858

Insurance per hour=858/1100= Rs. 0.78

Shelter & housing= $\frac{Rs.78{,}000+Rs.7{,}800}{2} \times \frac{1.5}{100}$= Rs. 643.5

Shelter & housing per hour= Rs. 643.5/1100= Rs. 0.58

Operational cost

Repair and maintenance cost @5% = $78{,}000 \times \frac{5}{100} =$ Rs. 3900

Repair and maintenance cost per hour = Rs. 3900/1100= Rs. 3.54

Total cost of operation for rotary unit

= Rs.6.38+ Rs.5.07 +Rs.0.78+Rs 0.58+Rs 3.54= Rs.16.35/h

Appendix C-2Calculation of cost of operation of Bullock pair

Assumptions:

- Annual hours of usage = 240h
- Cost of bullock pair = Rs.40,000
- Salvage value = 10%
- Operational hours per day = 8h
- Life span = 12 yrs

Calculation of Fixed Cost

Salvage value for the bullock pair = Rs. 40,000 × (10/100) = Rs. 4,000

Depreciation cost = (Rs. 40,000 – Rs. 4,000)/12 = Rs. 3,000

Depreciation cost per hour = Rs. 3,000/240 = Rs. 12.5

Interest @13 = $\frac{Rs.40,000 + Rs.4,000}{2} \times \frac{13}{100}$= Rs. 2,750

Interest per hour = Rs. 2,750/240 = Rs. 11.45

Housing cost @ 20% = $\frac{Rs.40,000 + Rs.4,000}{2} \times 0.2$=Rs.4400

Housing cost per hour =Rs.4400/240 =Rs.18.33

Operational cost

Health and maintenance cost @5% =Rs. 2,000

Health and maintenance cost per hour =Rs.2, 000/240 = Rs.8.33

Labour cost @ Rs.213/head/full day =Rs. 26.65 per hour

Feeding cost per day:

8kg paddy straw @ Rs.90/quintal = Rs. 7.2

Cattle feed 2 @ Rs.1962/quintal = Rs. 39.24

Total feed cost per day = Rs. 46.44

Cost of feeding per hour = Rs. 5.81

Total cost of operation for bullock pair

=Rs.12.5 + Rs.11.45 + Rs.18.33 + Rs.8.33 + 26.65+5.805

=Rs.83.06/h

Appendix C-3Calculation of Cost of operation of pulse thresher operated in rotary system

Assumptions;

- Annual hours of usage =240hr
- Cost of little millet thresher =Rs 35000
- Salvage or Junk value =10%
- Operational hours per day = 8 h
- Life span =8 yrs

Calculation of Fixed Cost

Salvage value for the rotary unit = Rs 35,000 × (10/100) = 3500

Description cost = (Rs 35,000 - Rs 3500) / 8= Rs 3935.5

Description cost per hour = Rs 39.5.5/240= Rs 16.40

Interest @13% = $\frac{Rs.35,000 + Rs.3500}{2} \times \frac{13}{100}$= Rs. 2502.5

Interest per hour = Rs. 2502.5/240 = Rs. 10.42

Insurance= $\frac{Rs.35,000 + Rs.3500}{2}\times\frac{2}{100}$= Rs 385

Insurance per hour= Rs. 385/240= Rs. 1.60

Shelter & housing= $\frac{Rs.35,000 + Rs.3,500}{2}\times\frac{1.5}{100}$= Rs. 288.75

Shelter & housing per hour= Rs. 288.75/240= Rs. 1.20

Total fixed cost = 16.40 + 10.42+ 1.60 + 1.20 = Rs. 29.62/h

Variable cost

Repair and maintenance cost @5% = Rs. 1750

Repair and maintenance cost per hour = Rs. 1750/240= Rs. 7.29

Labour cost @ Rs.213/head/half day =Rs.6.65 per hour

Total variable cost = 7.29 + 6.65 = Rs. 13.94/h

Total cost of operation for sorghum thresher cum cleaner = FC +VC = 29.62 + 13.94 = Rs. 43.56 /h

