DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF TRIPHAL PEELING UNIT

THESIS

Submitted in partial fulfillment of the requirements

for the Degree of

MASTER OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

(FARM MACHINERY AND POWER ENGINEERING)

By

Mr. Bagde Chetan Shivprasad

(ENDPM/2020/180)

DEPARTMENT OF FARM MACHINERY AND POWER ENGINEERING,

COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY,

DAPOLI

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VIDYAPEETH, DAPOLI, RATNAGIRI (MS) 415 712

AUGUST, 2023

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Under the Guidance of

(Dr. S. V. Pathak)
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AUGUST, 20 23

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF TRIPHAL PEELING UNIT"** or part thereof has neither been submitted for any other degree or diploma of any University nor the data have been derived from any thesis/publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.

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Date: 02/08/2023 ENDPM/2020/180

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CERTIFICATE

This is to certify that the thesis/dissertation entitled, "**DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF TRIPHAL PEELING UNNIT**"submitted for the degree of M.Tech. (Farm Machinery and Power Engineering) of the College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by Mr. Bagde Chetan Shivprasad (ENDPM/2020/180) under my supervision and that no part of this thesis has been submitted for any other degree. The Student had completed all the Course and Research requirement as per the norms in regular mode and has published one research paper from his M.Tech. work.

The assistance and help received during the course of investigation have beenfully acknowledged.

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Date: 02 /08 /2023

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THESIS APPROVAL BY THE STUDENT'S ADVISORY COMMITTEE

INCLUDING EXTERNAL EXAMINER

This is to certify that the thesis/project report entitled, "**DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF TRIPHAL PEELING UNIT**" submitted by Mr. Bagde Chetan Shivprasad (ENDPM/2020/180) to the College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfilment of the requirements for the M.Tech. (Farm Machinery and Power Engineering) in the subject having Renewable Energy Sources as Minor subjects of Department of Electrical and other Energy Sources has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One/ Two External Examiner after an open Viva Voce examination in the presence of External Examiner on the same held on.

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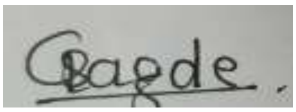

Place: Dapoli

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(Bagde Chetan Shivprasad)

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Abbreviations	Meanings
Avg.	Average
CAET	College of Agricultural Engineering and Technology
cm	Centimetre
d. b.	dry basis
DBSKKV	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth
Dept.	Department
Engg.	Engineering
et al.	and others
etc.	et cetera
Fig.	Figure
FMPE	Farm Machinery and Power Engineering
g	gram
M. S.	Mild Steel
MT	Metric tonnes
h	hour
hp	Horse Power
i.e.	that is
kg	kilogram
kg/h	Kilogram per hour
kw	kilowatt
m	metre
min	minute
mm	millimetre
M.S	Mild Steel
rpm	revolutions per minute
Sec	second
T.A	Texture Analyser
viz.	Namely
w.b.	wet basis

Glossary

Sphericity

Sphericity was defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain.

Bulk density (BD)

The bulk density of seed was the ratio of its mass to total volume.

True density

The true density defined as the ratio of mass of the sample to its true volume.

Porosity (ϵ)

The porosity is the fraction of the space in the bulk grain which was not occupied by the grain.

Coefficient of Static Friction

The static coefficient of friction may be defined as the friction force acting between surfaces of contact at rest with respect to each other.

CHAPTER I
INTRODUCTION

Spices are aromatic substances with vegetable origins that come from a variety of plant parts, including leaves, bark, fruit, flower buds, stems, roots, seeds, etc. Because they contribute flavour, taste, and colour to food preparations. Spices are used as seasonings and condiments. Due to their potent antioxidant, preservative, anti-microbial, and antibiotic capabilities, spices are also utilised in medicine. The total amount of spices produced worldwide is 22.04 lakh tonnes. Out of the, 56 spices producing nations, India's production is of 14,96,990 tonnes (Yogesh, 2014), whereas Bangladesh's 1,36,000 tonnes, Turkey with 1,32,000 tonnes, China and China Mainland, Pakistan, Ethiopia, Iran, Nepal, Colombia, and some other countries, are traditionally concentrating in production of spices (Yogesh, 2014).

India produces more than 50 different spices and is the world's top producer, consumer, and exporter of spices and spice-related goods. Along with many other spices, India is a significant supplier of chilli, turmeric, cumin, and pepper. Additionally, the nation imports diverse spices to satisfy local taste preferences because Indian dishes would be incomplete without a variety of spices. The state that produces the most spices in India is Andhra Pradesh. Gujarat, Karnataka, Rajasthan, Tamil Nadu, Assam, Kerala, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, and West Bengal are also key spice-producing states in India. Chilli, the principal spice crop, accounts for around 34 per cent of the nation's total spice production and accounts for approximately 29 per cent of the land under cultivation. Garlic accounts for 14 per cent of total production and 6 per cent of total land area, while turmeric accounts for 14 per cent and 5 per cent, respectively. Pepper accounts for 2 per cent of spice production and accounts for 9 per cent of total spice space in the country, whereas seed spices account for 17 per cent of production and 41 per cent of space (IASRI website). Table 1.1 depicts the trends in area, production, and productivity of spices in India during the last six years.

Table 1.1 Trend in area, production and productivity of Spices for the last six years

Year	Area (ha)	Production (tonnes)	Productivity (Kg/ha)
2015-16	3464.438	6989.723	2018
2016-17	4110.997	10469.720	2547
2017-18	3906.982	9566.991	2449
2018-19	4003.500	9300.306	2323
2019-20	4306.065	10171.452	2362
2020-21	4528.176	10679.221	2356

Source: Spices Statistics at a Glance 2021

Among different states, Rajasthan occupies the major area under spices owing to seed spices cultivation followed by Gujarat, Madhya Pradesh, Uttar Pradesh, Karnataka, Andhra Pradesh, Kerala etc. Madhya Pradesh ranks first in terms of production of spices followed by Rajasthan, Gujarat, Andhra Pradesh, Telangana, Karnataka, Maharashtra, Assam etc(Anonymous, 2021).

In Maharashtra the average share of Horticulture in Gross State Value Added (GSVA) of Crop sector is 28.4 per cent (Anonymous, 2021). Condiments and spices production increased by 3.9 percentage in the year 2020-21 than 2019-20 with production 1,308 MT in 2020-21 and 1,359 MT in 2020-21(Anonymous, 2021). Area and production of condiments and spices in Maharashtra state is shown in table 1.2.

Table 1.2 Area and Production of Spices and Condiments in Maharashtra

Crop	Area (ha)			Production (MT)		
	2019-20	2020-21	Percent Change	2019-20	2020-21	Percent change
Spices & Condiments	79.72	84.25	5.7	1,308	1,359	3.9

Source: Horticulture Area Production Information System (HAPIS), GoI 2021

In Maharashtra Konkan region is a highly dynamic and vibrant part of the Western Ghats range of the Maharashtra having favourable agricultural climate of the tropics. Geographically, this hilly region with long coastal sea shore is gifted with a wide range of horticultural potentials. It is a coastal strip of land bounded by Sahydri hills on the east and the Arabian sea at on the west. Maharashtra's Konkan region consist of Raigad, Ratnagiri, Sindhudurg, Palghar and Thane districts. Konkan region is specially known as horticultural zone (Bhattacharrya *et. al*., 2017).

1.1 About Triphal

The genus *Zanthoxylum* (family *Rutaceae*) contains a fascinating group of plants found around the world from the tropics to temperate zones. With over 200 species, ranging from small shrubs to large trees, *Zanthoxylum* spp. are characterized by sharp thorns on either the stem or leaves. Various *Zanthoxylum* spp. are well recognized as Asian spices, including hua jiao in China, sansho in Japan and chopi and sancho in Korea (Austin and Felger 2008). Indian prickly ash, also known as *Zanthoxylum rhetsa* (Triphal), is a species of flowering plant in the *Rutaceae* family that can be found from India east to the Philippines and south to northern Australia (Hartley *et. al.,* 2013).

1.2. Triphal Plant Physiology

Triphal is a deciduous shrub or tree with pinnate leaves with nine to twenty-three leaflets and male and female flowers. Panicles are white or yellowish, and they are followed by red, brown, or black spherical follicles. The main stem of triphal trees, which can reach a height of 25 metres, is covered in conical prickles. Branchlets have a few prickly points. It bears alternating, complex leaves that are 30-45 cm long. The rachis and petiole are typically thorny. The leaflets are ovate-oblong or lanceolate, opposite and subopposite, with an oblique base, a caudate-acuminate apex, and a 1.5-3 cm long acumen. The margins are whole to remotely crenate, with glands in the crenation sinuses. Panicles are terminal or pseudoterminal and 10-25 cm long (from the topmost leaf axil). Male blooms are 1.5-2.5 mm long, while pedicels are 1-2 mm long. Four valvate, elliptic-oblong, obtuse, white or creamy yellow petals and four sepals with ovate-triangular, obtuse, subentire, or fimbriate edges. The anthers are yellow and oblong. Female blooms measure 1.5 to 2.5 mm in length. Male flowers do not have staminodes, pedicels, sepals, or petals. (Zhang and Hartley 2008).

Small flowers born in terminal cymose panicles are visible from June to November. The fruits are visible from October to January. The pericarp, seed, and bark are all aromatic (Chandrashekharan 1952).

1.3 Uses of Triphal

Triphal has a long history of use as a folk remedy for a variety of illnesses, including stomach aches, toothaches, intestinal worms, rheumatism, scabies, snakebites, fever, and cholera. It is important in medicine because it has anti-cancer characteristics as well as antioxidant, anti-bacterial, anti-fungal, anti-diabetic, anti-septic, and anti-helminthic properties (Kala, 2005). It is the most well-known "Konkani spice". With a coconut masala, it is primarily used in fish preparations and a few vegetarian recipes.

In folk medicine, it is employed. Its dried fruits are consumed as an appetiser, spice, and digestive aid. The oil has a lovely perfume resembling sweet orange, and the pericarp of the unripe fruits is aromatic and tastes like orange rind. The woody pericarp of the tiny fruits is used as a spice by the inhabitants of Goa, the Konkan and Kanara coasts, and Coorg, especially with seafood dishes (anonymous, 2016).

1.4 Present Scenario of Triphal in Konkan

The Konkan region is hilly, primarily famous for its spices production and horticultural crops. With the limited resources at their disposal, farmers are only able to cultivate rice as a main agricultural crop, with the majority of other regions being covered with horticulture plants because the available land is fragmented and machine use is prohibited. Triphal is a rare horticultural plant that hasn't attracted farmers' notice despite wasting tonnes of yield with no use for processing.

Unique spices called triphal are mostly grown in Konkan region. A scattered production of Triphal has been observed in Kolhapur, Pune, Raigad, Ratnagiri, and Sindhudurg districts. To know the exact production of triphal in Konkan region Survey has been done in different Talukas of the Kolhapur, Pune, Raigad, Ratnagiri, and Sindhudurg districts, In which questions were asked to local triphal traders, Sarpanch of villages, farmers having triphal plants in their land or house premises, officials of agriculture departments like Talathi, Krishi-Sevak, Gram Sevak etc. After analyzing the data it is surprisingly found that in Konkan region yearly 120 MT while in some parts of Kolhapur and Pune districts 21 MT triphal was produced approximately and most of them was purchased by traders. Traders sell all those triphal to Cosmetic companies, Spices companies etc. Also it was made available in local market. The data from the survey is given in table 1.3.

Table 1.3 Production Data of Triphal

Sr. No.	District	Production (MT)
1	Palghar	20
2	Thane	15
3	Raigad	17
4	Ratnagiri	30
5	Sindhudurg	38
6	Kolhapur	12
7	Pune	9

1.5 Basic Problem in Mechanization aspects

There are so many farm machineries are available for harvesting as well as processing of different spices. But for triphal there is no machinery because in harvesting and processing of triphal there are some constrains they are discussed below.

1.5.1. Harvesting

Triphal plant grows upto height of 25 m. shown in plate 1.1 The main trunk of triphal tree bears conical prickles (Plate 1.2). Branchlets also have few thorny points ((Zhang and Hartley 2008). Tree bears the fruits in bunches (Plate 1.4). It is very difficult and dangerous work to harvest triphal from the tree. As there is no mechanical devices available, people in Konkan region avoids harvesting of triphal. They either collect triphal fruits which are underlaying the tree after ripening or only harvest the fruits which are in range of catcher or long bamboo (Plate 1.3). Fruits which are at top of the tree and those which are out of range of catcher remains untouchable and due to sun’s heat it cracked (Plate 1.5). Seeds inside it fall under a tree discreetly.

Plate 1.1 Triphal Tree

Plate 1.2 Prickles on Main Trunk

Plate 1.3 Harvesting of Triphal

Plate 1.4 Bunch of Triphal Fruits

Plate 1.5 Matured Fruits of Triphal

1.5.2 Separating seeds from the pericarp

Currently, there is no defined method available for separation of seeds from the pericarp. Women in the Konkan region painstakingly separate the seeds from the outer pericarp. In most cases, just the outer pericarp is used, with the seeds being discarded. After harvesting the triphal bunches, they are all collected and sundried. The outer pericarp fractures and opens as a result of sun drying, revealing the dark black seed inside. The seed is joined to the pericarp by a single thread-like ligament. Separated seeds and pericarps are shown in plate 1.6. To separate the seeds and pericarps, women smashed the triphal with their own hands. A burning sensation is produced during this operation as a result of direct contact of the hand with the oil in the seeds. Thrones of triphal are sometimes pierced in the hands of ladies, causing wounds (plate 1.7). Manual processing of triphal is shown in plate 1.8

Plate 1.6 Separated Pericarps and seeds

Plate 1.7 Wounded palm of women labour in Separation Process

Plate 1.8 Manual Processing of Triphal

1.6 Present Condition about Triphal Processing

The handling and processing of the triphal are still in the neglection stage due to lack of knowledge about it. In whole Maharashtra triphal is only grown in Konkan region. But sadly due to unawreness about the triphal there is no any processing machine or processing plant in Konkan region. Traders buy triphal from the farmers at very cheap price, process it manually and sold it to the big spices industries and pharamacutical industries making big profit.

1.7 Justification of work

Processing of triphal is highly skilful operation. Triphal is still peeled by hand using an antiquated procedure that is laborious and time-consuming, discouraging farmers from working on it and eventually preventing it from meeting consumer demand. It not only causes injuries to hands but also required high amount of labour. In order to uplift this spices crop it is necessary to develop the proper peeling unit for the quality production of triphal. The importance of a product can be increased by properly developing technology, which can also inspire young people to start their own businesses. The development of the peeling unit may contribute to changing the current triphal situation in this area.

By keeping all the above views in mind a project entitled "Design, Development and Performance Evaluation of Triphal Peeling Unit" has been undertaken with following objectives:

1. To study engineering properties related to peeling of Triphala.
2. To design and develop Triphala peeling unit.
3. To Test and evaluate performance of developed Triphala peeling unit.

CHAPTER II

REVIEW OF LITERATURE

For the purpose of designing and developing the Triphal Peeling Unit, past researcher's study on the use of triphal and its chemical compositions was cited. Since Triphal's engineering properties have not yet been measured, research on measuring engineering properties of other biological materials is referenced. The chapter includes reviews under the following headings.

2.1 Chemical Compositions and Uses of Triphal.

2.2 Engineering Properties of Biological Material.

2.3 Seed Detachment Force.

2.4 Developed Peeling or Decorticating Machines.

2.5 Performance Evaluation.

2.6 Cost Economics.

2.1 Chemical Compositions and Use of Triphal

Kala *et. al*., (2005) studied timur's (*Zanthoxylum rhesta*) traditional uses and conservation. They discovered that timur shrubs can be preserved in an environment where commercial fruit tapping was becoming more and more competitive and where local investors' top priorities were maximisation of profit. Timur can be grown as an understorey shrub in both forested areas and marginal, unproductive soil. To evaluate the likelihood of economic gain from timur farming, a proper agronomic study was necessary.

Rana *et. al*., (2010) studied the volatile constituents of the seed coat of *Zanthoxylum rhetsa* by gas chromatography, mass spectrography and concluded that there were thirty-four compounds, accounting for 87.4 per cent. The major compounds were terpinen-4-ol (32.1 per cent), a-terpineol (8.2 per cent), sabinene (8.1 per cent), b-phellandrene (7.4 per cent) and 2-undecanone (7.1 per cent).

Gurav *et. al*., (2018) performed mineral composition and proximate study of *Zanthoxylum rhetsa.* The study reveals that both ripe and unripe fruits were chosen to assess their nutritional value and ethnomedicinal significance. Researchers discovered that the unripe fruit of *Zanthoxylum rhetsa* included the largest amounts of dry content (53.2 ± 0.32 per cent), ash (4.0 ± 0.10 per cent), crude fibre (6.5 ± 0.51 per cent), and crude fat (5.5 ± 1.56 per cent). Only zinc was (20 ± 0.04) greater than expected for the various macronutrients and micronutrients in ripe *Z. rhetsa* fruits. The highest amount of sodium (820 ± 0.10 mg) found in unripe *Z. rhetsa* fruit.

2.2 Engineering Properties of Biological Materials

Coskuner and Karabab, (2006) examined the coriander seeds' physical characteristics in relation to their moisture content, which ranged from 7.10 to 18.94 per cent. (d.b.). With an increase in moisture content, the length of the seed decreased linearly in the moisture range from 4.74 to 4.61 mm, while the width, thickness, arithmetic mean diameter, and geometric mean diameter increased linearly from 3.67 to 3.93 mm, 3.39 to 3.54 mm, 3.93 to 4.03 mm, and 3.88 to 3.99 mm, respectively. Whereas 0.820 to 0.867, 24.97 to 28.52 mm^3, and 42.09 to 45.62 mm^2, respectively, the sphericity, seed volume, and seed surface area all grew nonlinearly. It was observed as the weight of 1,000 seeds went risen linearly from 8.72 to 9.71 g. While bulk density declined linearly from 234.1 to 220.2 kg/m^3 in the range of moisture content between 7.10 per cent and 18.94 per cent, (d.b.), real density increased nonlinearly with moisture content from 332 to 349 kg/m^3. Additionally, coriander seeds' porosity values grew nonlinearly from 33.03 per cent to 35.79 per cent. On the plywood surface, the maximum static coefficient of friction was discovered. The static coefficient of friction increased nonlinearly for plywood, polypropylene knitted bags, polyvinyl chloride, galvanised iron, cast polypropylene, and stainless steel surfaces, from 0.435 to 0.877, 0.425 to 0.775, 0.379 to 0.839, 0.364 to 0.781, 0.344 to 0.650, and 0.325 to 0.694, respectively. With an increase in moisture content, the angle of repose increased linearly from 24.9 to 30.7.

Ahmadi *et. al.,* (2009) determined some mechanical and physical properties of fennel seed in the range of 7.78 to 21.67 per cent (d.b.). of moisture content. At a moisture level of 7.78 per cent (d.b.), the average length, width, and thickness were 58.87, 18.96, and 15.64 mm, respectively. The study found that the thousand seed weight increased from 5.5 to 9.2 g, the porosity increased from 55.91 per cent to 62.21 per cent, the static and dynamic angles of repose decreased from 37.6 to 46.6 and 41 to 53.3, respectively, the coefficient of friction on the surfaces of glass, plywood, and galvanised iron sheet was 0.55 to 0.74, 0.45 to 0.63, and 0.43 to 0.66, respectively, the deformation on width section increased from 1.68 to 1.86 mm. The rupture force on the seed length and breadth sections reduced from 198.93 to 78.68 N and 600.65 to 186.44 N, respectively, while the bulk density decreased from 413.51 to 352.39 kg/m^3.

Bagherpour *et. al*., (2009) examined the lentil seed's physico-mechanical properties. With a rise in moisture content from 8 to 20 per cent (w.b.), the average rise in diameter, thickness, thousand-grain mass, angle of repose, and porosity was about 10 mm, 8 mm, 17 g, 10˚ and 6 per cent, respectively. However, the true and bulk densities decreased by about 10 and 13 per cent, respectively. As the moisture content rose, the coefficient of static friction increased in comparison to surfaces made of glass (by 31 per cent), galvanised steel (by 33 per cent), and plywood (by 17 per cent). Lentil seed deformation, rupture energy, and rupture force all decreased as moisture content rose. At a moisture content of 8 per cent, compression tests were performed with loading rates of 1, 3, and 6 mm/min. The results show that as the loading rates increased from 1 to 10 mm/min, respectively, the force needed to break the seed increased from 159.6 to 182.32 N. As the loading rate increased, seed deformation reduced from 0.61 to 0.18 mm, exhibiting a negative trend.

Mollazade *et. al*., (2009) measured moisture-dependent physical and mechanical properties of cumin seeds. The following characteristics of the seed were found to increase with increasing moisture content. The length increased from 5.14 mm to 5.58 mm, width from 1.33 mm to 1.55 mm, thickness from 0.97 mm to 1.05 mm, arithmetic mean diameter from 2.48 mm to 2.73 mm, geometric mean diameter from 1.88 mm to 2.09 mm, surface area from 10.34 to 12.66 mm^2, thousand seed weight from 2.9 g to3.9 g, porosity from 51.22 per cent to 64.11 per cent), true density from 917.8 g/cm^3 to 1030.6 g/cm^3. While rupture force and energy together with seed length and width were found to reduce from 83.74-56.17 N, 132.95-84.47 N, 50.66-27.52 mJ, and 67.8 to 33.36 mJ, respectively, bulk density was found to decrease from 447.66-369.88 kg/m^3. The sphericity increased from 36.63 per cent to 37.5 per cent as the moisture content grew from 7.24 per cent to 14.5 per cent (d.b.). and then decreased from 37.5 per cent to 21.38 per cent (d.b.).

Sharma *et. al.*, (2010) investigated some physical properties of tung seed. The study revealed that tung seed had an average of 13.24 per cent (d.b.) moisture and 40.37 per cent oil content. The average seed length, width, thickness were 22.61 mm, 20.35 mm, 13.95 mm, respectively. The average surface area of tung seed was observed as 1084.20 mm^2, while the sphericity and aspect ratio were 0.82 and 90.07 per cent, respectively. The average bulk density of seed was 0.502 g/cm^3 while the true density was 0.995 g/cm^3, and the corresponding porosity was 49.88 per cent. The terminal velocity was 8.3 m/s.

Zahedi *et. al*., (2010) investigated black cumin's moisture-dependent physical characteristics. The range of the moisture content on wet basis was 5.1 per cent to 18.75 per cent. At a moisture content of 5.1 per cent (w.b.), the average length, width, thickness, and 1,000 seed mass were 3.11 mm, 1.59 mm, 1.09 mm, and 2.76 g, respectively. As moisture content grew from 5.1 per cent to 18.75 per cent (w.b.), the geometric mean diameter and sphericity increased from 1.75 mm to 1.79 mm and 56.34 per cent to 56.98 per cent, respectively. While true density and porosity increased from 1,009.4 kg/m^3 to 1,071.2 kg/m^3 and 46.5 per cent to 54.59 per cent, respectively, in the same moisture range, the bulk density dropped from 539.3 kg/m^3 to 486.4 kg/m^3. Angle of repose, terminal velocity, and surface areas were observed to increase from 32.5° to 33.3°, 5.6 m/s to 5.92 m/s, and 8.14 mm^2 to 8.46 mm^2, respectively, while the moisture content increased from 5.1 per cent to 18.75 per cent (w.b.) In the moisture range of 5.1 per cent-

18.75 per cent (w.b.), the static coefficient of friction increased on four structural surfaces viz. galvanised iron sheet (0.37-0.41), mild steel (0.36-0.39), aluminium (0.32-0.34), and plywood (0.53-0.58), respectively.

Balasubramanian *et. al.,* (2011) determined physical properties of cinnamon (*Cinnamomum verum*) bark. The values of length, breadth and thickness were 48.38 mm, 7.34 mm and 1.37 mm, respectively. Unit volume and surface area were 214.80 mm^3 and 159.68 mm^2, respectively. Bulk density and true density for grade were 144.56 kg/m^3 and 177.60 kg/m^3, respectively. Porosity, angle of repose was 14.20 per cent and 40.69°, respectively. The coefficient of static friction with respect to different surfaces viz., plywood, galvanized iron and aluminum sheet were 0.86, 0.94 and 0.80, respectively.

Gharibzahedi *et. al*., (2011) evaluated the physical properties of castor seed as a function of moisture content in the range of 6.24 to 12.56 per cent (d.b.). They came to the conclusion that, at a moisture level of 6.24 per cent (d.b.)., the average length, width, thickness, and mass of 1,000 seeds were 10.24 mm, 6.81 mm, 5.05 mm, and 195 g, respectively. As moisture content increased from 6.24 to 12.56 per cent (d.b.)., the geometric mean diameter and sphericity increased from 7.06 to 7.16 mm and 67.62 to 67.84 per cent, respectively. The bulk density dropped from 517.64 to 497.65 kg/m^3 in the same moisture range, but the true density rose from 908.99 to 989.65 kg/ m^3 and the associated porosity rose from 43.05 to 49.71 per cent. The repose angle, terminal velocity, and surface area all increased when the moisture content rose from 6.24 to 12.56 per cent (d.b.). to 31.5 to 34.30, 5.56 to 5.79 m/s, and 131.97 to 136.08mm^2, respectively. In the moisture range of 6.24 to 12.56 per cent (d.b.)., static coefficient of friction increased on three structural surfaces: glass (0.249-0.271), stainless steel (0.314-0.334), and plywood (0.324-0.344).

Singh *et. al.,* (2011) studied engineering and biochemical properties of 11 flaxseed varities including Sheela, Sweta, Garima, Sharda, Rashmi, Shikha, Padmini, Shekhar, Neelam, LC-2063, and LC-2023, were determined and compared. Average dimensions were determined to be 4.59 to 5.73 mm in length, 2.30 to 2.93 mm in breadth, and 0.85 to 1.06 mm in thickness. Among these 11 kinds of flaxseed, Neelam variety had the maximum surface area, geometric mean diameter, unit volume, and 1000-seed mass, while LC-2023 had the lowest values. The rupture force ranged from 30.57 to 46.87 N, while the angle of repose ranged from 19.3 to 23.5°. Protein content ranged from 17.78 per cent to 24.62 per cent, and linolenic acid concentration ranged from 37.05 per cent to 54.59 per cent (on a fat basis).

Khura *et. al.,* (2013) determined the physical properties of large cardamom. Geometrical mean diameter, sphericity, bulk density and mean values of angle of repose of the freshly harvested large cardamom capsules were observed to be 18.53 ± 1.73 mm, 0.76, 332.21 ± 14.24

kg/ m^3 and 28.74 ± 4.04°, respectively. Whereas for dried large cardamom capsules the values were found to be 11.113 ± 0.92 mm, 0.56, 393.109 ± 9.622 kg/m^3 and 29.84 ± 2.93°, respectively. The peak static coefficient of friction of freshly harvested large cardamom over mild steel, plywood and plastic film surfaces were 0.386, 0.463 and 0.359, respectively. However, for dried large cardamom capsules, the observed values were 0.436, 0.394 and 0.155, respectively.

Grewal and Singh (2016) evaluated the physical and frictional properties of PBR-91 variety of Mustard seeds as function of their moisture contents. The geometric mean diameter, arithmetic mean diameter, sphericity , surface area, thousand seeds mass increased of from 1.61-1.92 mm, 1.58-1.92 mm, 0.921-0.991,8.14-11.58 mm^2 and 4.21 to 6.51 g respectively for the increase in the level of moisture from 6 per cent to 18 per cent w.b. The bulk density, true density and porosity decreased from 0.906-0.798 g/cc, 1.199-0.924 g/cc and 24.43-13.63 per cent, respectively. The angle of repose for this variety was found to increase with increasing moisture content.

Yamgar and Dhande (2019) determined properties and fruit detachment force (FDF) of Nutmeg Konkan Vishwashri. The average length, breadth and thickness of Nutmeg were found to be 60.30, 45.11 and 38.61 mm, respectively. Whereas, the average sphericity and size or equivalent diameter were 0.78 and 47.18 mm, respectively. The unit volume, surface area and projected area of the Nutmeg were found to be 55.00 cm^3, 69.94 cm^2 and 17.50 cm^2, respectively. The bulk density of matured fruit was found to be 0.58 g/cm^3. The average weight of matured whole fruit, nut, mace and pericarp were found to be 43.71, 5.95, 2.39, and 37.08 g, respectively. The average fruit detachment force FDF for matured fruit was found to be 1.39 kg. Similarly FDF/W ratio of matured and un-matured fruits were found to be 0.019 kg/g and 0.029 kg/g respectively.

Bako *et. al*., (2020) examined acha grain's engineering properties in order to the development of processing equipment. Study found that the average seed measured 1.84 mm in length, 0.85 mm in breadth, and 0.75 mm in thickness, respectively. The geometric and arithmetic means of the average diameters were 1.05 mm and 1.15 mm, respectively. The average values for roundness, sphericity and aspect ratio were 0.5840 ± 0.011, 0.5732 ± 0.013 and 0.4678 ± 0.012, respectively. The average volume, projected area, and surface area were 0.61 ± 0.029 mm^3, 3.49 ± 0.25 mm^2 and 1.23 ± 0.033mm^2, respectively. The dry basis average moisture content was 14.73 ± 2.14 per cent, and the weight of a thousand kernels was 0.827 ± 0.03 g. The porosity was 32.52 ± 1.34 per cent, and the average bulk and true densities were 1092.862 ± 4.13 kg/m^3 and 1626.156 ± 2.91 kg/m^3, respectively. It was found that the seed's average terminal velocities, drag coefficients, and Reynolds numbers were 3.97 ± 0.015 m/s, 0.684 ± 0.062, and 311.37 ± 13.47, respectively.

2.3 Seed Detachment Force

Yilmaz *et. al*., (2009) determined strength and deformation parameters for sesame (*Sesamum indicum L*.) stalk. Using a computer-aided cutting tool, they computed values based on the force versus displacement curve. The tests were carried out at four different stalk sections and at four different moisture contents (10 per cent, 20 per cent, 40 per cent, and 60 per cent d. b.) (upper, middle and lower). The bottom stalk portion at 10 per cent moisture content experienced the maximum shearing stress of 6.00 N/mm^2. Values of the bioyield force rose as moisture content increased. The stalk sections had a substantial impact on bioyield stress ($p < 0.01$) but the moisture content had no discernible effect. The top stalk section had a modulus of elasticity of 14.50 N/mm^2 at 10 per cent moisture level, whereas the lower stalk segment had a modulus of elasticity of 30.51 N/mm^2 at 20 per cent moisture content.

Hoseinzadeh *et. al*., (2010) measured silique picking force for canola. They choose three canola varieties (*Brassica napus L*.), three stem moisture contents, three fertiliser dosages, and three pull out velocities to measure the silique picking force. Their results demonstrated that all of the factors tested had a substantial impact on the axial picking force of siliques with a 1 per cent level of significance. As stem moisture content increased from 40.5 to 60.2, silique picking force increased from 3.234 N to 5.164 N.

Pathak *et. al*., (2017) determined the optimum seed-detaching force for cumin seeds. They found that design and development of the threshing and other processing machinery for cumin was heavily influenced by the mechanical properties of the grain. The test was run for AVANI-111 cumin seeds at a seed moisture content of 9.01 per cent (d.b.), with the texture analyser setup and the results show no discernible relationship between seed diameter and seed detaching force. The average force needed to separate a seed was found to be 0.408 ± 0.146 N. They concluded that the results can be efficiently used to design prototypes with the best construction materials and power sources.

Gabrielly *et. al*., (2019) reported that, when the moisture content of the sorghum grains declined, more power was required to break the grains, corresponding to values between 47.17 and 78.44 N, 61.81 and 69.66 N, and 52.07 and 70.89 N for temperatures between 60 and 100 °C. While the proportional deformation modulus increased with decreasing moisture level, the compression force needed to distort grain sorghum decreased as moisture content rose.

2.4 Developed Peeling and Decorticating Machines

Majumdar (2002) suggested several design factors for threshing machinery and advised that the output capacity of the thresher should not be less than 85 kg of wheat per kWh. The threshing efficiency should be at least 96 per cent, with a maximum grain loss of 5 per cent. Cylinder speed was found to have a substantial impact on threshing performance across all machine designs. While un-threshed grain reduces as cylinder speed rises, power consumption and shattered grain rise.

Bansal and Lohan (2009) developed an axial flow seed crop thresher with the goal of minimising seed damage. There was a stationary concave rasp bar type threshing cylinder utilised. The cylinder's design dimensions were 520 mm in diameter and 512 mm in length. In accordance with the needs for threshing and the physical characteristics of various crops, cylinder speeds ranging from 8.2, 9.5, 11.0, 12.2, 14.7, and 17.6 m/s were offered. Cleaning system was consist of blower, aspirator, and oscillating sieve. At optimum combination of cylinder sped and concave clearance at different seed moisture contents to thresh oilseeds and pulse crops, the performance parameters were within acceptable ranges of visible seed damage 12% and threshing efficiency 195% with threshed seed germination percentage of green gram (88%), black gram (90%), soybean (90%). chickpea (90%) and sunflower (86%). The germination percentages were above the minimum seed standards suggested by ISTA, (1999)

Maunde *et. al*., (2010) developed manual cowpea thresher. The findings showed that in order to prevent rubbing influence on the crop, primary and secondary threshing must be performed before the actual threshing with the drum. The manual cowpea thresher's power requirements, drum speed, and design throughput capacity were 0.18 kW, 100 rpm, and 147 kg/h, respectively (without seed separation and cleaning).

Suhendra *et. al*., (2010) developed and tested a vertical axis rotating pepper decorticator According to the study, typical pepper decortication for white pepper was done by soaking harvested pepper for 8-14 days and physically removing the pericarp. Soaking may cause pepper to stink, infect it with germs, and diminish its volatile oil content. Aside from that, the colour of the pepper was heavily influenced by the quality of the water. To address the issue, a pepper decorticator that did not require soaking was developed. The decortication mechanism was created by shearing the pepper on a gap between a static vertical cylinder and a vertical axis revolving tube powered by an electric motor. A grooved rubber sheet was linked between the inner gap of the static cylinder and the outer gap of the rotating tube. While rotating, the peppers enter the gap and were spun and adorned by compressive and shearing forces. Experiments were carried out with three different angular speeds (524, 480, and 352 rpm), three different gap widths (3.8, 3.2, and 2.7 mm), and three different rotating cylinder length changes (10, 7 and 5 cm). The results show that the width of the gap and the length of the rotating cylinder had a significant effect on the pepper decortication performance. Meanwhile, the angular speed had just a tiny influence. The best results were obtained with a rotational speed of 352 rpm, a gap width of 3.2 mm, and a cylinder length of 5 cm, resulting in 83.2 per cent decortication, 11.2 per cent broken pepper, and a capacity of 10.3 kg/h.

Tajudeen *et. al*., (2011) designed, developed and evaluated performance for motorized prosopis africana pod thresher. They discovered that a threshing performance index of 92.55 per cent, consisting of a threshing efficiency of 98.03 per cent, a cleaning efficiency of 94.45 per cent, a seed loss index of 2.36 per cent, and a mechanical damage index of 1.59 per cent, was attained. For best results, a combination of 1200 rpm cylinder and fan speeds, 30 kg/h feed rate, and a moisture content of the pods of 6 per cent (w.b.) advised. The capacity of the thresher was 70 kg/h.

Pandey (2018) developed a thresher with better cleaning efficiency by developing a sieve and blower assembly based on the physical characteristics of fenugreek seed. The aspirator had to be positioned parallel to the threshing cylinder at one end of the counter shaft. The aspirator blower's impeller blade and the circular casing, which had a total diameter of 230mm, were constructed from MS sheet. Four radial blades were included with the aspirator blower, and they combined rectangular and triangular shapes. There were three reciprocating sieves used. The top sieve was 990 x 355 mm in size, with 5 mm-diameter holes that were 30 degrees inclined. The middle and bottom sieves measure 840 mm × 355 mm and have holes that were 4 mm and 2 mm, respectively. The sieve assembly was able to reciprocate at 350 strokes per minute with the aid of a suitable belt and pulley system with a stroke length of 40 mm.

2.5 Performance evaluation

Kepner *et. al.,* (1972), stated that the performance of a thresher depends upon the parameters like the moisture content of the crop, the peripheral speed of the cylinder, the clearance between concave and cylinder, and the feed rate of the machine.

Kamble *et. al.,* (2003) designed a millet thresher for pearl. Based on its design and operational parameters, evaluating it at various cylinder speeds (450, 700, 850 rpm), concave clearance (5, 10, 15mm), moisture content (10.2, 14.5, 17.2 per cent), and feed rate (300, 400, 500kg/h). The highest threshing efficiency attained was 96.8 per cent, the lowest grain damage was 2.75 per cent, the grain loss was 2.10 per cent, and the maximum germination was 87 per cent, with a minimum energy consumption.

Zakaria (2006), changed the threshing drum of a local stationary thresher to segregate flax seed and reduce stalk damage. An automatic apparatus that calculates the separation time and signals when the seeds were separated has been designed and manufactured. The thresher was tested with four different feed rates of 8.57, 12.86, 17.14, and 21.43 kg/min, four different drum speeds of 24.25, 25.81, 27.33, and 28.85 m/s, and two different threshing drums with eight and twelve fingers each arranged in five sets, as well as three different separating times of 10, 15, and 20 seconds. They calculated machine productivity, stalk damage, energy needs, and seed losses. With a drum speed of 28.85 m/s, feed rate of 8.57 kg/min, 12 drum fingers, and a separation time of 15 seconds, the created thresher performed at its best. The maximum threshing efficiency was 96.92 per cent, while the minimal seed losses, seed and stalk damage, and energy need were 1.33 per cent, 3.48 per cent, 3.26 per cent, and 1.26 kW, respectively.

Zaky (2006), suggested that the ideal conditions were the drum speed in the range of 3.3 to 4.4 m/s clearance range of 2.5-3 mm, and the air velocity should be 2 m/s, the energy consumption was 25.12 kWh/ton, and the criterion cost was 752 L.E/ton in order to reduce the seed damage and total losses of black seed with an acceptable level of cleaning efficiency.

Afify *et. al.*, (2007) evaluated the performance of a developed small thresher. In threshing black seed at various conditions, including drum speeds of 200, 250, 300, and 350 rpm, feed rates of 600, 700, 800, and 900 kg/h, and moisture contents of 11.82, 13.63, 15.72, and 17.61 per cent, (w.b). The end results showed that 2.85 kWh/ton of energy was needed to achieve the minimum seed loss of 2.63 per cent, stripping efficiency of 99.31 per cent, threshing efficiency of 98.74 per cent, and cleaning efficiency of 95.88 per cent.

Sinha *et. al.*, (2009) studied the influence of moisture content, concave clearing, and cylinder speed on visual damage, internal damage, germination per centage, and threshing efficiency of chickpea seed crop with three levels of moisture content (8, 10 per cent, and 12 per cent), three levels of cylinder peripheral speed (8.05, 8.94, and 13.42 m/s). The results indicate that the cylinder speed was the most important factor in determining the amount of visual and internal injuries. Moisture content had a negative impact on internal damage levels in threshed seed. The cylinder speed of 8.94 m/s, concave clearance of 14 mm, and moisture level of 10 per cent resulted in excellent quality seed with little visual and internal harm and optimal threshing efficiency.

Khodabakhshian *et. al*., (2011) evaluated performance a centrifugal peeling system for pistachio nuts. A factorial design based on completely randomized blocks was used by them to evaluate the performance of the centrifugal peeling system for pistachio nuts as a function of moisture content {in five levels: 4.10, 10.50, 20.10, 28.50, and 36.10 per cent (d.b.) and peripheral speed of a separate rotating circular base-plate (in four levels: 35, 40, 45, and 50 m/s).} It showed peeling efficiency and breakage per cent were used to describe overall performance. Peeling effectiveness and breakage increased as peripheral speed increased and pistachio moisture content decreased. According to their results of an optimization technique, the machine should be operated at a peripheral speed of 50 m/s and a moisture level of 4.10 per cent (d.b.) for the best peeling performance. Peeling efficiency and breakage per cent in these circumstances were 96.5 and 8.7 per cent, respectively.

Saiedirad *et. al*., (2011) investigated cylinder thresher machine crop characteristics for threshing cumin. The results of study showed that when moisture content increased from 7 per cent to 13 per cent, separated seed and damaged seed decreased from 92.8 per cent to 90.4 per cent and 10.1 per cent to 7.6 per cent, respectively. However, with an increase in cylinder speed from 12.8 to 16.5 m/s, the proportion of split seed, broken stems, and damaged seed increased. The cylinder form had little effect on the weight per centage of separated seeds, but it had a big effect on the weight per centage of broken stems and damaged seeds. It was discovered that the rub bar cylinder was preferable to the rasp bar cylinder. The rub bar cylinder, 16.5 m/s cylinder speed, and 7 per cent grain moisture content were the best conditions for cumin threshing.

Prasanna and Naveen (2012) tested the ragi MR1 and HR911 variates. At 9.8 per cent grain moisture content, the cultivar MR1 had the maximum threshing efficiency of 79.6 per cent. The best threshing efficiency of 79.0 per cent was attained for variety HR911 at a grain moisture level of 10.1 per cent. It was discovered that threshing of ragi crop is more efficient at 10 per cent to 13 per cent grain moisture level. Despite the fact that mechanical damage to grain was significant and seed germination was reduced when threshed at a lower i.e. 10 per cent grain moisture level.

Tiwari and Chauhan (2018) investigated how the geometry of the round spiked threshing cylinder affected the efficiency of threshing wheat crops. Study reveals that, the threshing cylinder tip diameter, spike thickness, and feed rate were regarded as independent variables. While output capacity, total power consumption, specific power consumption, broken grain loss, total grain loss, threshing efficiency, and cleaning efficiency were dependent characteristics. The study used round spiked plain pegs with diameters of 6, 8, and 10 mm and lengths of 75, 100, and 125 mm. The findings indicate that a threshing cylinder with round spikes produced the highest output capacity and threshing efficiency for wheat crop threshing, which were 369.3 kg/h and 99.87 per cent at tip diameter of 600 mm and spike thickness of 6 mm, respectively, corresponding to a maximum feed rate of 780 kg/h. The wheat straw size needed for a round spiked threshing cylinder to have the best output capacity and threshing efficiency was 22.67 mm, which was comparable to a maximum feed rate of 780 kg/h at a 600 mm tip diameter and a 6 mm spike thickness. A circular spiked threshing cylinder with a tip diameter of 600 mm and a spike thickness of 6 mm offered the greatest results for increased threshing efficiency, fine straw quality, and low specific power consumption, with total grain loss within the permissible limit.

2.6 Cost Economics

Naik *et. al.,* (2010) reported that threshing recognized to be very labour intensive operation and involved considerable human drudgery. Further delay in threshing operation result in delay in sowing of the next crop and hence it reduced the yield. Studies on the effect of moisture content, feed rate, and cylinder speed on the performance of thresher were done for different make threshers

Dhananchezhiyan *et. al*., (2013) studied the comparative performance of mechanical and traditional threshing method of paddy crop. They reported that The saving in cost and time of the portable power paddy thresher were 86.5 per cent and 95 per cent, respectively as compared to manual threshing. The break-even point for the developed portable power paddy thresher was 205 hours of use per year.

Chaturvedi and Rathor (2018) evaluate the performance of developed thresher in which they compared it with traditional method of threshing. The study revealed that the costs of manual threshing operation by hand beating method was 8.25 Rs/kg with 5 men, for tractor operation it was 14.65 Rs/kg and for developed millet thresher it was 4.34 Rs/kg.

Sial (2018) tested economic evaluation of the newly developed ragi thresher cum pearler and compares the cost of operation with the traditional method like manual hand beating and foot trampling, and reported that 65 to 70 per cent reduction of the operational cost as compare to the conventional method. The operating cost for threshing one kg of ragi by the developed ragi thresher was calculated as Rs 1.44/kg the total operating cost of machine was Rs. 76.56 per hour. In case of traditional method, it was coming around Rs. 26.65 per hour and Rs. 5.24 per kg for hand beating method but in case of foot trampling method it was about Rs. 4.20 that was costlier as compare to the developed thresher cum pearler.

The review concluded that the physical properties of spices like linseed, fenugreek, coriander, fennel, lentil, cumin, tung, cinnamon were different from each other. Also there was great effect of moisture content of the commodity on the engineering properties. Reviews given by Balsubramanium (2011), Singh *et. al.* (2011) and Grewal (2016) gives the methods to find the engineering properties of triphal. Reviews showed the relation between different engineering properties and their use in design of machinery. Hence the Engineering properties of triphal were measured for designing of triphal peeling unit.

For the peeling and threshing of spices mostly rasp bar type of cylinder were used. Many reviewers standardized the parameters such as cylinder speed, concave clearance, grate clearance, sieve stroke length for different crops like cowpea, pepper, African pod, millet etc. The variations studied from different reviews results were necessary to study the effect of machine and operational parameters for different peeling mechanisms.

CHAPTER III

MATERIAL AND METHODS

The material and methodologies needed to conduct experiments to investigate the engineering and physical properties of triphal, as well as the development of a triphal peeling unit, its performance assessment, and cost economic analysis were all covered in this chapter.

3.1 The Study Area

The fabrication and performance evaluation of triphal peeling unit were conducted in the FMPE workshop, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (MS). It was located at 17.7677º N latitude and 73.1910ºE longitude. For determination of physical and engineering properties of triphal experiments were conducted at Agri. Process Engg. Laboratory, Central Institute of Agricultural Engineering, Bhopal (M.P.).

3.2 Engineering Properties

Engineering properties were the properties which were useful and necessary in the field of different farm machineries in development and study were also suitable for carrying out different post harvest activities. In operations while handling of spices seeds and flowers the properties which play an important role were physical, mechanical, frictional, aerodynamic properties etc. Basic information on these properties of triphal was of great importance towards efficient process and equipment development for the peeling of triphal. An attempt has been made to measure some of the engineering properties usually encountered in design and development of the triphal peeling unit.

3.2.1 Physical Properties of Triphal

For determination of physical properties of triphal the samples were purchased from local market of Dapoli. The properties which were measured under this study were length, width, breadth, moisture content, geometric mean diameter, bulk density, true density, porocity etc.

3.2.1.1 Moisture content

Triphal were collected in adequate quantity from local market of Dapoli, Maharashtra, India. Triphal were cleaned manually to remove all foreign materials such as dust, dirt and broken and immature fruits. The initial moisture content of Triphal was determined by using the standard hot air oven method using the following formula (AACC, 2000).

$$MC\ (\%) = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \qquad ...(3.1)$$

Where, MC= Moisture content on dry basis, %;

W1= Initial weight of the bowl, g;

W2 = Sample weight before drying +bowl weight, g;

W3 = Sample weight after drying + bowl weight, g

Samples of desired moisture content levels were prepared by adding calculated amount of distilled water by using following equation and mixed thoroughly (Sacilink *et. al*., 2002).

$$Q = W_i \times \frac{mf - m_i}{100 - mf} \quad ...(3.2)$$

Where, Q = Weight of water to be added, g;

Wi = Initial weight of seed sample, g;

m_i = Initial moisture content of seed sample (% db); and

mf= Final moisture content of seed sample (% db).

Plate 3.1 Triphal Samples Kept in Hot Air Oven to Measure Moisture Content

3.2.1.2 Linear Dimension of Triphal

To determine the size and shape of Triphal, length, breadth and thickness of randomly selected 25 samples were measured by using a digital vernier caliper with least count reading 0.01 mm and its average were recorded.

The dimensions of the triphal can be used to choose the appropriate sieve size so that can separate the triphal seeds from the kernals. However, sieve parameters- size, shape and spacing of screen openings, angle of inclination, screens stroke length can also be determined by using the dimension of the triphal and seeds (Mohsenin, 1986 and Dutta, 1988).

Plate 3.2 Measurement of linear dimensions of Triphal

3.2.1.3 Size of Triphal

The arithmetic mean diameters (AMD), geometric mean diameter (GMD), square mean diameter (SMD), an equivalent diameter (EQD), of triphal were calculated by using the following relationships (Mohsenin, 1986).

$$AMD = \frac{(L + B + T)}{3} \qquad \ldots(3.3)$$

$$GMD = (LBT)^{1/3} \qquad \ldots(3.4)$$

$$SMD = \sqrt{(LB + BT + TL)} \qquad \ldots(3.5)$$

$$EQD = \frac{(AMD + GMD + SMD)}{3} \qquad \ldots(3.6)$$

Where, L=Length of seed, mm;

B= Breadth of seed, mm; and

T= Thickness of seed, mm.