Total cost of operation of sorghum thresher cum cleaner in rotary mode

= Rs. 16.35 + Rs. 83.06 + Rs.43.56 = Rs. 142.97 /h

Total operational cost = Rs. 142.97/120.21 = Rs. 1.18 /kg

Appendix C-4Calculation of cost of operation of pulse thresher with motor

Assumptions;

- Annual hours of usage =240hr
- Cost of Little Millet thresher =Rs 45000
- Salvage or Junk value =10%
- Operational hours per day = 8 h
- Life span =8 yrs

Calculation of Fixed Cost

Salvage value for the rotary unit =Rs 45,000 × (10/100) = 4500

Description cost = (Rs 45,000-Rs 4,500)/8= Rs 5063

Description cost per hour = Rs 5063/240= Rs 21.10

Interest @13% = $\frac{Rs.45,000 + Rs.4,500}{2} \times \frac{12.5}{100}$= Rs. 3094

Interest per hour = Rs. 3094/240 = Rs. 12.89

Insurance= $\frac{Rs.45000+Rs.4500}{2}\times\frac{2}{100}$= Rs 495

Insurance per hour= Rs. 385/240= Rs. 2.06

Shelter & housing= $\frac{Rs.45000+Rs.4,500}{2}\times\frac{1.5}{100}$= Rs. 371.25

Shelter & housing per hour= Rs. 371.25/240= Rs. 1.55

Total fixed cost = 21.10 + 12.89+ 2.06 + 1.55 = Rs. 37.59/h

Variable cost

Repair and maintenance cost @5% = Rs. 2250
Repair and maintenance cost per hour = Rs. 2250/240= Rs. 9.37
Labour cost @ Rs.213/head/full day =Rs. 26.65 per hour

Total variable cost = 9.37 + 26.65 = Rs. 36.02/h

Total cost of operation for sorghum thresher cum cleaner =FC + VC = 37.59 + 36.02 = Rs. 73.61/h

Electricity cost = Rs. 5/kWh × 0.746 = Rs. 3.73/h

Total cost of operation sorghum thresher cum cleaner operated with electric motor was

= Rs. 73.61 + Rs. 3.73 = Rs. 77.34/h

Total operational cost = Rs. 77.34 / 120.21 = Rs. 0.64/kg

Appendix C-5 Calculation of cost of operation of conventional method of green gram threshing