The knowledge of the geometric mean diameter can be used in the determination of cylinder concave clearance of the peeling unit.

3.2.1.4 Surface area (S)

The surface area (S) was calculated by using the expression given by (Singh *et. al.*, 2010).

$$S = \pi(GMD)^2 \qquad \ldots(3.7)$$

Where, GMD = Geometric mean diameter, mm.

3.2.1.5 Sphericity (ϕ)

Sphericity was defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain and it was determined using following formula (Mohsenin, 1986).

$$\phi = \frac{(LBT)^{\frac{1}{3}}}{L} \quad \ldots(3.8)$$

Where, L=Length of seed, mm;

B= Breadth of seed, mm; and

T= Thickness of seed, mm.

3.2.1.6 Bulk density (BD)

The bulk density of seed was the ratio of its mass to total volume. It was determined by using standard test weight procedure by filling a 25ml measuring cylinder with triphal at constant rate, striking the top level and weighing the contents (IS:4333 part III). Bulk density was then calculated as the ratio between the sample weight and the volume of the cylinder (Akaaimo and Raji, 2006; Mwithiga and Sifuna, 2006).

$$BD = \frac{Ws}{Vs} \quad \ldots(3.9)$$

Where, BD = Bulk density in g/cm^3 ;

Ws=Weight of the sample in g; and

Vs =Volume occupied by the sample, cm^3.

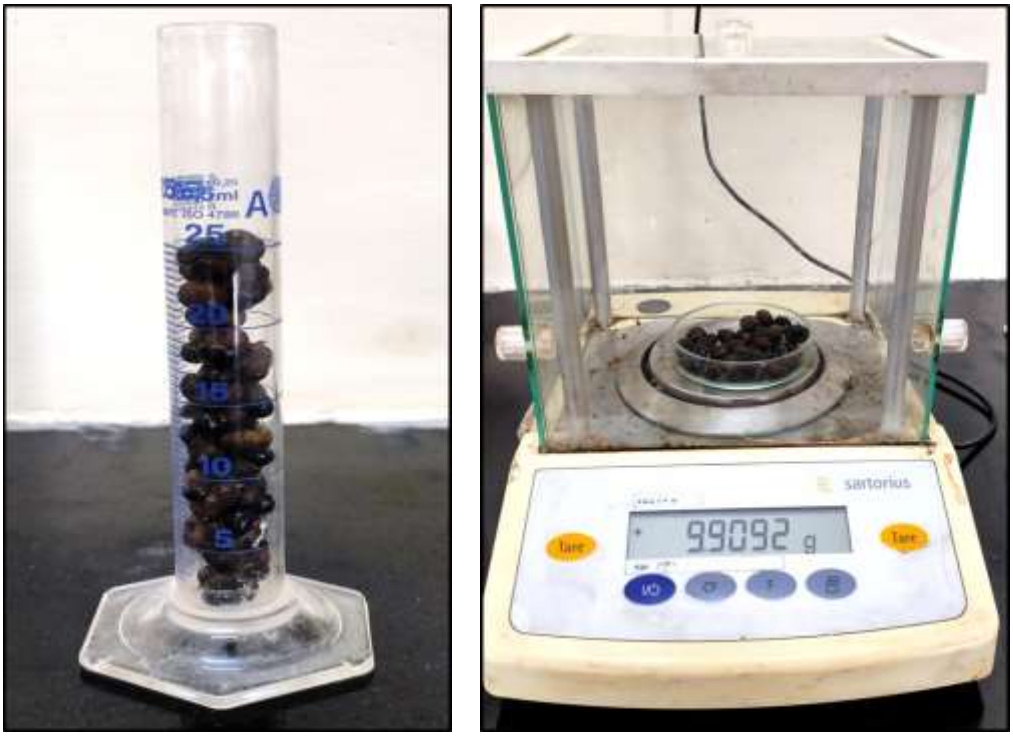

Plate 3.3 Measuring Bulk Density of triphal

3.2.1.7 True density

The true density defined as the ratio of mass of the sample to its true volume, It was determined using the toluene (C_7H_8) displacement method. Toluene was used in place of water because it was absorbed by triphal to a lesser extent. 15 millilitres of toluene were placed in a 25 ml graduated measuring cylinder and 3g seeds were immersed in the toluene (Mwithiga and

Sifuna, 2006; Ovelade *et al*., 2005). The amount of displaced toluene was recorded from the graduated scale of the cylinder. The ratio of weight of triphal to the volume of displaced toluene gave the true density.

True volume of triphal (ml) = (Initial toluene level in measuring cylinder) – (final moisture level in measuring cylinder) …(3.10)

$$TD = \frac{W_s}{T_{VS}} \quad \text{…(3.11)}$$

Where, TD = True density in g/cm^3;

Ws = Weight of Triphal in g; and

Tvs = True volume of Triphal, cm^3.

Plate 3.4 Measuring True Density of triphal

The knowledge of density of triphal was needed in separating the product from undesirable material. Density of triphal decides the size of screening surface.

3.2.1.8 Porosity (ϵ)

The porosity was the fraction of the space in the bulk grain which was not occupied by the grain. The porosity was calculated from the values of true density and bulk density using the equation:

$$\varepsilon = \frac{TD - BD}{TD} \times 100 \quad \text{…(3.12)}$$

Where, ε = Porosity;

TD = True density, g/cm^3; and

BD = Bulk density, g/cm^3.

Percent of voids of unconsolidated materials such as grains and other porous materials was often needed in the design of air flow mechanisms

3.2.2 Mechanical Properties

Some mechanical properties like coefficient of friction, angle of repose, seed detachment force, were selected for the study.

3.2.2.1 Coefficient of Static Friction

The static coefficient of friction may be defined as the friction force acting between surfaces of contact at rest with respect to each other. The coefficient of static friction for triphal was determined against five different surfaces i.e. stainless steel, wood, mild steel, plastic, and aluminum using the inclined plane method. This involves placing the triphal on adjustable tilting surface equipment with the surface formed using five different material sheets. Manually, the inclination of the plate was increased gradually until the specimen starts to slide down and at that point, the angle of tilt 'α' in degree was read on a graduated scale (protractor). The angle of inclination with the horizontal was measured by a scale provided and was taken as an angle of internal friction and tangent of the angle was taken as co-efficient of friction between surface and triphal as in following equation (Patel *et. al.*, 2013).

$$\mu = tan\ \alpha \qquad \ldots(3.13)$$

Where, μ = coefficient of static friction (dimensionless) and;

α = angle of inclination of material surface (^{o}).

Plate 3.5 Different surfaces sheet for the measurement of coefficient of friction of triphala

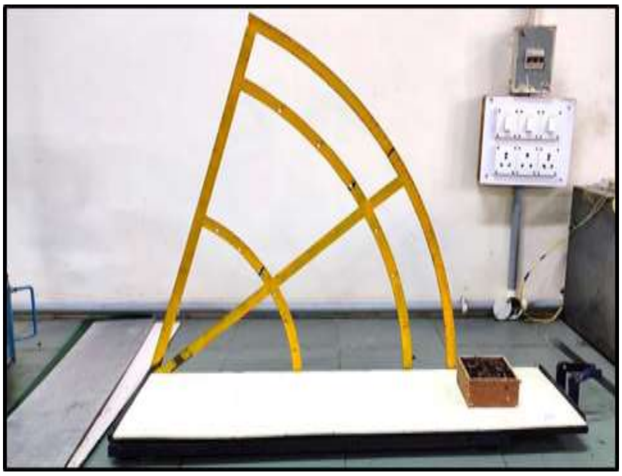

Plate 3.6 Measuring coefficient of friction of triphal

The knowledge of coefficient of friction of the food grain's on various surfaces was necessary in analysis and design of post-harvest grain handling, processing and storage equipment such as grain bin conveyors flow of food grain from bins by gravity or loaded auger. A machine can only be started or stopped if forces of static coefficient of friction or dynamic friction were overcome by the power source. Therefore, information on coefficient of friction was vital in estimating the power requirement of machines.

3.2.2.2 Angle of Repose

Angle of repose was determined by using an apparatus which was consist of circular platform of 41.5cm diameter and having sidewalls 10 cm high. At one side of apparatus rod was attached on which funnel whose height can be adjusted with pulling up and down and fixing it with the provided tightening nut and bolt arrangement. To measure the angle of repose, funnel was filled with the triphal and stopper was engaged at time of filling. Then height of funnel was adjusted at 15 cm to allow free fall of the triphal through hopper. Then heap of the triphal formed on the circular platform whose height can be measured with scale. Diameter was measured with scale. After measuring the height and diameter of heap formed, angle of repose can be calculated by following equation.

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad \ldots(3.14)$$

where, H = Height of the cone, cm; and

D = Diameter of cone, cm.

The angle of repose of triphal was used in the determination of the angle at which the hopper of the the peeling unit will be slanted so it has free flow of the triphal.

Plate 3.7 Measuring angle of repose of triphal

3.2.2.3 Seed Detachment Force

The experiment was carried out to find the detachment force of the seed from the kernals. The texture analyzer TA.XT Plus (Stable Micro System UK) having load cell capacity 5/25/50 kg of Engineering Properties Laboratory, Agro Produce Processing Division, Central Institute of Agricultural Engineering, Bhopal (M. P.) was used for determination of force. The texture analyzer consisted of two primary components: hardware (load cell with a platform to hold sample and moving head for holding probe) and software (Exponent Lite) for recording and calculating the test results. Before performing the tests, the machine was calibrated for load and distance for each test. The load calibration was done to check whether the load cell was accurate in sensing the force imposed over the sample. For calibrating 10 g were suspended on the crosshead and selected the desired option under T.A. settings. Similarly, calibrated the movement of the cross ensure the compliance of the set deformation (strain) of the sample. After calibrating the texture analyzer, a sample of triphal was placed in tensile grips probe. The force required to detachment of seed was abstracted from the graph shown and procedure repeated for 10 times to get the average mean value. (Pathak *et al*., 2017)

Table 3.1 Texture Analyser Setting

Sr. No.	Caption	Value	Units
1.	Test mode	Tension	-
2.	Pre-test speed	1.00	mm/sec
3.	Test speed	0.50	mm/sec
4.	Post-test speed	10.00	mm/sec
5.	Target mode	Distance	-
6.	Distance	5.00	mm/sec
7.	Trigger Type	Auto(Force)	-
8.	Trigger Force	10.00	g
9.	Advanced option	Off	

3.2.2.4 Crushing Force of Triphal and Stalk

The crushing force of triphal and stalk was determined in this experiment. The texture analyzer TA.XT Plus was used to calculate force (plate. 3.7). The machine was calibrated for weight and distance for each type of test prior to starting the tests. The load calibration was performed to see whether the load cell was accurate in sensing the force imposed over the triphal and stalk sample. For Calibrating 10 N were suspended on the crosshead and the desired option was selected under T.A. settings. Similarly, calibrated cross movement ensures the sample's conformity with the prescribed deformation (strain). A triphal sample was placed on the platform after calibrating the texture analyzer. To construct the force-time curves, different probes were utilised for different tests based on the settings. The force needed to rupture or deform was extracted from the graph and the technique was repeated five times to obtain the average mean value. A similar procedure was followed for the stalk (Kingsly *et. al.*,2006).

These mechanical properties like seed detachment force, crushing strength of triphal and stalk crushing strength were usefull in the selection of power source for the pelling machine.

3.3 Design Considerations

As upto now all the processing were done with hands by women labours like drying in sun, beating the triphal stalks to separate it from the groups, picking the separated seeds and kernals and then winnowing it with the hand winnower (Soop) to remove the remaining foreign particles. Without any standard reference developing a standard machine or procedure to peel out triphal and separate seeds from kernel was tough work, therefore for this purpose conducted the numbers of different experiments to find out suitable material and procedure to achieve the goal. Following development requirements were envisaged for the proposed development of the triphal peeling unit.

Plate 3.8 Measuring seed detachment force using Texture Analyser

- The developed machine should be easy to operate, simple in construction and should have minimum cost.
- It should be capable of performing various functions like separating seed from kernels, breaking of stalk, separation of stalks and seeds from the main product.
- Seed and product can be separated using 6.5 mm sieve.
- Machine should be vertical axis to minimize the damage during peeling.
- In peeling operation it cannot produce specific length of stem.
- In first phase seeds and product gets separated.
- In second phase, product gets cleaned from stalks.

- The machine should be operated by a single phase electric motor so that it could be easily available at farmer's field / threshing yard.
- Electricity consumption and cost of operation of the machine should be low.

Considering these considerations, triphal peeling unit was developed. Triphal peeling unit was essentially consisted of two main units, peeling unit and clening unit.

3.4 Design, Development and Testing of Triphal Peeling Unit components

3.4.1. Power Requirment

Power required to separate seeds from the kernels of the triphal was expressed as (Gbabo *et., al.* 2013)

$$P = T \times \omega \quad \ldots (3.15)$$

$$\omega = 2\pi N / 60 \quad \ldots (3.16)$$

$$T = F \times r \quad \ldots (3.17)$$

Where, P= Power required, watt;

T= Torque of the drum, Nm

ω = Angular velocity, rad/sec

N= Speed, rpm

F= The force required to separate seed from the kernels, N

r = The distance of point of force application from axis of rotation, m

Among the mean seed detachment force and mean stalk rupture force, stalk rupture force (25 N) was highest. For spices like triphal and black pepper peeling lower rotational speed (400 rpm) was required (Suhendra *et., al.* 2010). Hence it was considered for the calculations of power requirements.

$$\omega = 2\pi \times 400 / 60$$
$$= 41.88 \text{ rad/sec.}$$

$$T = F \times r$$
$$= 25 \times 0.1$$
$$= 2.5 \text{ Nm.}$$

$$P = T \times \omega$$
$$= 2.5 \times 41.88$$
$$= 104.7 \text{ W.}$$

Considering the factor of safety 10 per cent of 104.7 W (Suhendra *et., al.*2010), 120 W (0.16 hp) single phase motor with upto 300 rpm controller was selected for the triphal peeling unit.

3.4.2 Main frame

Frame supported the whole assembly including grate, sieve assembly, motor and transmission. The frame was made up of 25 X 25 mm M.S. angle to reduce the weight of the machine so it can be made easy to transport from one place to another. The overall height, width and length of the main frame were 520, 360, 770 mm, respectively. Isometric view and schematic view of main frame were shown in fig 3.1

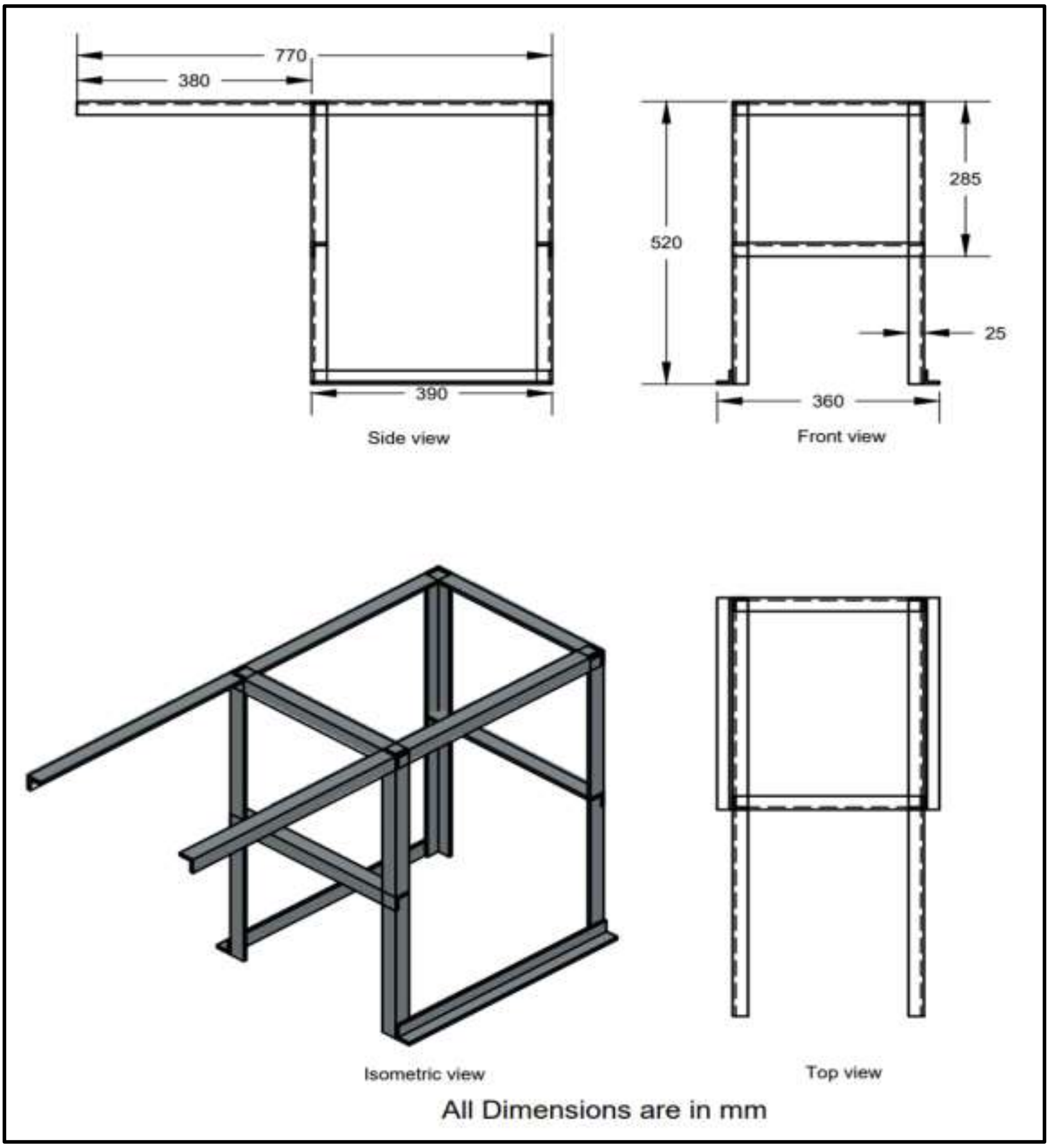

Fig. 3.1 Design of Main frame

3.4.3. Design of Hopper

Feeding hopper was constructed as per guidelines given by IS 9020:2002 (safety requirement). M.S. sheet of 16 gauge was used for fabrication of the hopper. The total length and of hopper were 600 mm and width at outer end was 385 mm while at inner end it was 230 mm. The angle of inclination was 25 degrees which was more than angle at which triphal just started to slide down (21 degree) for stainless steel which was measured in measuring of coefficient of friction for triphal and stainless steel. The schematic view of hopper were shown in fig 3.2

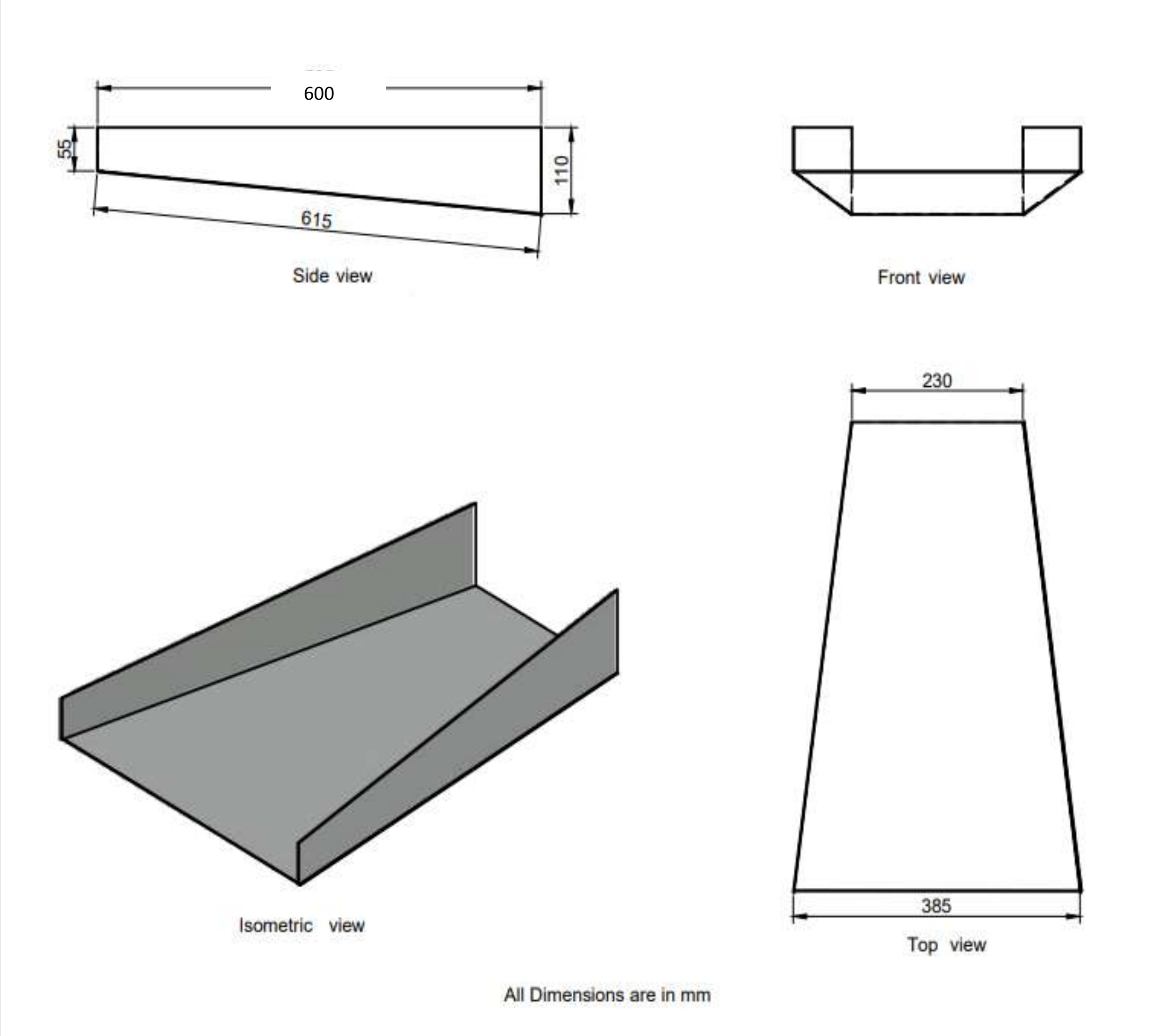

Fig 3.2 Design of Hopper

3.4.4 Design of internal cylinder

Triphal seeds require very small amount of force to get separated from the kernels. Hence it required low RPM for effective peeling. As geometric mean diameter of triphal was 10 mm it was useful in design of the grate as to keep the grate clearance 10 mm. The speed of internal drum was assumed upto 400 rpm and effective peripheral speed of peeler cylinder was 3.8 to 3.9 m/sec. (Suhendra *et., al.* 2010). Using peripheral speed of internal cylinder and speed of cylinder, diameter of cylinder was calculated using eqn 3.18.

$$D_c = \frac{V \times 60}{\pi \times N} \qquad \ldots(3.18)$$

Where, D_c = Diameter of cylinder

V = Peripheral speed of cylinder

N = Speed of cylinder

Peripheral speed of cylinder and speed of cylinder was considered 3.85 m/sec and 300 rpm for vertical axis peeling machine (Suhendra *et., al.* 2010).

$$D_c = \frac{3.85 \times 60}{\pi \times 300}$$

$$= 0.183 \text{ m}$$

$$= 183 \text{ mm}$$

$$\approx 185 \text{ mm}$$

Hence the diameter of the cylinder was taken 185 mm. Length of cylinder was considered as 2.5D for the vertical axis peeling machine (Suhendra *et., al.* 2010), which comes out to be 462.5 mm but due to limitation of height of machine it was considered as 432 mm To provide the rubbing force on triphal mild steel solid bars of 6 mm diameter were welded lengthwise. The circular plate of 179 mm diameter were cut and bars having 6 mm diameter were welded along the plate to form a 185 mm diameter cylinder. Similar 2 more cylinders of diameter 183 mm and 187 mm were fabricated for getting different grate clearances. The detailed schematic view was given in fig 3.3.

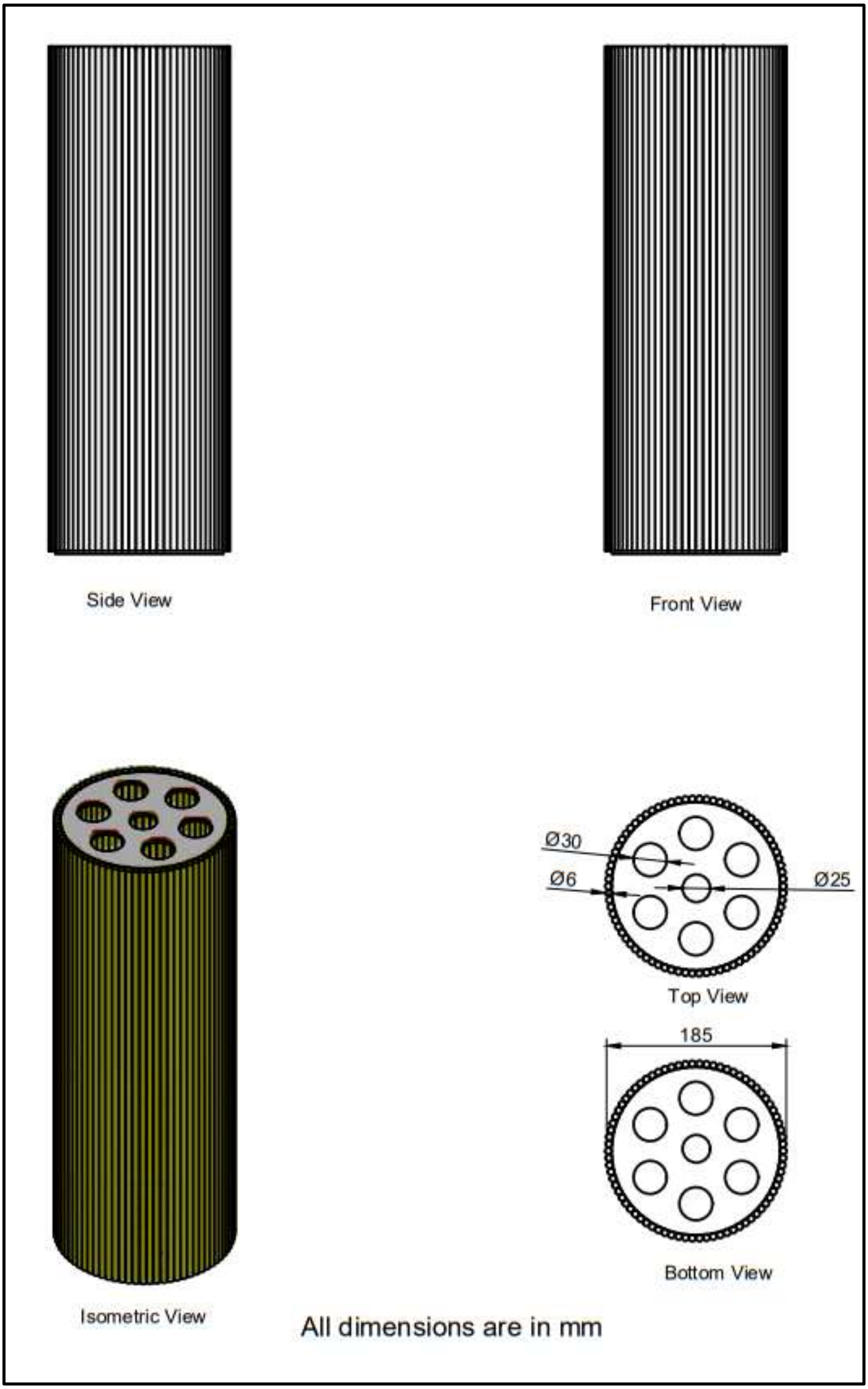

Fig 3.3

Developed Internal Cylinder

3.4.5. Design of Grate

From the design considerations, it was clear that grate could not be made from metal. But corrugation was required to rub the triphal between two surfaces. In order to overcome this problem grate was made from the plastic tube of outer diameter 10 mm and inner diameter 6 mm. Steel rod of 6 mm diameter was inserted in tube to provide rigidity. Two mild steel plates of thickness 3 mm was laser cut into square piece of 310 × 310 mm. In the upper plate 220 mm diameter was laser cut. On the periphery 6.3 mm diameter holes were pierced across the circumference to hold the steel rods and tube.

Similarly, lower plate was of 195 mm diameter was used, at four corners of plates holes was made to hold both plates together. Rods were inserted in between two plates in such a way that the complete cylinder assembly looks like helix to provide the more corrugated surface to peel the triphl. Total 62 no. of bars were required to fill the periphery of plate. Both plates were covered by covering plates to hold the rods on its place. Distanace between two plates can be varied by adjusting nuts at the corners of the plate. Schematic view of grate were shown in fig 3.4

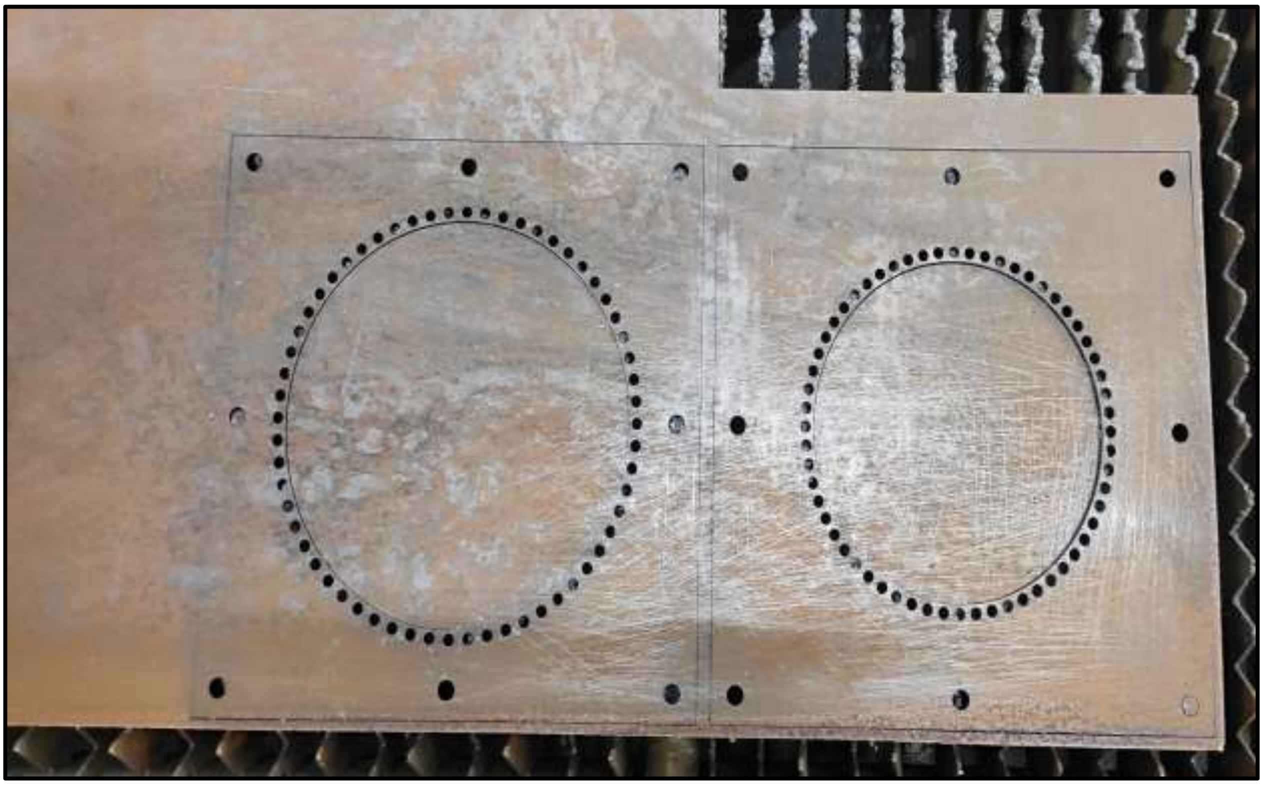

Plate 3.9 Laser Cutting of M.S Sheet for Grate

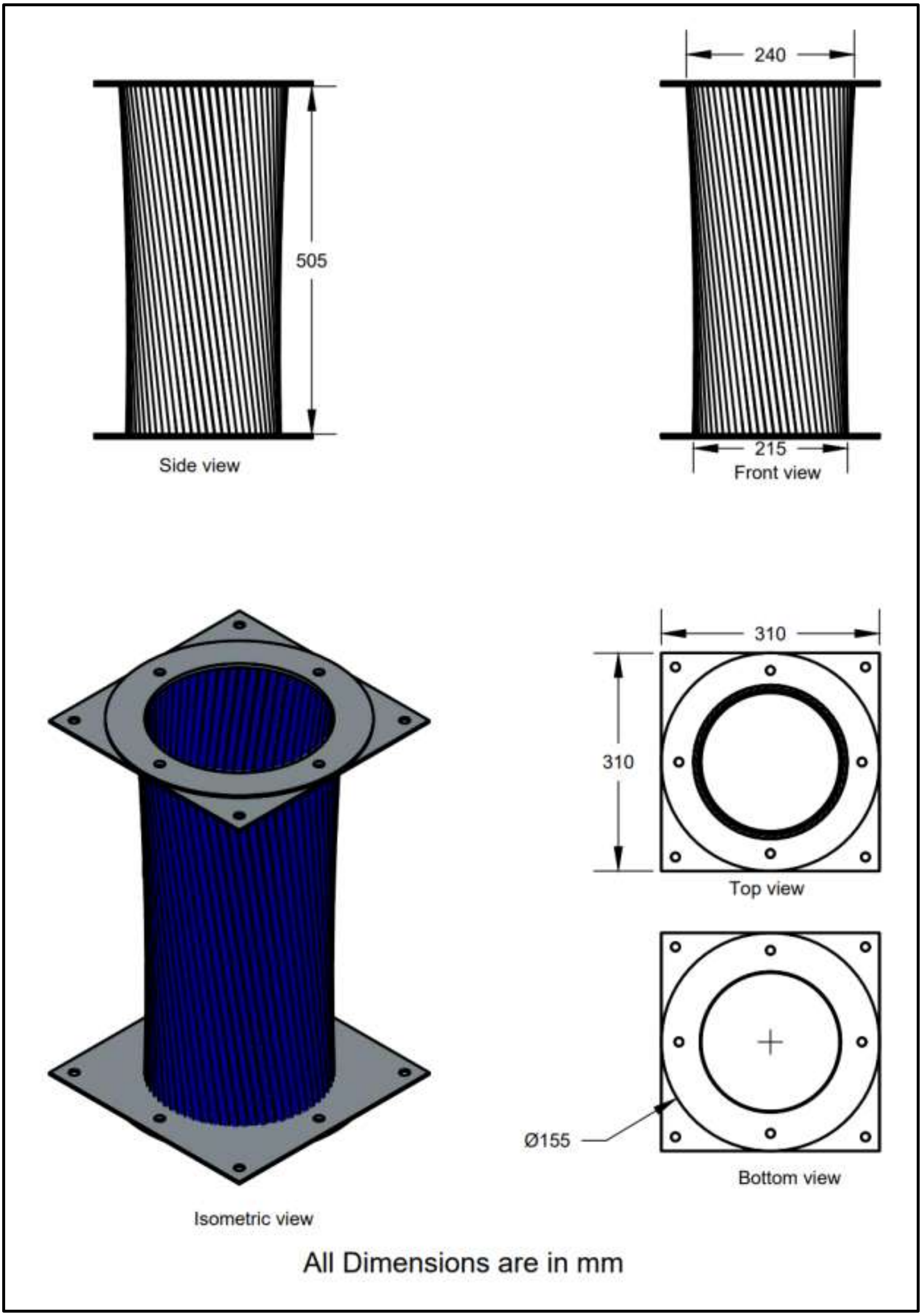

Fig 3.4 Design of grate

3.4.6 Design of Sieve

The shape and size of sieve were selected based on geometric mean diameter of triphal. Geometric mean diameter of triphal was found to be 10 mm for 18 per cent moisture content. 11 mm size was selected to separate triphal and seeds from the stalks. And 6.5 mm sieve size was selected to separate seeds from triphal. The assembly slope was kept 43˚ as the angle of repose of the triphal was found to be 42.71˚.

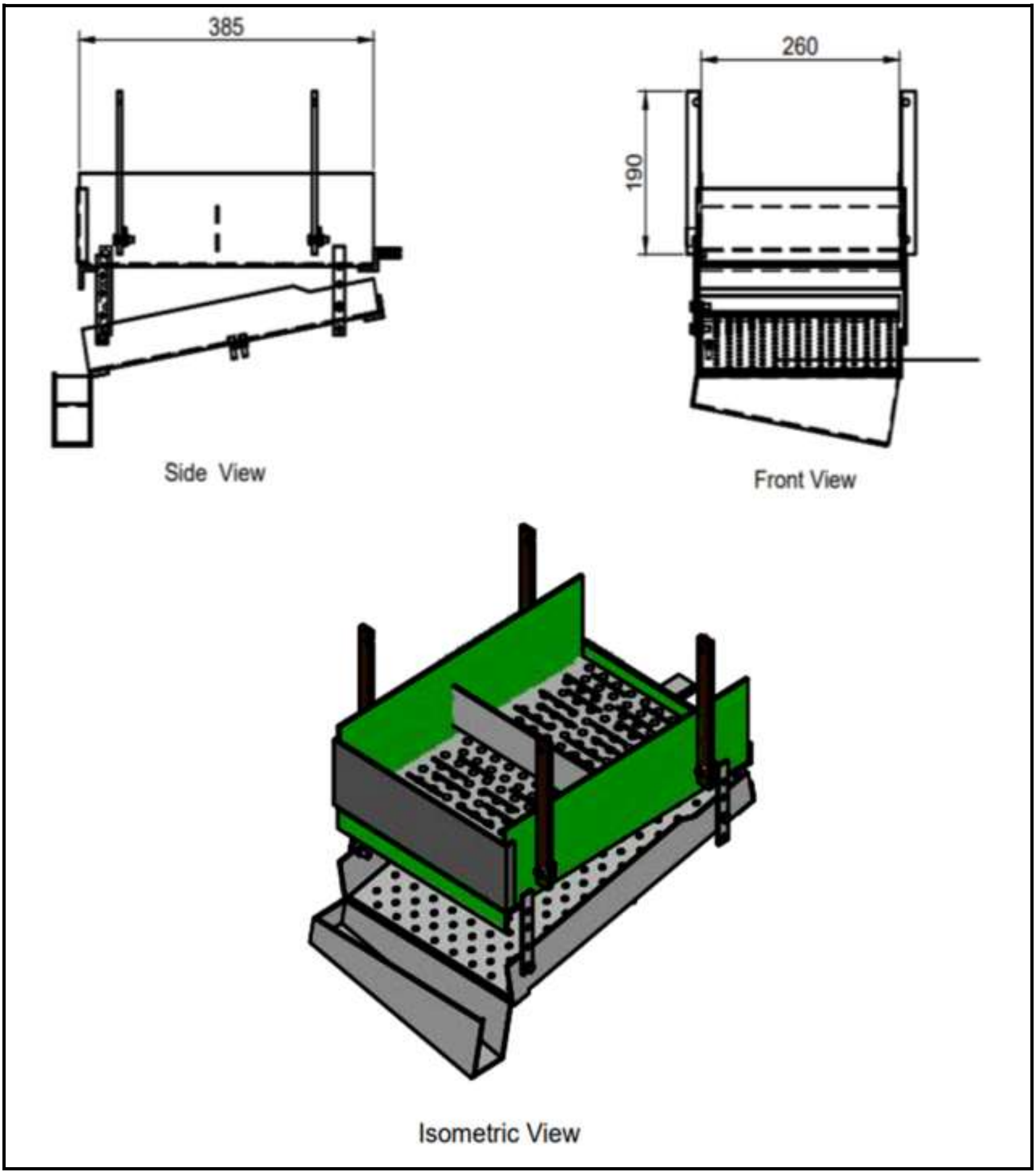

Fig 3.5 Design of Sieve

Width of the sieve was 260 mm and length was 385 mm as it had to handle 8 kg/h of feed material. The sieveing unit was made up of two rectangular sieve of size 260 mm × 385 mm. Out of which upper plate had opening of 11 mm and lower plate had circular opening of the 6.5 mm diameter. Schematic view of the sieve was shown in fig 3.5

3.4.7 Power Transmission

Single phase 120 watt (0.16 hp) motor was used as a power source. Pulley at motor was of 127 mm diameter. Eccentric was attached to the motor pulley and sieve which converts rotational motion of the pulley to the reciprocating motion of the sieve. There was a belt and pulley system to the main shaft of the cylinder. Pulley at shaft had diameter of 65 mm. Belt used was A 21/13 × 535. Motor gives output of about 300 rpm which was transmitted through the 127 mm diameter pulley of motor to 65 mm diameter pulley of main shaft resulting in increase of rpm upto 600 rpm.

3.4.8 Assembly of the Machine

The complete assembly of the machine was mounted on the mainframe. Initially the sieve assembly was fixed with proper hing arrangement with m. s flat of size 25 × 5 mm, the oscillation mechanism was attached with sieve assembly which was powered through 0.16 hp motor. On the frame grate was mounted with the mounting nuts and bolts of 12 mm size. Internal cylinder was mounted on the main shaft with the help of bosch on both ends of the cylinder. It was locked with the square key of 8 mm size. Discharge chute was installed at lower end of the frame so it was convenient to pass the shaft through it. Internal cylinder was placed inside grate. Lower end was fixed at the lower bearing and upper and was locked with the rectangular angle frame with bearing. At side of the top of angle frame hopper was installed with the help of nuts and bolts of size 12 mm. At lower end of shaft pulley of 65 mm size was installed and at motor 127 mm size pulley was installed. Both pulleys were connected with V belt. The eccentric of the sieve was connected with the motor. Motor was connected to the speed controller. And Machine was completely assembled. Complete assembly of the machine was shown in plate 3.10.

Plate 3.10 Completely Assembled Developed Triphal Peeling Unit

3.4.9 Developed triphal peeling unit

The specifications of developed triphal peeling unit was given at table 3.2. The schematic view of developed triphal peeling unit were given in fig 3.6

Table 3.2 Specifications of Developed Triphal Peeling Unit

Sr. No.	Parameters	Specification
A) Internal cylinder		
1	Diameter, mm	183, 185, 187
2	Length, mm	432
3	Bar diameter, mm	6
B) Hopper		
1	Length, mm	595
2	Width, mm	
	i) outer end	385
	ii) inner end	230
C) Grate		
1	Height , mm	505
2	Upper outer diameter, mm	240
3	Lower outer diameter, mm	215
D) Main frame		
1	Height, mm	520
2	Length, mm	770
3	Width, mm	390
E) Shaft		
1	Length, mm	775
2	Diameter, mm	25
F) Sieve Box		
1	Length, mm	380
2	Width, mm	255
G) Overall dimensions of machine		
1	Height, mm	1060
2	Length, mm	850
3	Width, mm	390

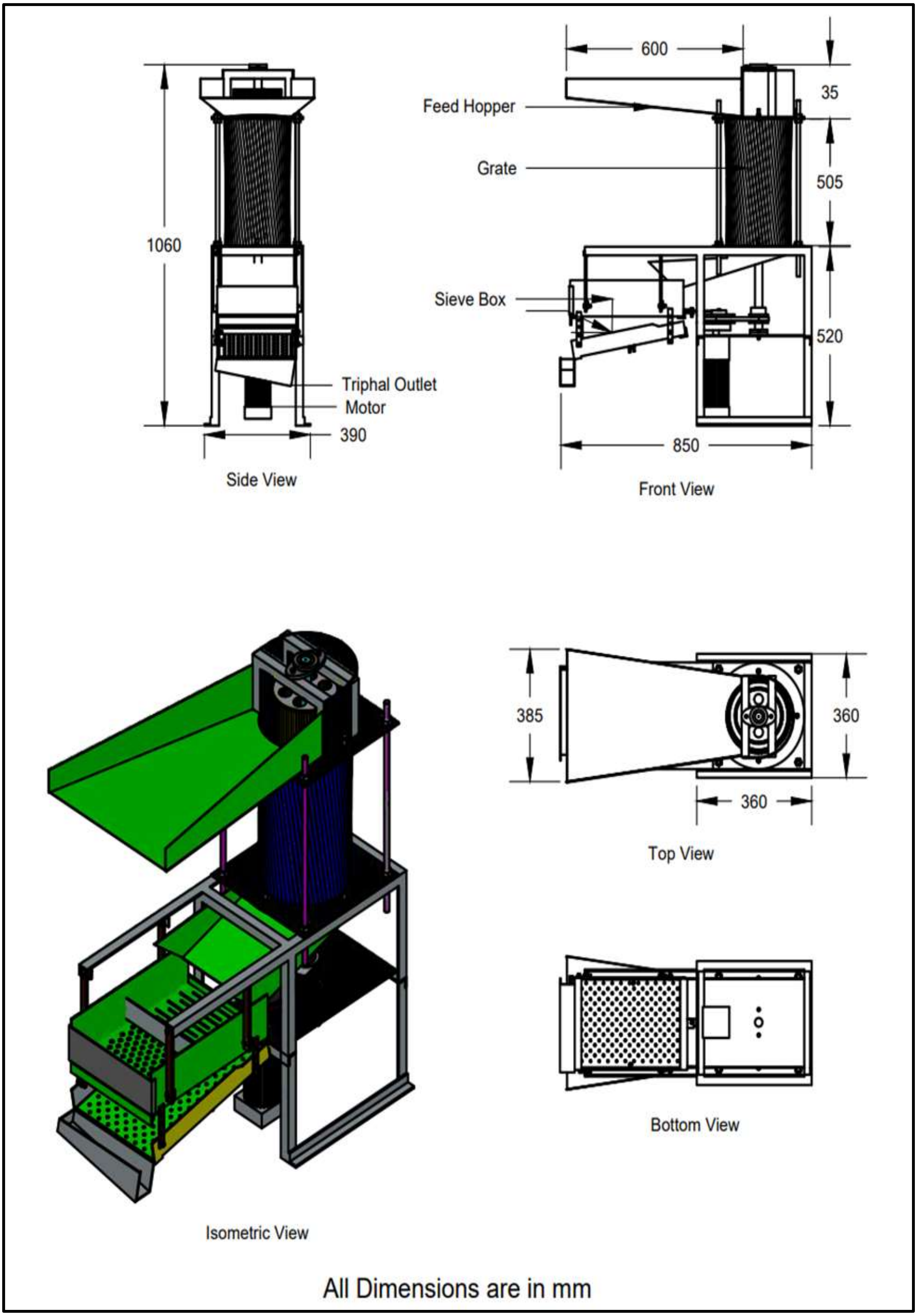

Fig 3.6 Developed Triphal Peeling Unit

3.5 Working of Machine

In working of machine control unit of the motor was connected to the power source. From control unit speed of the machine can be adjusted and machine can be turned on and off. After setting required speed and turning on the machine the raw triphal was feeded from the hopper. Due to the rotation of the cylinder triphal was pulled inside of concave and cylinder. Due to friction between concave and cylinder, seeds gets separated from triphal. Mixture of seeds stalks and triphal came out from the discharge unit. Mixture falls on the upper sieve which was constantly shaking. In upper sieve stalks remains on sieve while seeds and triphal falls on second sieve. In second sieve triphal rides over the sieve and collect at main triphal outlet while seeds falls from the sieve.

3.6 Performance Evaluation of Triphal Peeling Unit

3.6.1 Test at No Load Condition

The peeling unit was run at no load condition for 10 min at specific speed. Energy meter was connected with thresher for measuring the power consumption at no load for one hour. It was observed that there was no rising of bearings temperature, slippage of belts, unusual wear or slackness of belt or part during the running condition (IS: 6284-1985, 1986).

3.6.2 Test at Load condition

The machine was run to observe the performance of the machine i.e., peeling efficiency, Damage Triphal per cent, unpeeled triphal per cent and capacity of machine.

The performance of developed triphal peeling unit was evaluated. Performance was evaluated at different levels of independent variables to study on selected dependent variables. Each experiment was replicated three times for better accuracy of result. The following independent and dependent variables were considered for evaluation of machine.