Calculation of cost of operation of thresher by manual hand beating

Labour cost @ Rs.213/head/day =Rs. 26.625 per hour

Operational cost = Rs. 26.625/6.91 = Rs. 3.85/kg

Appendix D: Design of Pulse Thresher on AUTO CAD Student Version

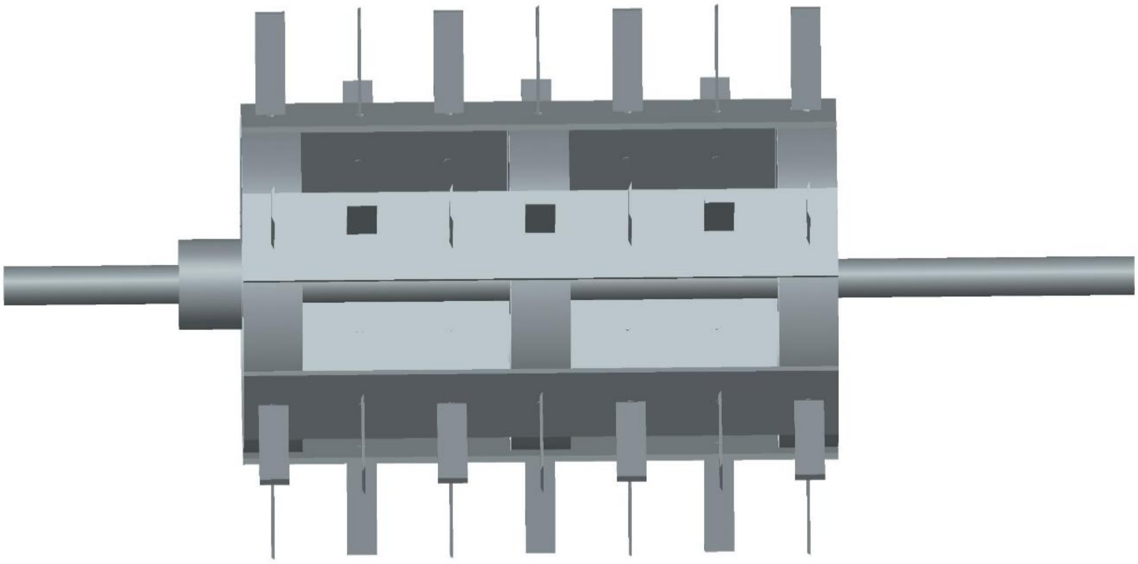