Table 3.3 Different parameters of developed peeling unit

Sr. no.	Variables	Parameters	Level	Ranges
1.	Independent variables	Cylinder Speed, rpm	3	300 – 400 - 500
		Grate Clearance, mm	3	8 – 10 - 12
		Sieve Stroke Length, mm	3	10 – 20 - 30
2.	Dependent Variables	Peeling Efficiency, %		
		Triphal Damage, %		
		Unpeeled Triphal, %		
		Capacity of Machine, kg/h		

3.6.3 Experimental Design for Performance Evaluation of Developed Triphal Peeling Unit

Response surface methodology was employed to evaluate performance of developed triphal peeling unit using three independemt parameters viz. cylinder speed, grate clearance, and sieve stroke length on four dependent parameters viz. Peeling efficiency, Damage Triphal per cent, Unpeeled triphal per cent and Capacity of machine.

The design setup consist of 17 experimental runs, including 5 center point runs as shown in table 3.4. The optimum conditions of process variables were derived using desirability function. Design Expert 13 trial version software was used for statistical analysis

Table 3.4 Experimental Design for Performance Evaluation of Developed Triphal Peeling Unit

Run	Cylinder Speed, rpm [A]	Grate Clearance, mm [B]	Sieve stroke length, mm [C]
1	400	10	20
2	400	10	20
3	400	10	20
4	300	8	20
5	500	10	30
6	300	10	30
7	400	8	10
8	400	12	10
9	400	10	20
10	500	8	20
11	400	12	30
12	500	10	10
13	300	10	10
14	400	10	20
15	500	12	20
16	300	12	20
17	400	8	30

3.6.4 Material and instruments used during performance evaluation

Different instruments were used for performance evaluation of developed triphal peeling unit. Details of the instruments used were given in table 3.5

Table 3.5 Instruments used in testing of triphal peeling unit

Sr.	Instrument	Use	L.C.

no.			
1.	Tachometer	To measure the speed of rotating parts	
2.	Stop watch	To measure time required for the operation	0.01 sec
3.	Energy meter	To measure electricity consumption	
4.	Spanner Set	To assemble or dismantling of machine	
5.	Electric weighing balance	To measure the weight of samples	2 g

3.6.5 Validation of Data

For the final performance of the experimental setup, the setup was set as per obtained standard values from design expert 13 (trial version) software of cylinder speed, grate clearance and sieve stroke length. Observations were recorded in laboratory testing of experimental setup. Then setup was taken over farmers field for the performance evaluation at obtained standard settings. The performance of the developed triphal peeling unit were analyzed and the observations were recorded.

3.7 Costs Evaluation of the Machine

Cost of peeling operation was worked out on the basis of the prevailing market price of peeling unit, labour charges, repair and maintenance. Cost of peeling operation was calculated on the basis of Rs/h. For calculation of cost of machine assistance was drawn from IS: 9164, the procedure for calculation of cost of operation of triphal peeling unit was given as below.

3.7.1 Fixed cost of machine

i. Depreciation: This cost reflects the reduction in value of a machine with use (wear) and time (obsolescence). It was the loss of value of a machine with the passing of time and calculated by the formula (IS 9164: 1979):

$$D = \frac{C - S}{L \times H}$$

…(3.19)

Where, D = Depreciation per hour;

C = Initial cost of implement, Rs;

S = Salvage value @ 10 % of C, Rs.;

L = Working life of machine in years; and

H = Number of working hours per year;

ii. Interest of investment: Interest was calculated on the average investment of the machine, taking into consideration the value of the machine in first and last year (IS 9164: 1979)

$$I = \frac{C + S}{2} \times \frac{i}{H} \quad \text{…(3.20)}$$

Where, I = Interest per hour; and

i = 10% per year;

iii. Shelter/ housing cost: Housing cost was calculated on the basis of the prevailing rate of the locality and generally taken as 1% of the initial cost of the machine per year. (IS 9164: 1979)

Therefore,

Total fixed cost = Depreciation + Interest + Housing/Shelter cost

3.7.2 Variable cost

i. Electricity cost: Electricity cost = Electricity Consumed (kWh/h) × Electricity Charges (Rs/kWh)

ii. Repair maintenance cost: Cost of repairs and maintenance varies between 5 to 10% of the initial cost of the machine per year. (IS 9164: 1979)

iii. Labour wages: Wages of labour was calculated on the basis of actual wages of the worker in present time. (IS 9164: 1979)

Therefore,

Total variable cost (TVC) = Electricity cost + Repair and maintenance cost + Labour wages

Then,

Total cost (TC) = Total Fixed Cost (TFC) + Total Variable Cost (TVC)

CHAPTER IV

RESULTS AND DISCUSSION

The triphal peeling unit was developed as per considerations discussed in chapter III. Engineering properties of triphal were studied and performance of the machine was evaluated at selected independent variables to study their effect on selected dependent parameters. This chapter deals with the results on experiments of engineering properties of triphal and performance evaluation of the triphal peeling unit. The results on economics of use of the developed thresher along with the other methods have been discussed.

4.1 Engineering Properties of Triphal

Engineering properties viz. physical and mechanical properties were discussed as below.

4.1.1 Physical Properties of Triphal

Parameters under physical properties were linear dimensions of triphal, bulk density, true density and porosity of the triphal were studied at four different moisture content viz.16, 18, 20 and 22 % moisture content (d.b.). Physical properties of triphal were determined from lower to higher moisture content as the same study was done by Grewal *et., al.* in 2016 for mustard seeds. Amongst all the moisture content the size, surface area and sphericity of triphal were presented at 18 % moisture level. The results were discussed as below.

4.1.1.1 Moisture Content of the Triphal

Moisture content of the triphal was measured as per the procedure given in article no 3.2.1.1. The triphal samples were sun dried for five days and its moisture content was measured. The moisture content was found to be 16 %. Detailed calculations were given in Appendix- A. From 16 % moisture content sample 18, 20, 22 % moisture content samples were made with the procedure given in article no 3.2.1.1.

4.1.1.2 Linear Dimensions of Triphal

The results on linear dimensions i.e. length, breadth and thickness of triphal were found out within the moisture range of 16 % to 22 % and it was furnished in table 4.1

Table 4.1 Linear Dimensions of Triphal

Sr. No.	Moisture Content %	Length (mm)	Width (mm)	Thickness (mm)
1	16	8.22	9.75	9.43
2	18	10.33	10.25	10.32
3	20	12.20	11.10	12.23
4	22	14.30	12.20	13.30

From the table 4.1, it was seen that length of the triphal ranged from the 8.22 mm to 14.30 mm. As moisture content increse length also increased. Width of triphal vary from 9.75 to 12.20 mm with moisture ranged from 16 % to 22 %. As moisture content increased from 16 % to 22 % thickness increased from 9.43 mm to 13.30 mm. Relations between length, width and thickness of the triphal with moisture content was shown in fig. 4.1 to 4.3.

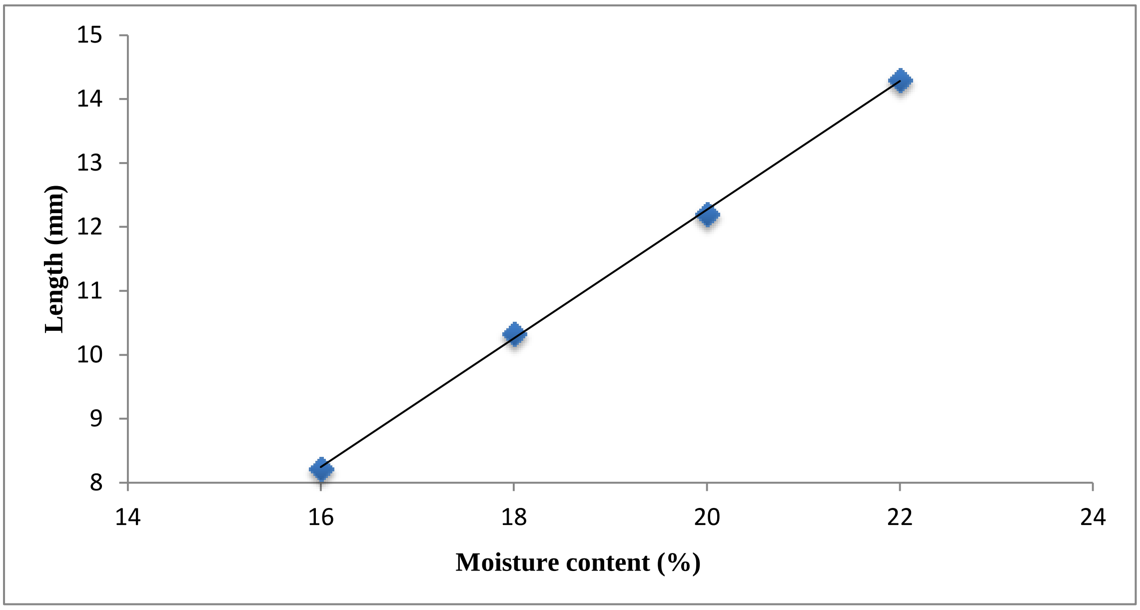

Fig 4.1 Relation between Moisture Content and Length of Triphal

Fig 4.1 showed relation between moisture and length of triphal. Linear regression equation of the relation was as follows.

$$y = 1.0055x - 7.842 \ (R^2 = 0.9995) \qquad \ldots(4.1)$$

Where, y = Length, mm;

x = Moisture Content, %.

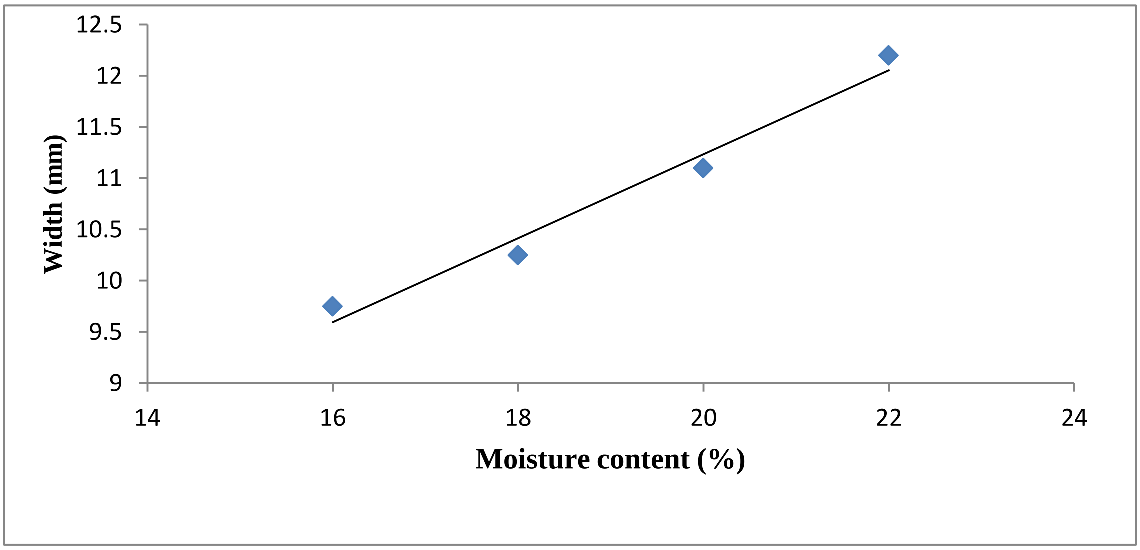

Fig 4.2 Relation between Moisture Content and Width of Triphal

Relation between width and moisture content was shown in fig. 4.2. Relation between width and moisture content of triphal can be represented by the following regression equation.

$$y = 0.41x + 3.035 \quad (R^2 = 0.9738) \qquad \ldots(4.2)$$

Where, y = Width, mm;

x = Moisture Content, %.

Relation between thickness of moisture content and thickness of triphal was shown in fig 4.3. Regression equation for relation between thickness and moisture content was as follows

$$y = 0.6755x - 1.5175 \quad (R^2 = 0.9808) \qquad \ldots(4.3)$$

Where, y = Thickness, mm;

x = Moisture Content, %.

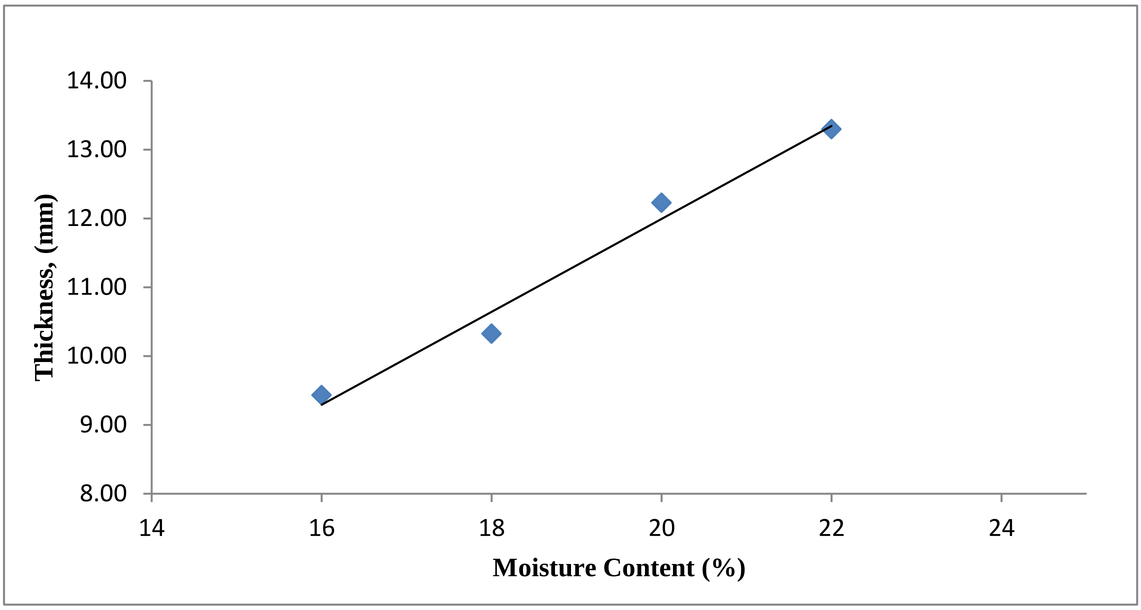

Fig 4.3 Relation between Moisture Content and Thickness of Triphal

Trend of linear dimensions found to be similar to the findings of Joshi *et., al.* (1993) in pumpkin seed and kernel, Jha (1999) in makhana, Baryeh (2001) in bambara groundnut, Kaleemullah (2002) in red chillies and Singh *et., al.* (2009) in barnyard millet grain and kernel.

4.1.1.3 Size of Triphal

Size of triphal was calculated by the arithmetic mean diameters (AMD), geometric mean diameter (GMD), square mean diameter (SMD), an equivalent diameter (EQD) at 18 % moisture content. The results on size of triphal had been furnished in table 4.2

Table 4.2 Size of Triphal

Sample No.	Arithmetic Mean Diameter (mm)	Geometric Mean Diameter (mm)	Square Mean Diameter (mm)	Equivalent Diameter (mm)
1	9.50	9.48	16.44	11.80
2	10.59	10.59	18.34	13.17
3	10.26	10.26	17.77	12.77
4	9.66	9.65	16.72	12.01
5	10.19	10.19	17.65	12.68
6	10.25	10.25	17.75	12.75
7	9.35	10.33	17.91	12.86
8	8.90	8.89	15.41	11.07
9	9.12	10.12	17.52	12.58
10	9.66	10.66	18.46	13.26
11	9.16	9.14	15.85	11.38
12	9.00	11.00	19.05	13.68
13	10.35	10.35	19.65	14.12
14	10.40	9.40	18.02	12.94
15	9.62	9.61	16.65	11.96
16	10.88	9.72	18.85	13.54
17	9.91	9.90	17.16	12.32
18	10.17	10.16	19.34	13.89
19	10.01	9.01	17.33	12.45
20	9.33	10.32	19.61	14.08
21	11.22	11.22	21.17	15.20
22	9.10	10.10	19.22	13.81
23	9.11	9.09	15.76	11.32
24	10.27	10.26	19.51	14.01
25	10.08	10.07	19.19	13.78
Sum	249	249.75	450.34	323.45
Average	9.96	9.99	18.01	12.94
Range	8.90-11.22	8.89-11.22	15.41-21.17	11.07-15.20
SD	0.12	0.12	1.42	1.02
CV	0.01	0.01	0.07	0.08

From the table 4.2, it was seen that the arithmetic mean diameter ranged between 8.90 mm to 11.22 mm and geometric mean diameter ranged between 8.89 mm to 12.22 mm having average value of 9.96 mm and 9.99 mm, respectively. The Standard deviation and coefficient of variation was found to be identical i.e. 0.12 and 0.01, respectively. Square mean diameter lied in range of 15.41 mm to 21.17 mm. Average value of square mean diameter was 18.01 mm and it had standard deviation and coefficient of variation of 1.42 and 0.07, respectively. Equivalent diameter lied in range of 11.07 to 15.20 mm, having average value of 12.94 mm. In these set of values of equivalent diameter standard deviation was 1.02 and coefficient of variation was calculated as 1.02 and 0.08, respectively.

4.1.1.4 Surface Area of Triphal

Surface area of the triphal was calculated with the equation 3.7 given. The results obtained were presented in table 4.3. From the table 4.3, it was observed that surface area of triphal was ranged in between 248.52 mm^2 to 469.17 mm^2. It had an average value of 341.65 mm^2. Standard deviation from the range was found to be 53.75 and coefficient of variation was 0.15. Details of reading were placed in Appendix – B.

Table 4.3 Surface Area of Triphal

Sr No.	Particulars	Values
1	Average	341.65 mm^2
2	Range	248.52 mm^2 – 469.17 mm^2
3	Standard deviation	53.75
4	Coefficient of variation	0.15

4.1.1.5. Spherisity (ϕ)

Spherisity determines the shape of triphal. It was calculated by the equation 3.8 given in chapter III. Obtained result were presented in table no. 4.4 and setails of observations were placed in Appendix C

Table 4.4 Sphericity of Triphal

Sr No.	Particulars	Values
1	Average	0.98 %
2	Range	0.92 % to 1.04 %
3	Standard deviation	0.03
4	Coefficient of variation	0.03

From the table 4.4, it was observed that sphericity of triphal was ranged in between 0.92 % to 1.04 % It had an average value of 0.98 %. Standard deviation and coefficient of variation was found to be identical i.e. 0.03.

4.1.1.6. Bulk Density`

Bulk density of the triphal was measured for four different moisture levels. Results obtained from different moisture level were shown in table 4.5

Table 4.5 Bulk Density of Triphal

Sr. No.	Moisture Content %	Bulk Density

		(g/cm^3)
1.	16	0.63
2.	18	0.51
3.	20	0.38
4	22	0.26

From the table 4.5 it was seen that as moisture content rises from 16 % to 22 %, bulk density decreases from 0.63 g/cm^3 to 0.26 g/cm^3. For 16, 18, 20 and 22 % moisture level bulk densities was found to be 0.63, 0.51, 0.38, 0.26 g/cm^3, respectively. Decrease in bulk density with increase in moisture content might be due to increase in mass resulting from the moisture gain of the sample was lower than the accompanying volumetric expansion of the bulk (Zahedi 2010). Relation between moisture content and bulk density was shown in fig 4.4

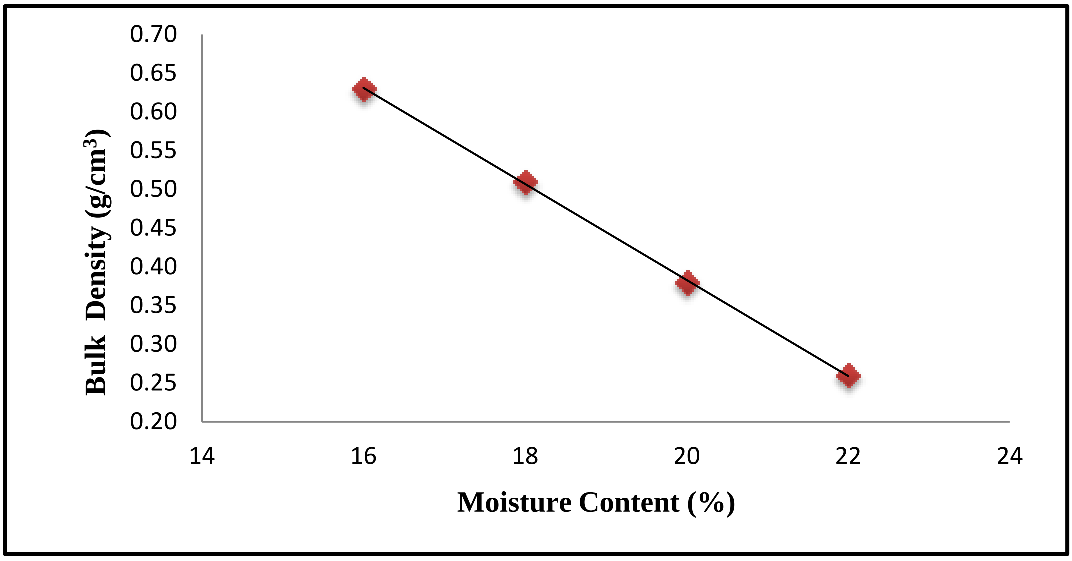

Fig 4.4 Relation between Moisture Content and Bulk Density of Triphal

Relation between bulk density of triphal and moisture content of triphal can be represented by following regression equation.

$y = -0.062x + 1.623, (R^2 = 0.9997)$ …(4.4)

Where y = Bulk density of triphal

x = Moisture content of triphal

Similar trends had been reported by Shepherd and Bhardwaj (1986), Dutta *et. al.*, (1988), Deshpande *et. al.*, (1993), Gupta and Das (1997), Bart-Plange and Baryeh (2003). It confirmed the observation of change in bulk density with increase in moisture content of triphal in the present study.

4.1.1.7 True Density of Triphal

True density of triphal was measured at four different moisture levels viz. 16, 18, 20, 22 %. Experimental results of true density of triphal was furnished in table 4.6. From the data in table 4.6 it was clearly seen that as moisture content of triphal increased from 16 % to 22 % true density of triphal also increased from 0.79 g/cm^3 to 1.35 g/cm^3. For 16 % moisture content true density was 0.79 g/cm^3. For 18, 20, 22 % moisture level true density was found to be 1.09, 1.17, 1.35 g/cm^3, respectively. Increase in true density with moisture content occurred due to increase in weight proportional to moisture content more than that its volume (Jha, 1999).

Table 4.6 True density of Triphal

Sr. No.	Moisture Content %	Average True Density (g/cm^3)
1.	16	0.79
2.	18	1.09
3.	20	1.17
4	22	1.35

From the fig. 4.5 it was clearly seen that linear relation between true density and moisture content existed. Equation 4.5 represented the regression equation between moisture content and true density.

$$y = 0.088x - 0.572, (R^2 = 0.9467) \quad \ldots(4.5)$$

where y = True density of triphal;

x = Moisture content

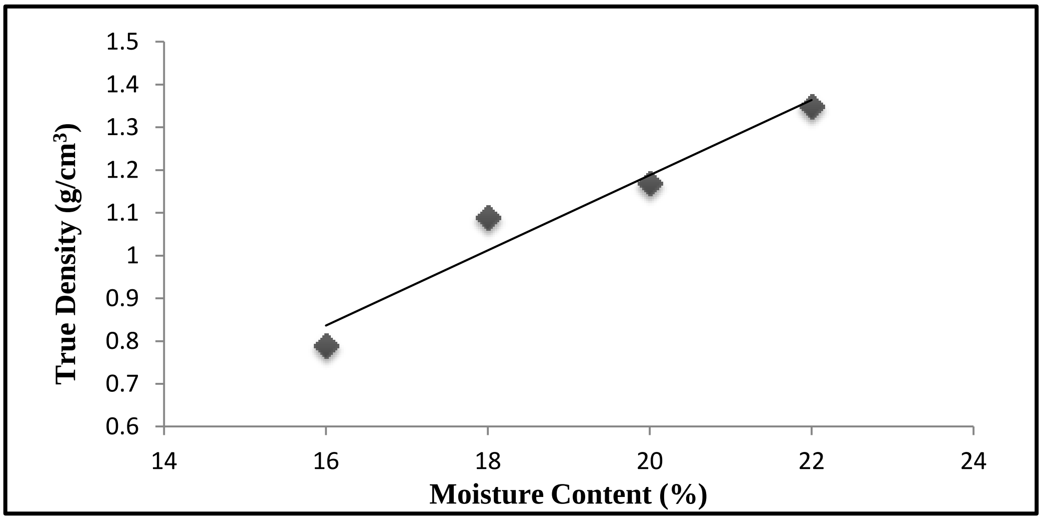

Fig 4.5 Relation between Moisture Content and True Density of Triphal

Trend of true density was found to be similar to the findings of Joshi *et., al.* (1993) in pumpkin seed and kernel, Jha (1999) in makhana, Baryeh (2001) in bambara groundnut, Kaleemullah (2002) in red chillies and Singh *et., al.* (2009) in barnyard millet grain and kernel.

4.1.1.8 Porosity

Porosity of the triphal at four different moisture content was calculated using equation 3.12. results obtained from were presented in table 4.7

Table 4.7 Porosity of Triphal

Sr. no.	Moisture Content %	Bulk Density g/cm^3	True Density g/cm^3	Porocity %
1	16	0.63	0.79	20.25
2	18	0.51	1.09	53.23
3	20	0.38	1.17	67.52
4	22	0.26	1.35	80.74

From the table 4.7, it was observed that porosity of triphal decreased from 80.74 % to 20.25 %, when the moisture content was lowered from 22 % to 16 % (d.b), respectively. For the moisture content 16, 18, 20, 22 % porosity was found to be 20.25, 53.23, 67.52, 80.74 %, respectively. The decrease in porosity with decrease in moisture content might be due to decrease in shape and size of triphal with reduction in moisture content.

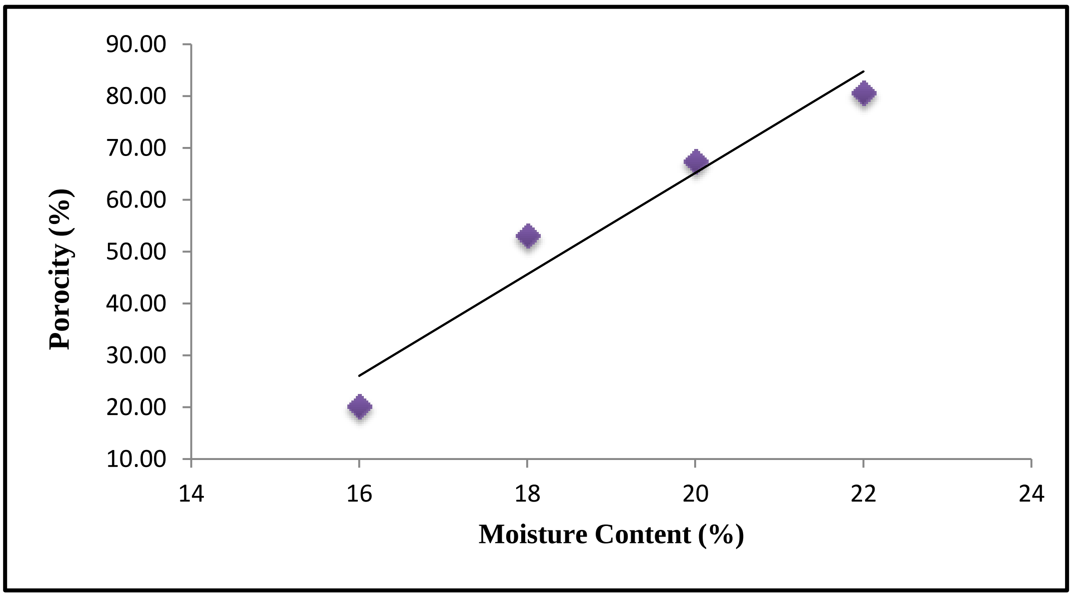

Fig 4.6 Relation between Moisture Content and Porosity

The porosity of triphal followed a linear relationship with moisture content which was indicated in fig 4.6 and followed the regression equation of the form:

$$y = 9.788x - 130.54, (R^2 = 0.9442) \quad \ldots(4.6)$$

where y = porosity;

x = Moisture content

Similar trend was observed by Singh and Goswami (1996) in cumin seeds and Suthar and Das (1996) in karingda seed.

4.1.2 Mechanical Properties

Some mechanical properties like coefficient of friction, angle of repose, seed detachment force, were selected for the study. Experimental results of these properties were discussed below.

4.1.2.1 Coefficient of static friction

Coefficient of friction was measured at four different moisture content for five different surfaces i.e. stainless steel, wood, mild steel, plastic and aluminum. Obtained results from experiment were shown in table no. 4.8

Table 4.8 Coefficient of Friction of Triphal for Different Surfaces

Sr No.	Moisture Content %	Coefficient of friction				
		Stainless Steel	Wood	Mild Steel	Plastic	Aluminum
1	16	0.34	0.46	0.28	0.32	0.25
2	18	0.49	0.53	0.38	0.42	0.39
3	20	0.64	0.56	0.44	0.48	0.50
4	22	0.74	0.65	0.49	0.54	0.63

From the table 4.8 it was seen that as moisture content increases, coefficient of friction also increased. For stainless steel, coefficient of friction increases from 0.34 to 0.74 with increase in moisture level from 16 % to 22 %. For wood, mild steel, plastic and aluminum coefficient of friction increased from 0.46 to 0.65, 0.28 to 0.49, 0.32 to 0.54, 0.25 to 0.63, respectively. Increase in coefficient of static friction with increase in moisture content might be due to higher cohesive force between triphal and test surfaces (Pandiselvam 2014).

Relations between moisture content and coefficient of friction between triphal and different surfaces were shown in fig 4.7. Changes in coefficient of friction with changes in moisture content of triphal on different surfaces followed linear relationships, and represented by regression equations from 4.7 through 4.11

$$\mu_w = 0.03M - 0.02, \ (R^2 = 0.9677) \quad \ldots(4.7)$$

$$\mu_m = 0.0675M - 0.73, \ (R^2 = 0.9918) \quad \ldots(4.8)$$

$$\mu_a = 0.0625M - 0.745, \ (R^2 = 0.9981) \quad \ldots(4.9)$$

$$\mu_p = 0.036M - 0.244, \ (R^2 = 0.9818) \quad \ldots(4.10)$$

$$\mu_s = 0.0345M - 0.258, \ (R^2 = 0.9726) \quad \ldots(4.11)$$

Where μ_w = Coefficient of static friction for wood and triphal

μ_m = Coefficient of static friction for mild steel and triphal

μ_a = Coefficient of static friction for aluminium and triphal

μ_p = Coefficient of static friction for plastic and triphal

μ_s = Coefficient of static friction for stainless steel and triphal

M = Moisture content

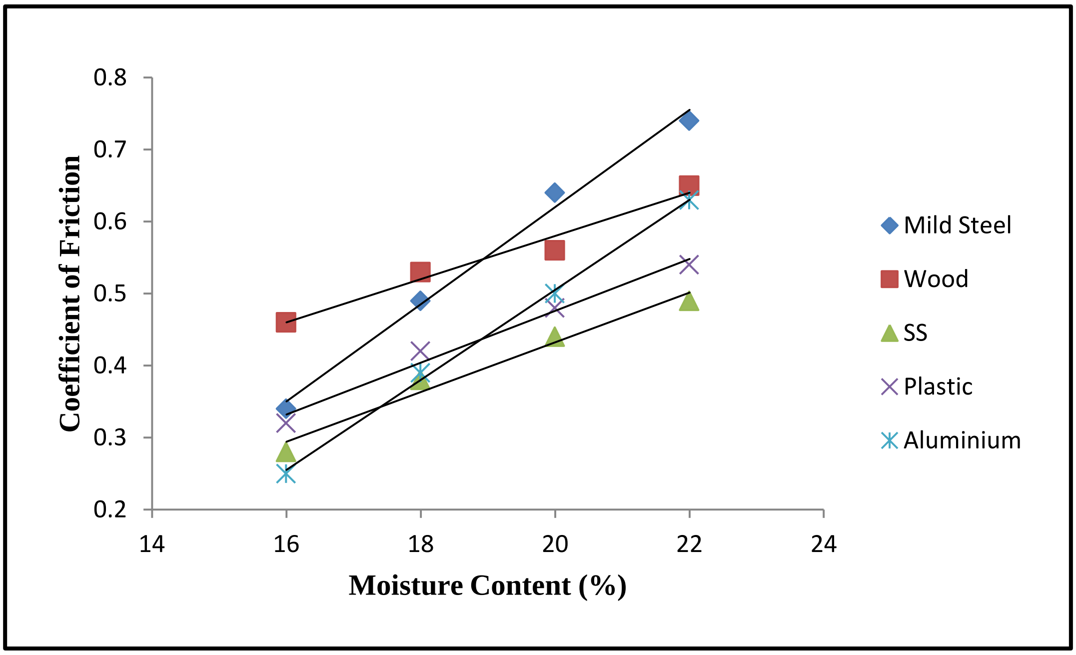

Fig 4.7 Relation between Moisture Content and Coefficient of Friction between Triphal and Different Surfaces

Simiar trends between moisture content and coefficient of friction for different surfaces were reported by Suthar and Das (1996) for karingda seed, Aviara *et., al.* (1999) for guna seed, Jha (1999) for makhana, Kaleemullah (2002) for chillies and Singh et al. (2009) for barnyard millet grain and kernel.

4.1.2.2 Angle of repose

Angle repose of triphal was measured at four different moisture content as per the procedure described in article no 3.2.2.2. Results of the experiments for angle of repose were described in table 4.9.

Table 4.9 Angle of Repose of Triphal

Sr. no.	Moisture content	Angle of repose (degrees)
1	(16 %)	38.68
2	(18 %)	42.71
3	(20 %)	44.43
4	(22 %)	47.67

From table 4.9, it was seen that for moisture content of 16 % angle of repose was 38.68˚, for 18 % of moisture content angle of repose was found to be 42.71˚, for 18 % moisture content angle of repose was 42.71˚ and for 22 % of moisture content angle of repose was found to be 47.67˚. It was seen that as moisture content increases angle of repose also increases. The increase in angle of repose of triphal with increase in moisture content might be due to increase in internal friction between triphal.

Relation between angle of repose and moisture content was found to be linear in nature, which can be expressed by following regression equation no 4.12

$y = 1.4345x + 16.117, (R^2 = 0.9788)$ …(4.12)

where y = Angle of repose

x = Moisture content

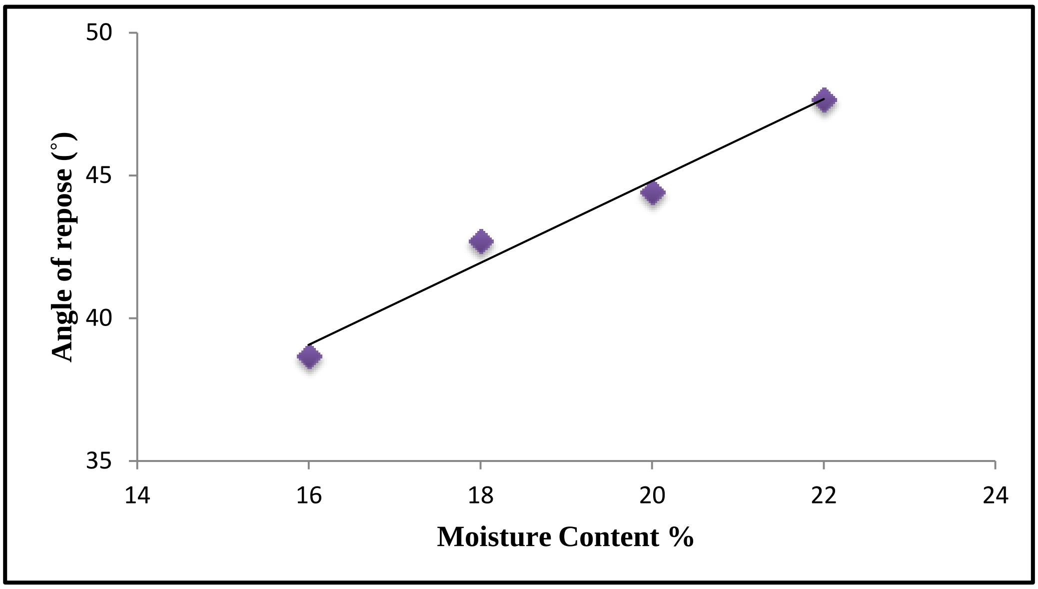

Fig. 4.8 Relation between Moisture Content and Angle of Repose

Similar results were recorded by Suthar and Das (1996) in karingda seed and kernel, Aviara *et., al.* (1999) in guna seed, Jha (1999) in makhana, Nimkar and Chattopadhyay (2001) in green gram.

4.1.2.3 Seed Detachment force

Seed detachment force of the triphal was measured as describe in article no 3.2.2.3. Results showed that triphal seeds need varied detaching force. The variation in values was attributed to the difference in morphology and petiole texture properties (Pathak *et. al*., 2017).

Table 4.10 Variation in Mean Seed detachment Force of Triphal

Sr. No.	Mean seed detaching force (N)	Mean seed detaching time(sec)
1	0.261	4
2	0.540	6.5
3	0.250	4
4	0.500	6
5	0.730	7.5
6	0.430	5
7	0.250	4
8	0.470	5.5
9	0.540	6
10	0.320	5
Mean	0.429	5.35
Std. Dev.	0.15	1.17

Overall ten samples were tested for measuring the seed detaching force and mean detaching force were presented table 4.10 and details were discussed in appendix D. From the table 4.10 it was observed that minimum and maximum mean force required for detachment of triphal seed was 0.25 N and 0.730 N, respectively. The mean force obtained was 0.429 N with respect to mean time of 5.35 sec.

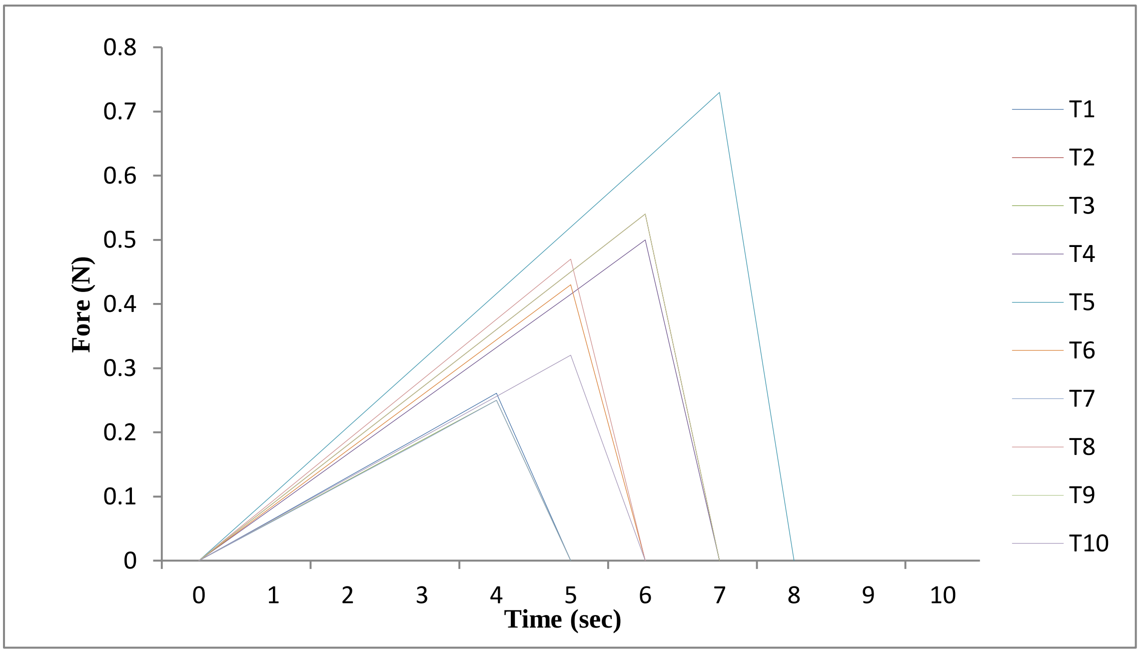

Fig 4.9 Graphical Representation of Seed Detachment Force of Triphal

Graphical representation of mean seed detachment force with respect to time was presented in fig 4.9. It was inferred that initially load moves linearly upto the peak detaching force, then it falls to zero in nearby one sec due to motion of load cell in texture analyzer. Also it was inferred that there was no relation between the seed dimension and detaching force with the confirmation of earlier results for siliqua (Hoseinzadeh *et., al*. 2010). Similar result trend was also observed by Pathak *et., al*. (2017) in the cumin seeds.

4.1.2.4 Crushing Force of Triphal and Stalk

Crushing force of triphal and stalk were calculated as described in article no 3.2.2.4. Results obtained were presented in table 4.11. From the table 4.11 it was seen that triphal crushing force was ranged between 52.38 N to 52.86 N with mean value of 52.60 N. Triphal stalk crushing force was in the range of 2549 g to 2562 g. It showed the average value of 2549.6 g, which was approximately about 25 N. So required force for peeling and crushing of stalks should be more than 25 N and less than 52.60 N. Singh *et. al.*, 2012 and Bhatt and Prasad 2018 reported the similar type of observations for linseed.

Table 4.11 Triphal Crushing Force and Stalk Crushing Force

Sample	Triphal Crushing force (g)	Triphal Stalk crushing force (g)

1	52.86	24.99
2	52.51	24.89
3	52.38	25.12
4	52.61	25.09
5	52.66	24.94
Mean	52.60	25.00

4.2 Performance Evalution of Triphal Peeling Unit

The performance of the developed triphal peeling unit was evaluated at three cylinder speeds (300, 400 and 500 rpm), three grate clearances (8, 10 and 12 mm) and three stroke sieve lengths (10, 20 and 30 mm) to study their effect on peeling efficiency, damage triphal , unpeeled triphal and capacity of triphal peeling unit. The performance was evaluated in randomized order the results were given in table 4.12

Table 4.12 Result of Testing of Triphal Peeling Unit according to CCRD experiment design

Run	Cylinder Speed, rpm [A]	Grate Clearance, mm [B]	Sieve stroke length, mm [C]	Peeling Efficiency, %	Triphal Damage, %	Unpeeled Triphal, %	Capacity of peeling machine, kg/h
1	400	10	20	97.5	3.1	2.5	8.0
2	400	10	20	98.0	3.0	2.0	7.9
3	400	10	20	97.6	3.0	2.4	7.9
4	300	8	20	76.0	7.2	24.0	5.3
5	500	10	30	94.0	4.6	6.0	8.7
6	300	10	30	88.0	4.2	12.0	5.7
7	400	8	10	96.5	7.9	3.5	6.0
8	400	12	10	82.8	2.1	17.2	6.5
9	400	10	20	96.8	3.1	3.2	8.1
10	500	8	20	95.0	11.5	5.0	8.5
11	400	12	30	81.5	2.3	18.5	8.2
12	500	10	10	95.5	4.5	4.5	8.3
13	300	10	10	87.0	4.1	13.0	5.4
14	400	10	20	97.1	2.9	2.9	8.0
15	500	12	20	79	2.1	21.0	8.5
16	300	12	20	78.5	2.7	21.5	5.9
17	400	8	30	95	8.2	5.0	6.3

Plate 4.1 Evaluating the Performace of Developed Triphal Peeling Unit

Plate 4.2 Separated Stalks

Plate 4.3 Clean Peeled Triphal

4.2.1 Effect of Cylinder Speed on Peeling Efficiency, Damage Triphal %, Unpeeled Triphal % and Capacity of Peeling Machine

Effect of cylinder speed on peeling efficiency, damage triphal %, Unpeeled Triphal % and capacity of peeling machine was studied and obtained results were presented in table 4.13.

Table 4.13 Effect of Cylinder Speed on Peeling Efficiency, Damage Triphal %, Unpeeled Triphal % and Capacity of Peeling Machine

Cylinder Speed, rpm	Peeling Efficiency, %	Damage Triphal, %	Unpeeled Triphal, %	Capacity of Peeling Machine, kg/h

300	82.37	4.55	17.63	5.57
400	93.64	3.9	6.36	7.43
500	90.87	5.6	9.13	8.5

It was observed that peeling efficiency was maximum viz, 93.64 % at 400 rpm. While it was lower at both 300 and 500 rpm cylinder speed. Damage triphal was maximum at 500 rpm and lowest at 400 rpm. Highest unpeeled triphal % was found to be 17.63 at 300 rpm cylinder speed and lowest at 400 rpm cylinder speed. Capacity of machine was found to be 5.57, 7.43 and 8.5 kg/h for 300, 400, 500 rpm, respectively. Ideal values of peeling efficiency, Damage Triphal %, unpeeled triphal % and capacity of peeling machine was found at 400 rpm cylinder speed. As at 300 rpm required force was not provided and at 500 rpm due to high speed triphal gets peeled easily.

4.2.2 Effect of Grate Clearance on Peeling Efficiency, Damage Triphal %, Unpeeled Triphal % and Capacity of Peeling Machine

Effect of Grate clearance on peeling efficiency, damage triphal %, unpeeled triphal % and capacity of peeling machine was studied and obtained results were presented in table 4.14.

Table 4.14 Effect of Grate Clearance on Peeling Efficiency, Damage Triphal %, Unpeeled Triphal % and Capacity of Peeling Machine

Grate Clearance, mm	Peeling Efficiency, %	Damage Triphal, %	Unpeeled Triphal, %	Capacity of Peeling Machine, kg/h
8	90.62	8.7	9.38	6.52
10	94.61	3.6	5.39	7.5
12	80.45	2.3	19.55	7.2

From table 4.14, it was observed that peeling efficiency was maximum viz, 94.61 % at 10 mm grate clearance. While it was lower at both 8 and 12 mm grate clearance. Damage Triphal was maximum at 8 mm and lowest at 12 mm grate clearance. Highest unpeeled triphal % was found to be 19.55 at 12 mm grate clearance and lowest at 10 mm grate clearance. Capacity of machine was found to be 6.52, 7.5 and 7.2 kg/h for 8, 10, 12 mm grate clearance, respectively. Ideal values of peeling efficiency, Damage Triphal %, unpeeled triphal % and capacity of peeling machine was found at 10 mm grate clearance. At lower grate clearance triphal gets stuck causing clogging and at higher grate clearance i.e. 12 mm triphal falls directly downwards due to gravity.

4.2.3 Effect of Sieve Stroke Length on Peeling Efficiency, Damage Triphal %, Unpeeled Triphal % and Capacity of Peeling Machine

Effect of sieve stroke length on peeling efficiency, Damage Triphal %, unpeeled triphal % and capacity of peeling machine was studied and obtained results were presented in table 4.15.

Table 4.15 Effect of Sieve Stroke Length on Peeling Efficiency, Damage Triphal %, Unpeeled Triphal % and Capacity of Peeling Machine

Sieve Stroke Length, mm	Peeling Efficiency, %	Damage Triphal, %	Unpeeled Triphal, %	Capacity of Peeling Machine, kg/h
10	91.57	4.65	8.43	6.55
20	92.61	4.2	7.39	7.5
30	89.62	4.8	10.38	7.2

From table 4.15, it was observed that peeling efficiency was maximum viz, 92.61 % at 20 mm sieve stroke length. While it was lower at both 10 and 30 mm sieve stroke length. Damage triphal was maximum at 10 mm and lowest at 20 mm sieve stroke length. Highest unpeeled triphal % was found to be 10.38 at 30 mm sieve stroke length and lowest at 20 mm sieve stroke length. Capacity of machine was found to be 6.55, 7.5 and 7.2 kg/h for 10, 20, 30 mm sieve stroke length, respectively. Ideal values of peeling efficiency, damage triphal %, unpeeled triphal % and capacity of peeling machine was found at 20 mm sieve stroke length. At lower sieve stroke length not enough vibration was supplied to mixture of triphal, seeds and stalks while at higher stroke length, due to higher amount of vibration mixture of seeds, triphal and stalks jumps out of sieve. The details about the observations were furnished in Appendix – E.

4.2.4. Combine Effects of Selected Independent Parameters on Dependent Parameters

Combine effect of of cylinder Speed, grate clearance and sieve stroke length on peeling efficiency, damage triphal and capacity of machine were studied and results were discussed below.

4.2.4.1 Combine Effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Peeling Efficiency

The combine effect of three cylinder speed viz., 300,400 and 500 rpm, grate clearance viz., 8, 10 and 12 mm and sieve stroke length viz., 10, 20 and 30 mm on peeling efficiency was studied. Graphical representations of these results were shown in fig 4.10 through 4.12.