Plate: D1 Thresher Cylinder

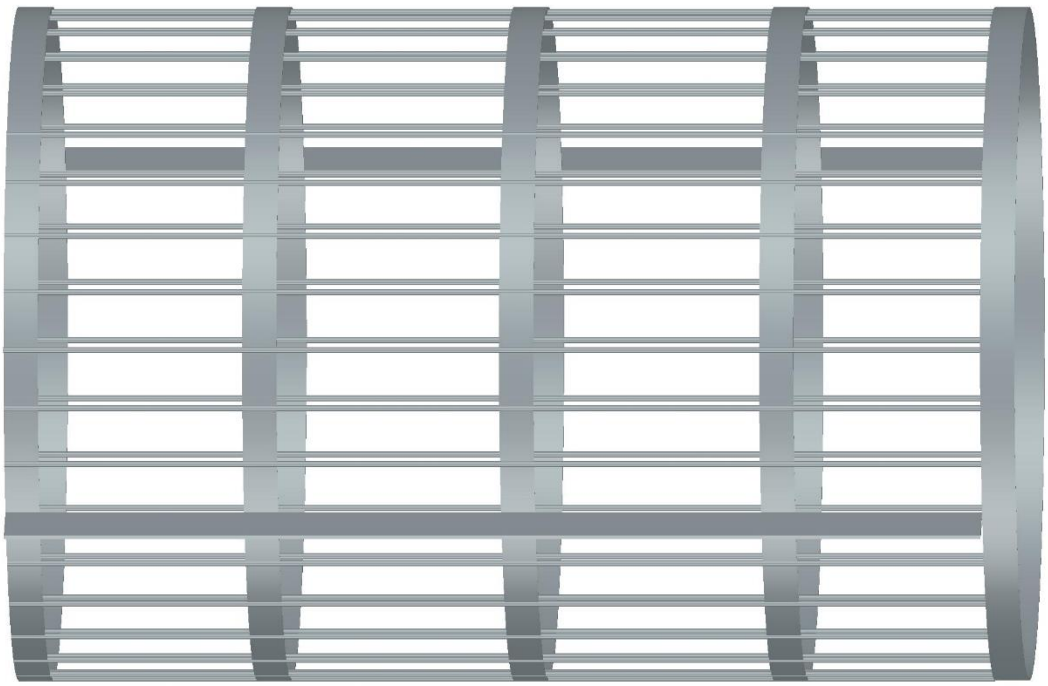

Plate: D2 Thresher Concave

Plate: D3Thresher Fan Blade

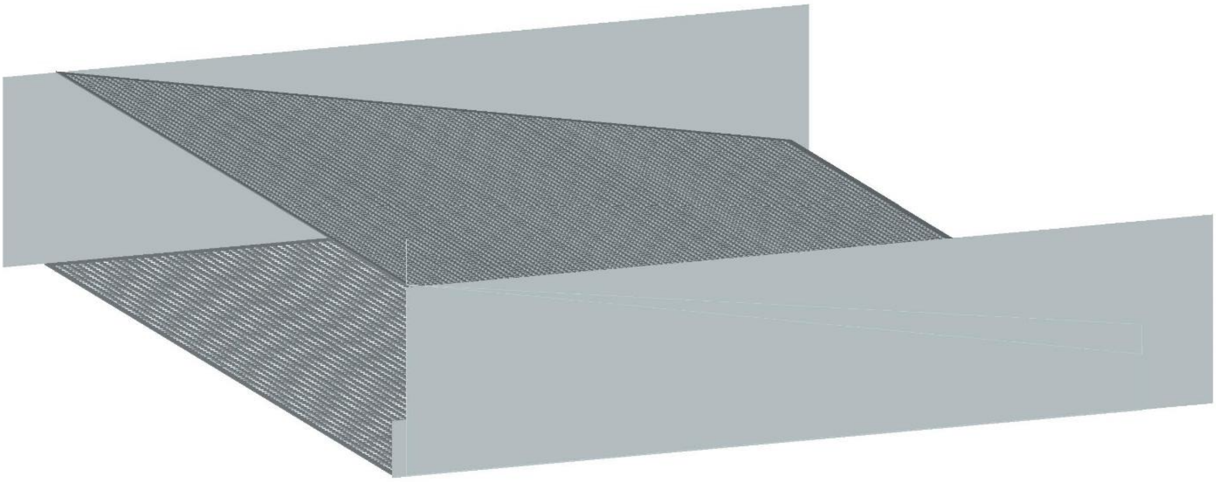

Plate: D4Separation Screen

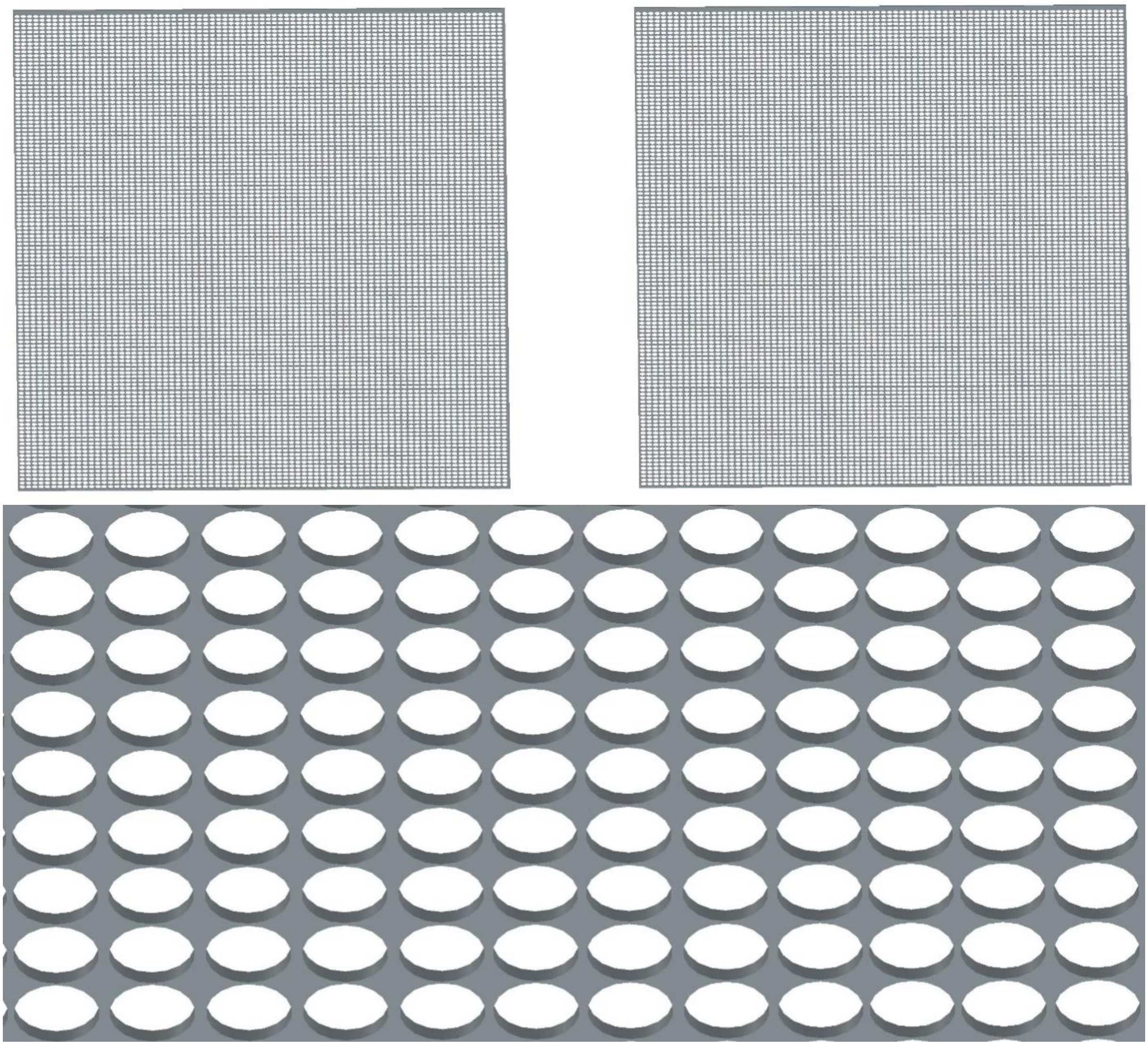

Plate: D5 Thresher Screen for Separation