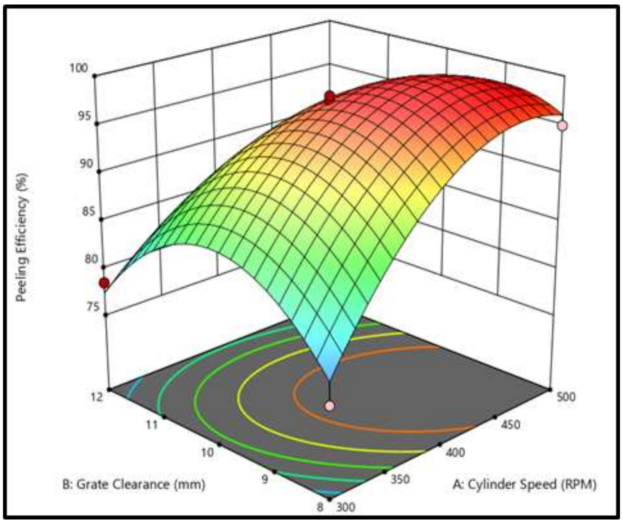

Fig. 4.10 Effect of Cylinder Speed and Grate Clearance on Peeling Efficiency

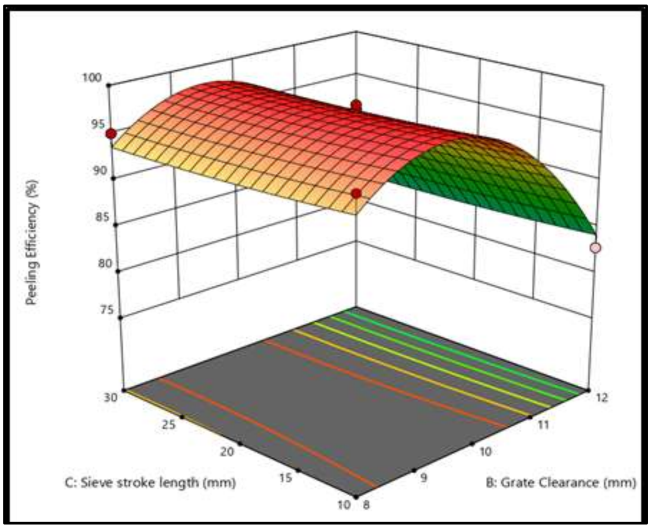

Fig. 4.11 Effect of Grate Clearance and Sieve Stroke Length on Peeling Efficiency

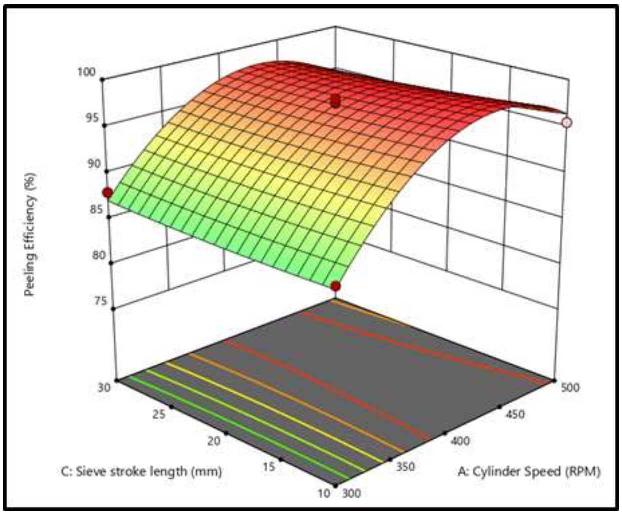

Fig. 4.12 Effect of Cylinder Speed and Sieve Stroke Length on Peeling Efficiency

From fig 4.10 it was perceived that peeling efficiency increases with increase in cylinder speed from 300 rpm to 500 rpm. It shows directly proportional relation to the cylinder speed. Peeling efficiency increases with increase in cylinder speed may be due to more peripheral speed which was responsible for higher acceleration and impact force on triphal. Such kind of observations were recorded by Kamble *et. al.* 2003. Peeling efficiency was lowest at 8 mm grate clearance due to clogging of triphal in small clearance. The peeling efficiency attended maximum value at 10 mm concave clearance afterward it decreases with increase in grate clearance as due to gravitational force triphal falls directly at bottom without coming in contact with the rubing grate and cylinder surface.

From fig 4.11, it was seen that sieve stroke length does not show any effect on peeling efficiency as sieve was the part of the cleaning mechanism and had no role in peeling of triphal. The effect of grate clearance on peeling efficiency was discussed earlier. Fig 4.12 represented the same result as fig 4.10 as it showed there was no effect of sieve stroke length on peeling efficiency and cylinder speed was directly proportional to the peeling efficiency.

The ANOVA shown in table no 4.16 indicated that, The Model F-value of 26.83 implies the model was significant. There was only a 0.01% chance that an F-value this large could occur due to noise. The model value F (26.83) suggesting quadratic model could be successfully used to fit experimental data (< 0.0001) as per F values indicated in table 4.16. P-values less than 0.0500 indicate model terms were significant at 5 % level. In this case A, B, AB, A^2, B^2 were significant model terms because A, B, AB, A^2, B^2 have direct relation in peeling mechanism while term C was the part of cleaning mechanism hence it does not show any significant effect. Values greater than 0.1000 indicated the model terms were not significant. If there were many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. The Lack of Fit F-value of 42.24 implies the Lack of Fit was significant. There was only a 0.17% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit was bad for the model to fit. The Predicted R^2 of 0.5616 was not as close to the Adjusted R^2 of 0.9356 as one might normally expect; i.e. the difference was more than 0.2. This may indicate a large block effect or a possible problem with model and/or data. Things to consider were model reduction, response transformation, outliers, etc. All empirical models should be tested by doing confirmation runs. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 was desirable. Ratio of 13.493 indicates an adequate signal. This model can be used to navigate the design space.

The regression equation representing variation of peeling efficiency % with different independent parameters were fitted in polynomial form given as

Peeling efficiency % = 97.4 + 4.25A - 5.0875B - 0.4125C - 4.625AB - 0.625AC + 0.05BC -6.55 A^2 - 8.725B^2 + 0.275C^2 …(4.13)

$R^2 = 0.9718$

Where,

A = Cylinder Speed (rpm)

B = Grate Clearance (mm)

C = Sieve stroke length (mm)

Table 4.16 ANOVA for Study of Effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Peeling Efficiency

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	969.41	9	107.71	26.83	0.0001	significant
A-Cylinder Speed	144.50	1	144.50	35.99	0.0005	Significant

B-Grate Clearance	207.06	1	207.06	51.57	0.0002	Significant
C-Sieve stroke length	1.36	1	1.36	0.3390	0.5787	Not significant
AB	85.56	1	85.56	21.31	0.0024	significant
AC	1.56	1	1.56	0.3891	0.5525	Not significant
BC	0.0100	1	0.0100	0.0025	0.9616	Not significant
A^2	180.64	1	180.64	44.99	0.0003	Significant
B^2	320.53	1	320.53	79.83	< 0.0001	Significant
C^2	0.3184	1	0.3184	0.0793	0.7864	Not significant
Residual	28.11	7	4.02			
Lack of Fit	27.25	3	9.08	42.24	0.0017	Significant
Pure Error	0.8600	4	0.2150			
Cor Total	997.52	16				
Std. Dev.	2.00					
Mean	90.34					
C.V. %	2.22					
R^2	0.9718					
Adjusted R^2	0.9356					
Predicted R^2	0.5616					
Adeq Precision	13.4933					

4.2.4.2 Combine Effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Damage Triphal %

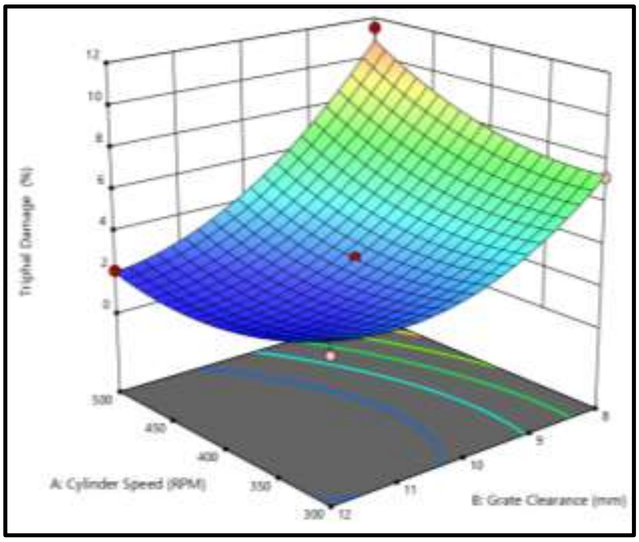

Fig. 4.13 Effect of Cylinder Speed and Grate Clearance on Damage Triphal

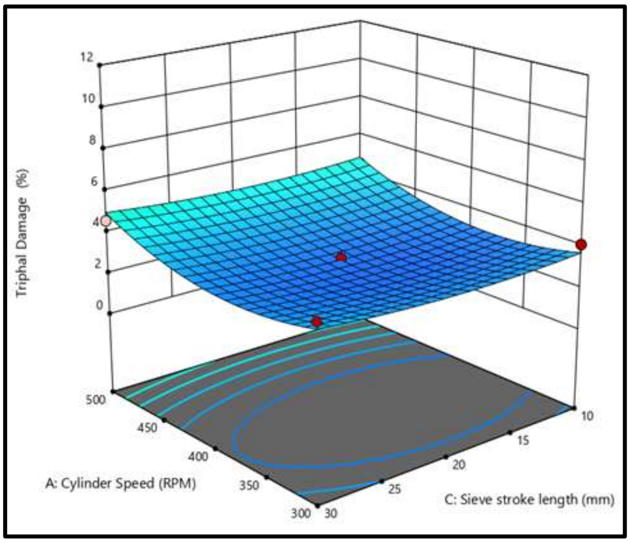

Fig. 4.14 Effect of Cylinder Speed and Sieve Stroke Length on Damage Triphal

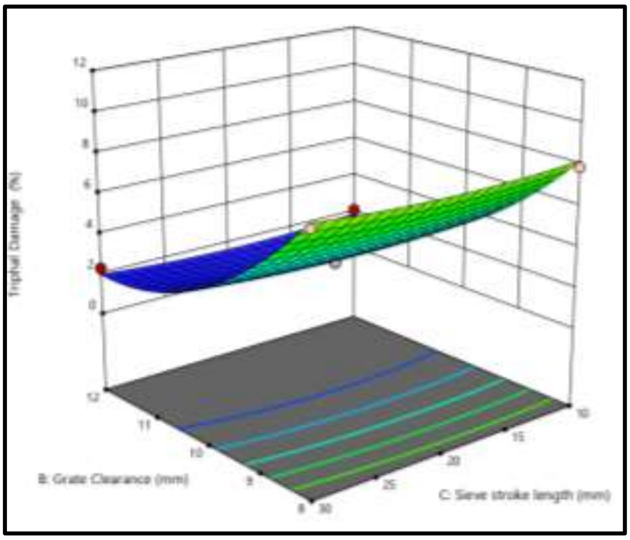

Fig. 4.15 Effect of Grate Clearance and Sieve Stroke Length on Damage Triphal

The effect of three cylinder speed viz., 300,400 and 500 rpm, grate clearance viz., 8, 10 and 12 mm and sieve stroke length viz., 10, 20 and 30 mm on Damage Triphal was studied. Graphical representations of these results were shown in fig 4.13 through 4.15.

From the fig 4.13, it was perceived that as at 300 rpm Damage Triphal was higher due to low acceleration force of triphal which may cause clogging and breaking of triphal. Then it was minimum at 400 rpm, again it increased with 500 rpm due to high speed. As grate clearance decreases Damage Triphal % increses this may happens due to small clearance. Decrease in clearance increases the rubbing of the triphal which was responsible for the more triphal to damage. Combinely maximum Damage Triphal was found at 500 rpm and 8 mm grate clearance which was about 11.5 %. Minimum Damage Triphal was at 500 rpm and 12 mm grate clearance as more space and speed was available to the tripahal. Fig 4.14 and 4.15 showed that sieve stroke length does not have any effect on the Damage Triphal . Similar trend were observed by kamble *et. al*., 2003 for pearl millet thresher and Singh *et. al*., 2011 for barnyard dehuller.

The ANOVA shown in table no 4.17 indicated that, The Model F-value of 50.77 implies the model was significant. There was only a 0.01% chance that an F-value this large could occur due to noise. The model value F (50.77) suggesting quadratic model could be successfully used to fit experimental data (< 0.0001) as per F values indicated in table 4.17. P-values less than 0.0500 indicate model terms were significant at 5 % level. In this case A, B, AB, A^2, B^2 were significant model terms because A, B, AB, A^2, B^2 have direct relation in peeling mechanism while term C was the part of cleaning mechanism hence it does not show any significant effect. Values greater than 0.1000 indicated the model terms were not significant. If there were many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. The Lack of Fit F-value of 79.40 implies the Lack of Fit was significant. There was only a 0.17% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit was bad for the model to fit. The Predicted R^2 of 0.7622 was not as close to the

Adjusted R^2 of 0.9655 as one might normally expect i.e. the difference was more than 0.2. This may indicate a large block effect or a possible problem with model and/or data. Things to consider were model reduction, response transformation, outliers, etc. All empirical models should be tested by doing confirmation runs. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 was desirable. Ratio of 23.843 indicates an adequate signal. This model can be used to navigate the design space.

The regression equation representing variation of peeling efficiency % with different independent parameters were fitted in polynomial form given as

Triphal damage % = $3.02 + 0.5625A - 3.2B + 0.0875C - 1.225AB - 0.025BC + 1.04A^2 + 1.815B^2 + 0.29C^2$ …(4.14)

$R^2 = 0.9655$

Where, A = Cylinder Speed (rpm)

B = Grate Clearance (mm)

C = Sieve stroke length (mm)

Table 4.17 ANOVA for study of effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Damage Triphal

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	110.68	9	12.30	50.77	< 0.0001	Significant
A-Cylinder Speed	2.53	1	2.53	10.45	0.0144	Significant
B-Grate Clearance	81.92	1	81.92	338.21	< 0.0001	Significant
C-Sieve stroke length	0.0613	1	0.0613	0.2529	0.6305	Not significant
AB	6.00	1	6.00	24.78	0.0016	Significant
AC	0.0000	1	0.0000	0.0000	1.0000	Not significant
BC	0.0025	1	0.0025	0.0103	0.9219	Not significant
A^2	4.55	1	4.55	18.80	0.0034	Significant
B^2	13.87	1	13.87	57.27	0.0001	Significant
C^2	0.3541	1	0.3541	1.46	0.2659	Not significant
Residual	1.70	7	0.2422			
Lack of Fit	1.67	3	0.5558	79.40	0.0005	Significant
Pure Error	0.0280	4	0.0070			
Cor Total	112.38	16				
Std. Dev.	0.4922					
Mean	4.50					
C.V. %	10.94					
R^2	0.9849					
Adjusted R^2	0.9655					
Predicted R^2	0.7622					

4.2.4.3 Combine Effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Unpeeled Triphal %

The effect of three cylinder speed viz., 300,400 and 500 rpm, grate clearance viz., 8, 10 and 12 mm and sieve stroke length viz., 10, 20 and 30 mm on unpeeled triphal was studied. Graphical representations of these results were shown in fig 4.16 through 4.18.

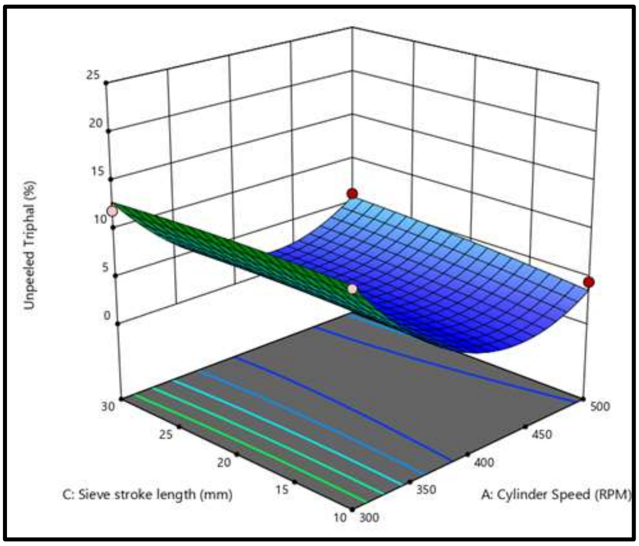

Fig. 4.16 Effect of Cylinder Speed and Sieve Stroke Length on Unpeeled Triphal

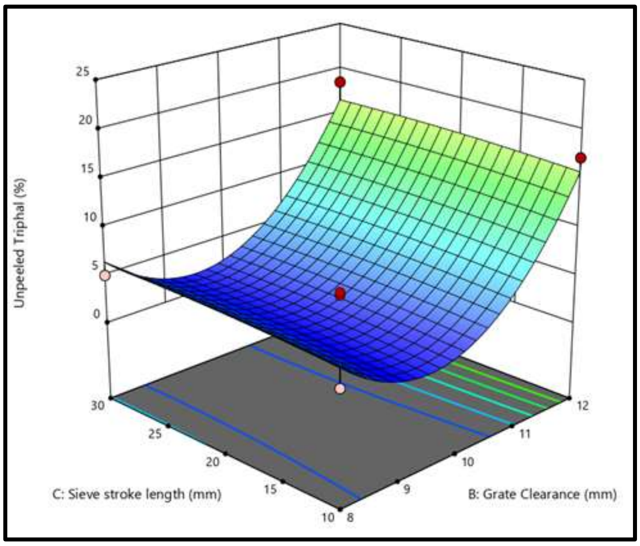

Fig. 4.17 Effect of Sieve Stroke Length and Grate Clearance on Unpeeled Triphal

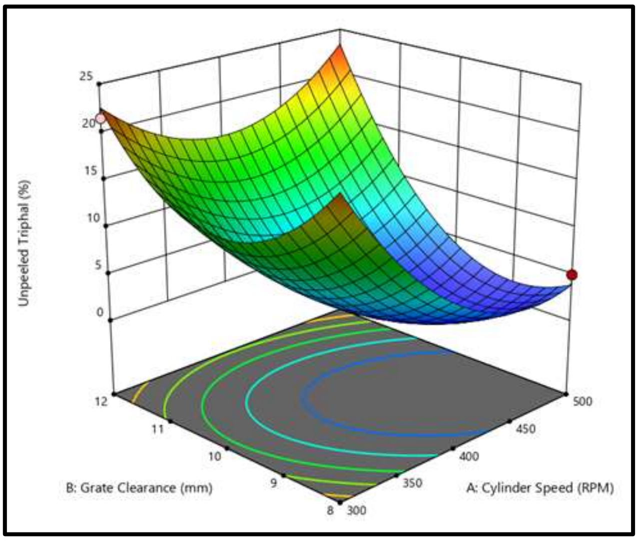

Fig. 4.18 Effect of Grate Clearance and Cylinder Speed on Unpeeled Triphal

From the graphical representations (fig 4.16) it was seen that sieve stroke length does not have any effect on unpeeled triphal % as it was the cleaning mechanism. From fig 4.17, it was seen that as grate clearance increases from 8 mm to 12 mm unpeeled triphal % also increases due to the more space between grate and cylinder triphal was likely to fall down due to gravitational force. At lower cylinder speed unpeeled triphal % was higher due to low impact force acts on triphal. At 300 rpm and 12 mm grate clearance, unpeeled triphal was highest about 21.5 %. (fig 4.18) unpeeled triphal was lowest at 400 rpm cylinder speed and 10 mm grate clearance which was about 2 %. Similar trend was observed by Suhendra *et. al*., 2010 in vertical axis rotating pepper decorticator.

The ANOVA shown in table no 4.18 indicated that, The Model F-value of 26.83 implies the model was significant. There was only a 0.01% chance that an F-value this large could occur due to noise. The model value F (26.83) suggesting quadratic model could be successfully used to fit experimental data (< 0.0001) as per F values indicated in table 4.18. P-values less than 0.0500 indicate model terms were significant at 5 % level. In this case A, B, AB, A^2, B^2 were significant model terms because A, B, AB, A^2, B^2 have direct relation in peeling mechanism while term C was the part of cleaning mechanism hence it does not show any significant effect. Values greater than 0.1000 indicated the model terms were not significant. If there were many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. The Lack of Fit F-value of 42.24 implies the Lack of Fit was significant. There was only a 0.17% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit was bad for the model to fit. The Predicted R^2 of 0.5616 was not as close to the Adjusted R^2 of 0.9356 as one might normally expect i.e. the difference was more than 0.2. This may indicate a large block effect or a possible problem with model and/or data. Things to consider were model reduction, response transformation, outliers, etc. All empirical models should be tested by doing confirmation runs. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 was desirable. Ratio of 13.493 indicates an adequate signal. This model can be used to navigate the design space.

The regression equation representing variation of peeling efficiency % with different independent parameters were fitted in polynomial form given as

$$\text{Triphal damage } \% = 2.60 - 4.25A + 5.09B + 0.4215C + 4.62AB + 0.625AC - 0.05BC + 6.55A^2 + 8.72B^2 - 0.275C^2 \quad \ldots(4.15)$$

$$R^2 = 0.9356$$

Where,

A = Cylinder Speed (rpm)

B = Grate Clearance (mm)

C = Sieve stroke length (mm)

Table 4.18 ANOVA for study of effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Unpeeled Triphal

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	969.41	9	107.71	26.83	0.0001	Significant
A-Cylinder Speed	144.50	1	144.50	35.99	0.0005	Significant

B-Grate Clearance	207.06	1	207.06	51.57	0.0002	Significant
C-Sieve stroke length	1.36	1	1.36	0.3390	0.5787	Not significant
AB	85.56	1	85.56	21.31	0.0024	Significant
AC	1.56	1	1.56	0.3891	0.5525	Not significant
BC	0.0100	1	0.0100	0.0025	0.9616	Not significant
A^2	180.64	1	180.64	44.99	0.0003	Significant
B^2	320.53	1	320.53	79.83	< 0.0001	Significant
C^2	0.3184	1	0.3184	0.0793	0.7864	Not significant
Residual	28.11	7	4.02			
Lack of Fit	27.25	3	9.08	42.24	0.0017	Significant
Pure Error	0.8600	4	0.2150			
Cor Total	997.52	16				
Std. Dev.	2.00					
Mean	9.66					
C.V. %	20.75					
R^2	0.9718					
Adjusted R^2	0.9356					
Predicted R^2	0.5616					
Adeq Precision	13.4933					

4.2.4.4 Combine Effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Capacity of Peeling machine (kg/h)

The effect of three cylinder speed viz., 300,400 and 500 rpm, grate clearance viz., 8, 10 and 12 mm and sieve stroke length viz., 10, 20 and 30 mm on capacity of triphal peeling machine was studied. Graphical representations of these results were shown in fig 4.17 through 4.19.

From fig 4.19 it was seen that from grate clearance 8 mm to 10 mm capacity of machine increases from 5.3 kg/h to 8.3 kg/h and then decreases to 6 kg/h upto 12 mm grate clearance. As cylinder speed increases capacity of the machine also increases. Machine capacity was maximum (8.3 kg/h) for the 500 rpm of cylinder speed and 10 mm grate clearance. Machine capacity was found to be minimum (5.3 kg/h) at 300 rpm cylinder speed and 8 mm grate clearance. From fig 4.20 it was seen that machine capacity was higher at 20 mm sieve stroke length and it lowers at both 10 mm and 30 mm sieve stroke length. Machine capacity attended highest value at 20 mm sieve stroke length and 10 mm grate clearance (fig 4.21). Similar results was observed by Suhendra *et. al*., 2010 in vertical axis rotating pepper decorticator.