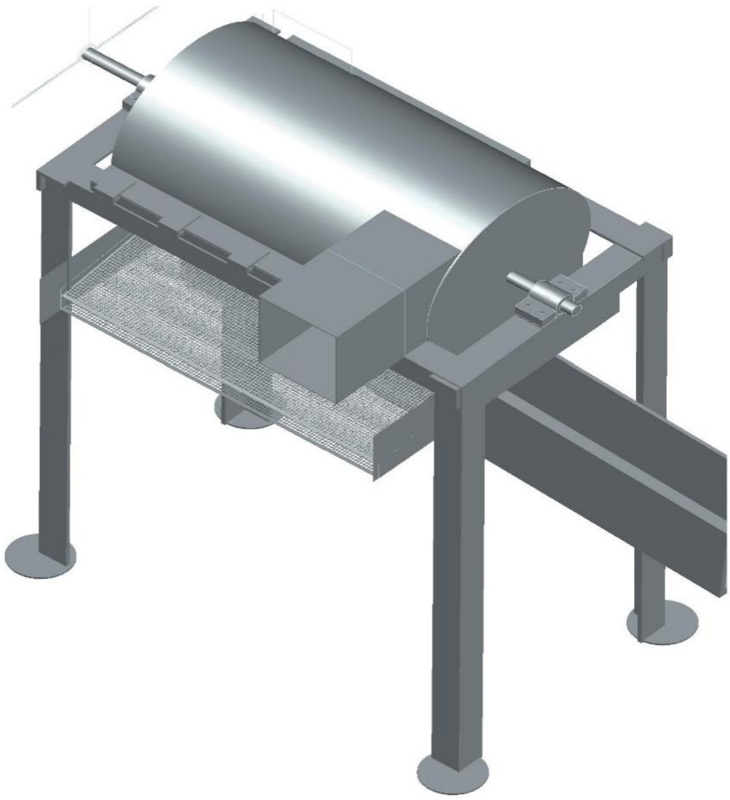

Plate: D6 Developed Pulse Thresher

Appendix E: Evaluation of Developed Machine

Plate: E1 Thresher in operation

Plate: E2 Evaluation of Thresher

Plate: E3 Thresher Operated by Bullock Power in Rotary Mode

Plate: E4 Demonstration watched by Dean of CAET, Bhubaneswar