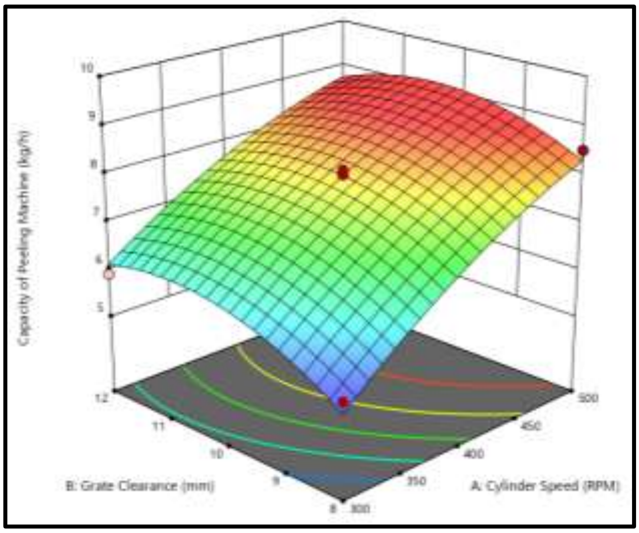

Fig. 4.19 Effect of cylinder speed and grate clearance on capacity of peeling machine

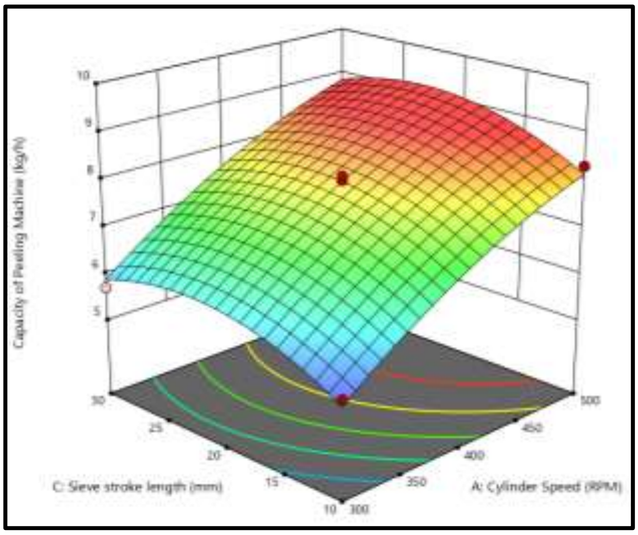

Fig. 4.20 Effect of sieve stroke length and cylinder speed on capacity of peeling machine

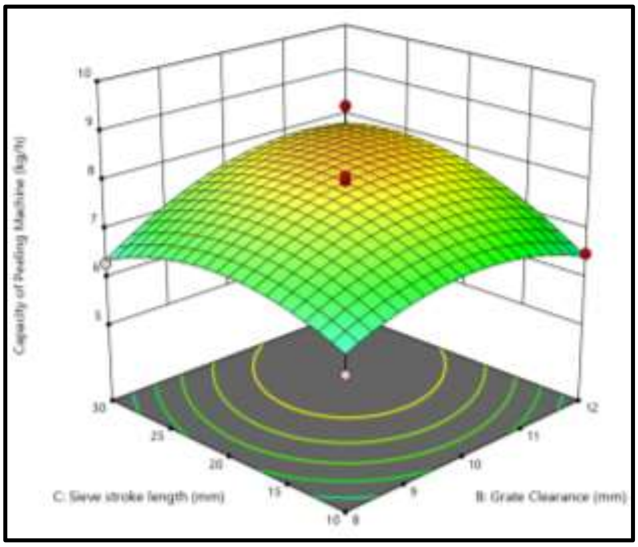

Fig. 4.21 Effect of grate clearance and sieve Stroke length on capacity of peeling Machine

The ANOVA shown in table no 4.19 indicated that, The Model F-value of 26.63 implies the model was significant. There was only a 0.01% chance that an F-value this large could occur due to noise. The model value F (26.83) suggesting quadratic model could be successfully used to fit experimental data (< 0.0001) as per F values indicated in table 4.19. P-values less than 0.0500 indicate model terms were significant at 5 % level. In this case A, B, C, B^2, C^2 were significant model terms. Values greater than 0.1000 indicated the model terms were not significant. If there were many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. The Lack of Fit F-value of 29.40 implies the Lack of Fit was significant. There was only a 0.35% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit was bad for the model to fit. The Predicted R^2 of 0.5933 was not as close to the Adjusted R^2 of 0.9395 as one might normally expect i.e. the difference was more than 0.2. This may indicate a large block effect or a possible problem with model and/or data. Things to consider were model reduction, response transformation, outliers, etc. All empirical models should be tested by doing confirmation runs. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 was desirable. Ratio of 1.262 indicates an adequate signal. This model can be used to navigate the design space.

The regression equation representing variation of peeling efficiency % with different independent parameters were fitted in polynomial form given as

Triphal damage % = 7.98 + 1.4625A + 0.375B + 0.3375C - 0.15AB + 0.025AC + 0.35BC - 0.3275A^2 - 0.6025B^2 - 0.6275C^2 …(4.16)

R^2 = 0.9395

Where, A = Cylinder Speed (rpm)

B = Grate Clearance (mm)

C = Sieve stroke length (mm)

Table 4.19 ANOVA for Study of Effect of Cylinder Speed, Grate Clearance and Sieve Stroke Length on Machine Capacity

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	23.76	9	2.64	28.63	0.0001	significant
A-Cylinder Speed	17.11	1	17.11	185.56	< 0.0001	significant
B-Grate Clearance	1.13	1	1.13	12.20	0.0101	significant
C-Sieve stroke length	0.9112	1	0.9112	9.88	0.0163	Significant
AB	0.0900	1	0.0900	0.9760	0.3561	Not significant
AC	0.0025	1	0.0025	0.0271	0.8739	Not significant
BC	0.4900	1	0.4900	5.31	0.0546	Not significant
A^2	0.4516	1	0.4516	4.90	0.0625	Nit significant
B^2	1.53	1	1.53	16.57	0.0047	Significant
C^2	1.66	1	1.66	17.98	0.0038	Significant
Residual	0.6455	7	0.0922			
Lack of Fit	0.6175	3	0.2058	29.40	0.0035	Significant
Pure Error	0.0280	4	0.0070			
Cor Total	24.40	16				
Std. Dev.	0.3037					
Mean	7.25					
C.V. %	4.19					
R^2	0.9735					
Adjusted R^2	0.9395					
Predicted R^2	0.5933					
Adeq Precision	16.2622					

4.3 Optimization of Parameters of Developed Triphal Peeling Unit

The performance of developed peeling unit was evaluated as per standard procedure and stastistical expeiments. The numeriacal multi response optimizing technique in Design Expert 13 trial version software was used. Parameters were selected in combination for optimization of values of cylinder speed, grate clearance, sieve stroke length, peeling efficiency, Damage Triphal %, unpeeled triphal % and capacity of peeling machine. The optimized combinations of selected parameters by using Response Surface Method were shown in fig 4.22.

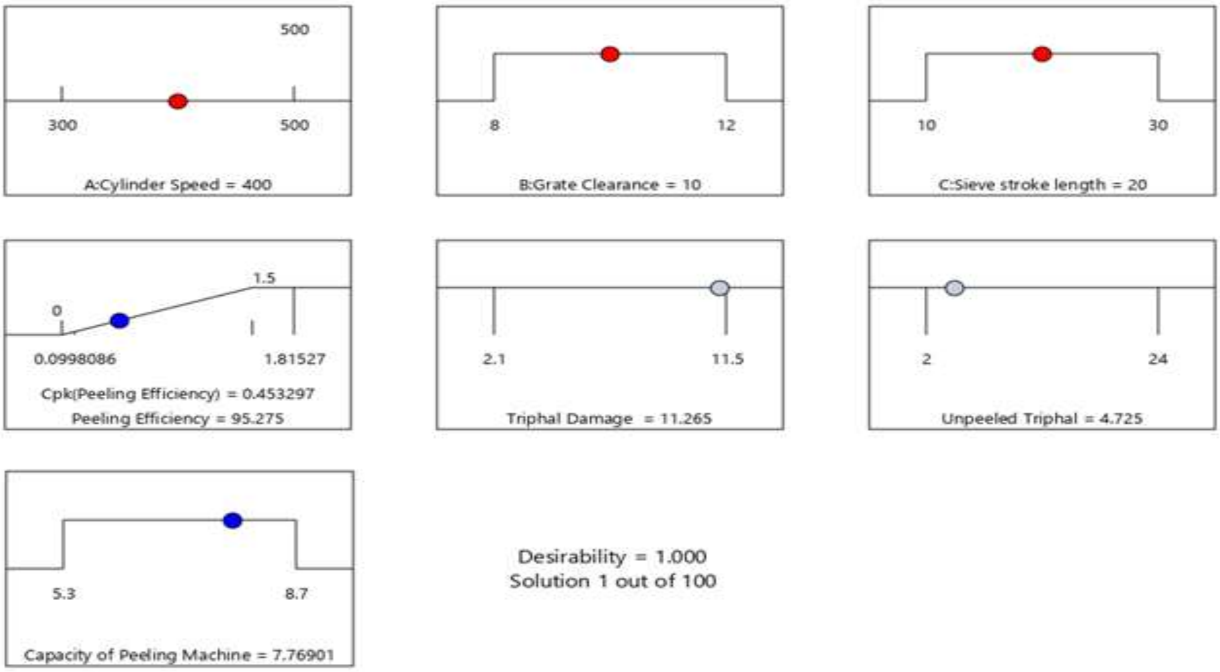

Fig 4.22 Optimized Combinations of Selected Parameters for Operation of Triphal Peeling Unit

Cylinder speed has significant effect on peeling efficiency. The optimization to optimum cylinder speed for better result of peeling efficiency was observed 385 rpm. The actual observed cylinder speed nearest to optimized value was 400 rpm. Optimized grate clearance for best peeling efficiency was 10 mm and observed value was same 9.5 mm. Among the three sieve stroke lengths viz. 10, 20 and 30 mm, the optimized sieve stroke length was 20 mm and observed value of sieve stroke length was also 19 mm. For the optimized values of selected parameters at the 18 % moisture content observed value of peeling efficiency was 98 %. Value of Damage Triphal was 3.1 %. The observed value of unpeeled triphal % was 3.2 %. The observed value of capacity of peeling mahine above was 8 kg/h.

Table 4.20 Optimization of selected parameters by using Response Surface Method

Parameters	Optimized value	Field Result value	Variation
Cylinder speed, rpm	400	385	15
Grate clearance, mm	10	9.5	0.5

Sieve stroke length, mm	20	19	1
Peeling Efficiency, %	95.27	98	- 2.73
Triphal Damage, %	11.26	3.1	8.16
Unpeeled triphal, %	4.72	3.2	1.52
Capacity of Machine, kg/h	7.76	8	- 0.24

4.4 Validation of Data

Triphal samples were procured from the local market and dried upto 18 % moisture content as per the requirement of the machine. For validation of data trials were taken at the farmer's field. The machine was selected and the performance was observed. During the testing optimized parameters of the machine, the peeling efficiency, Damage Triphal , unpeeled triphal and capacity of machine were observed as 98 %, 3.1 %, 3.2 % and 8 kg/h, respectively.

4.5 Cost Economics

For estimation of cost effectiveness of developed triphal peeling unit cost economics were calculated. The compared results for the cost economics were presented in table 4.17. Details about calculation were given in appendix F.

Table 4.21 Cost of Peeling of Triphal by Manual Method and Developed Triphal Peeling Unit

Sr. No.	Particulars	Manual peeling and cleaning of triphal	Peeling and cleaning of triphla using developed Triphal Peeling Unit
1	Capacity, kg/h	1.2	8
2	Labour Required	1	1
3	Triphal process per day, kg/day	9.6	64
4	Operating cost, Rs/kg	38.28	6.84
5	Time required per kg, (min/kg)	50	7.5

It was observed that capacity of manual triphal peeling in one labour and peeling of triphal with developed triphal peeling unit were 1.2 and 8 kg/h, repectively. Cost of operation when compared with manual manual triphal peeling with one labour and with developed triphal peeling unit were observed as 38.28 Rs/kg and 6.84 Rs/kg, respectively. So the developed peeling machine can save 6 times the cost of peeling operation as compare to manual operation.

CHAPTER V

SUMMARY AND CONCLUSIONS

India produces more than 50 different spices and is the world's top producer, consumer, and exporter of spices and spice-related goods. Along with many other spices, India is a significant supplier of chilli, turmeric, cumin, and pepper. Additionally, the nation imports diverse spices to satisfy local taste preferences as Indian dishes would be incomplete without a variety of spices. The state that produces the most spices in India is Andhra Pradesh. Gujarat, Karnataka, Rajasthan, Tamil Nadu, Assam, Kerala, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, and West Bengal are also key spice-producing states in India (Anonymous, 2021). In Maharashtra the average share of Horticulture in Gross State Value Added (GSVA) of Crop sector is 28.4 per cent (Anonymous, 2021). Condiments and spices production increased by 3.9 percentage in the year 2020-21 than 2019-20 with production 1,308 MT in 2020-21 and 1,359 MT in 2020-21(Anonymous, 2021) In Maharashtra Konkan region is a highly dynamic and vibrant part of the Western Ghats range of the Maharashtra having favourable agricultural climate of the tropics. Geographically, this hilly region with long coastal sea shore is gifted with a wide range of horticultural potentials. It is a coastal strip of land bounded by Sahydri hills on the east and the Arabian sea at on the west. Maharashtra's Konkan region consist of Raigad, Ratnagiri, Sindhudurg, palghar and Thane districts. Konkan region is specially known as horticultural zone (Bhattacharrya et. al., 2017).

The genus *Zanthoxylum* (family Rutaceae) contains a fascinating group of plants found around the world from the tropics to temperate zones. With over 200 species, ranging from small shrubs to large trees, *Zanthoxylum spp.* are characterized by sharp thorns on either the stem or leaves. Various *Zanthoxylum spp.* are well recognized as Asian spices, including hua jiao in China, sansho in Japan and chopi and sancho in Korea (Austin and Felger 2008). Indian prickly ash, also known as *Zanthoxylum rhetsa* (Triphal), is a species of flowering plant in the Rutaceae family that can be found from India east to the Philippines and south to northern Australia (Hartley *et. al.*, 2013). Processing of triphal is highly skilful operation. Triphal is still peeled manually using an antiquated procedure that is laborious and time-consuming, discouraging farmers from working on it and eventually preventing it from meeting consumer demand. It not only causes injuries to hands but also required high amount of labour. In order to uplift this spices crop it is necessary to develop the proper peeling unit for the quality production of triphal. The importance of a product can be increased by properly developing technology, which can also inspire young people to start their own businesses. The development of the peeling unit may contribute to changing the current triphal situation in Konkan area. Hence, the project entitled

"Design, Development and Performance Evaluation of Triphal peeling Unit" was undertaken for study.

Engineering properties were the properties which were useful and necessary in the field of FMPE in development of different farm machineries. Engineering properties were needed to carry out different post harvest activities. In operations while handling of spices seeds and flowers the properties which play an important role were physical, mechanical, frictional and aerodynamic properties etc. Basic information on these properties of triphal was of great importance towards efficient process and equipment development for the peeling of triphal. An attempt has been made to measure some of the engineering properties usually encountered in entire design and development of the triphal peeling unit. For determination of physical properties of triphal the samples were purchased from local market of Dapoli. The properties which were measured under this study were length, width, breadth, moisture content, geometric mean diameter, bulk density, true density, porosity, angle of repose, coefficient of friction seed detachment force etc.

The average values of length, breadth, thickness, arithmetic mean diameter, geometric mean diameter, square mean diameter, equivalent mean diameter, surface area and sphericity of triphal were 10 mm, 10 mm, 10.32 mm, 10.40 mm, 10.40 mm, 18.01 mm, 12.94 mm, 341.65 mm^2, 0.98 per cent, respectively for 18 per cent moisture content. By increasing moisture content from 16 per cent to 22 per cent (d.b), bulk density of triphal decreased from 0.63 g/cm^3 to 0.26 g/cm^3. True density and porocity increased from 0.79 g/cm^3 to 1.35 g/cm^3 and 20.25 per cent to 80.74 per cent, respectively. The angle of repose of triphal varied from 38.68˚ to 47.67˚, as the moisture content increased from 16 per cent to 22 per cent(d.b), respectively. Static coefficient of friction of triphal increased with increase in moisture content. For stainless steel, coefficient of friction increases from 0.34 to 0.74 with increase in moisture level from 16 per cent to 22 per cent. For wood, mild steel, plastic and aluminium coefficient of friction increased from 0.46 to 0.65, 0.28 to 0.49, 0.32 to 0.54, 0.25 to 0.63, repectively. The mean force required for detachment of seed from triphal was 0.429 N with respect to mean time of 5.35 sec.

Based on the physical and mechanical properties entire design and development of triphal peeling unit were carried out at CAET workshop, DBSKKV, Dapoli. which was essentially consist of two main units, peeling unit and cleaning unit. Peeling unit consist of grate and cylinder while cleaning unit consist of sieve. Parts of developed Triphal Peeling unit were main frame, hopper, internal cylinder, grate, sieve, motor and speed controller. The complete assembly of the machine was mounted on the mainframe. Initially the sieve assembly was fixed with proper hing arrangement with m. s flat of size 25 × 5 mm, the oscillation mechanism was attached with sieve assembly which was powered through 0.16 hp motor. On the frame grate was mounted with the mounting nuts and bolts of 12 mm size. Internal cylinder was mounted on the main shaft with the help of bosch on both ends of the cylinder. It was locked with the square key of 8 mm size. Discharge chute was installed at lower end of the frame so it was convenient to pass the shaft through it. Internal cylinder was placed inside grate. Lower end was fixed at the lower bearing and upper and was locked with the rectangular angle frame with bearing. At side of the top of angle frame hopper was installed with the help of nuts and bolts of size 12 mm. At lower end of shaft pulley of 65 mm size was installed and at motor 127 mm size pulley was installed. Both pulleys were connected with V belt. The eccentric of the sieve was connected with the motor. Motor was connected to the speed controller. And Machine was completely assembled.

After development of the triphal peeling unit its performance was evaluated as per the experimental design given by Design Expert 13 trial version software at laboratory and

The performance of the developed triphal peeling unit was evaluated at three cylinder speeds (300, 400 and 500 rpm), three grate clearances (8, 10 and 12 mm) and three stroke sieve lengths (10, 20 and 30 mm) to study their effect on peeling efficiency, triphal damage, unpeeled triphal and capacity of triphal peeling unit at Computer Laboratory, CAET, Dapoli. From the performance study, peeling efficiency was obtained in range of 78.5 to 98 per cent. Triphala damage was ranged in between 2.1 to 11.5 per cent. Unpeeled triphal was found to be from 2 per cent to 24 per cent. Capacity of machine was observed from 5.3 to 8.5 per cent

The optimized values were found of selected independent parameters through Design Expert 13 trial version software. Optimized values among three cylinder speeds (300, 400 and 500 rpm), three grate clearances (8, 10 and 12 mm) and three stroke sieve lengths (10, 20 and 30 mm) were obtained to be 400 rpm, 10 mm, 10 mm, respectively. Based on this output the machine was tested for field performance and the results were obtained as peeling efficiency, triphal damage, unpeeled triphal and capacity of machine were observed as 98 per cent, 3.1 per cent, 3.2 per cent and 8 kg/h, respectively, which was obtained within 5 to 10 per cent variation over the field.

In cost economics, it was observed that capacity of manual triphal peeling by one labour and peeling of triphal with developed triphal peeling machine were 1.2 and 8 kg/h, repectively. Cost of operation for manual triphal peeling with one labour and peeling of triphal with developed triphal peeling machine were 38.28 Rs/kg and 6.84 Rs/kg, which is 6 times lesser than the manual method or traditional method.

Conclusions

1. Linear dimensions, true density, porosity, coefficient of friction and angle of repose increases with increase in moisture content while bulk density decreases with inrease in moisture content
2. Seed detachment force was found to be 0.431 N.
3. Stalk crushing force was observed as 25 N.
4. Machine’s best result was found at 400 RPM cylinder speed, 10 mm grate clearance and 20 mm sieve stroke length.
5. At optimized operational parameters of machine obtained as peeling efficiency obtained 98 per cent, triphal damage was observed 3.1 per cent, unpeeled triphal was seen that 3.2 per cent and capacity of machine was 8 kg/h
6. Operating cost of developed machine was 6.84 Rs/kg. while in traditional operation it was 32.28 Rs/kg.

CHAPTER VI

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APPENDICES

APPENDIX A

Determination of Moisture Content

$$MC\ (\%) = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where, MC= Moisture content on dry basis, %;

W1= Initial weight of the bowl, g;

W2 = Sample weight before drying +bowl weight, g;

W3 = Sample weight after drying + bowl weight, g

Calculations for determination of Moisture Content of Triphal

Sr. No.	Sample	Sample No.	W_1 (g)	W_2 (g)	W_3 (g)	M.C. (%)	Average (%)
1.	Triphal	1	16.213	21.227	16.500	16.0	16
		2	16.221	21.231	16.51	15.9	
		3	16.215	21.235	16.50	16.1	

APPENDIX B

Determination of Surface Area of Triphal

Calculation of Surface Area of Triphal

Sample no.	L	B	T	GMD	S. Area
1	10.16	8.50	9.85	9.48	282.08
2	10.78	10.45	10.54	10.59	352.309
3	10.65	9.93	10.21	10.26	330.691
4	10.08	9.15	9.74	9.65	292.527
5	10.34	10.08	10.15	10.19	326.215
6	9.86	10.64	10.25	10.25	329.788
7	11.20	9.66	10.19	10.33	335.315
8	9.10	8.43	9.17	8.89	248.522
9	10.19	9.96	10.20	10.12	321.535
10	10.92	10.38	10.68	10.66	356.889
11	9.40	8.51	9.56	9.14	262.754
12	10.77	11.43	10.80	11.00	379.895
13	11.81	11.21	11.03	11.35	404.415
14	10.80	10.21	10.20	10.40	339.812
15	9.88	9.50	9.47	9.61	290.465
16	10.80	11.18	10.67	10.88	372.014
17	9.91	10.40	9.42	9.90	308.132
18	11.75	11.16	10.61	11.16	391.578
19	9.88	9.92	10.22	10.01	314.547
20	11.72	11.57	10.69	11.32	402.438
21	12.32	12.21	12.13	12.22	469.171
22	11.09	11.32	10.89	11.10	387.029
23	9.50	8.17	9.67	9.09	259.49
24	11.62	10.78	11.40	11.26	398.437
25	11.27	11.60	10.38	11.07	385.117

APPENDIX C

Calculation of the Sphericity of Triphal

Calculation of Spherecity of Triphal

Sample no.	L	B	T	Spherecity
1	10.16	8.50	9.85	0.93
2	10.78	10.45	10.54	0.98
3	10.65	9.93	10.21	0.96
4	10.08	9.15	9.74	0.96
5	10.34	10.08	10.15	0.99
6	9.86	10.64	10.25	1.04
7	11.20	9.66	10.19	0.92
8	9.10	8.43	9.17	0.98
9	10.19	9.96	10.20	0.99
10	10.92	10.38	10.68	0.98
11	9.40	8.51	9.56	0.97
12	10.77	11.43	10.80	1.02
13	11.81	11.21	11.03	0.96
14	10.80	10.21	10.20	0.96
15	9.88	9.50	9.47	0.97
16	10.80	11.18	10.67	1.01
17	9.91	10.40	9.42	1.00
18	11.75	11.16	10.61	0.95
19	9.88	9.92	10.22	1.01
20	11.72	11.57	10.69	0.97
21	12.32	12.21	12.13	0.99
22	11.09	11.32	10.89	1.00
23	9.50	8.17	9.67	0.96
24	11.62	10.78	11.40	0.97
25	11.27	11.60	10.38	0.98

APPENDIX D

Seed Detachment Force of Triphal

Seed Detachment Force of Triphal by Texture Analyser Setup

Time (Sec)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
0	0	0	0	0	0	0	0	0	0	0
1	0.065	0.09	0.0625	0.083	0.104	0.086	0.062	0.094	0.09	0.064
2	0.13	0.18	0.125	0.166	0.208	0.172	0.124	0.188	0.18	0.128
3	0.195	0.27	0.1875	0.249	0.312	0.258	0.186	0.282	0.27	0.192
4	0.261	0.36	0.25	0.332	0.416	0.344	0.25	0.376	0.36	0.256
5	0	0.45	0	0.415	0.52	0.43	0	0.47	0.45	0.32
6		0.54		0.5	0.624	0		0	0.54	0
7		0		0	0.73				0	
8					0					

APPENDIX E

Table 1. Combine Effects of Selected Independent Parameters on Dependent Parameters

Std	Run	A:Cylinder Speed RPM	B:Grate Clearance mm	C:Sieve stroke length mm	Peeling Efficiency %	Triphal Damage %	Unpeeled Triphal %	Capacity of Peeling Machine kg/h
9	7	400	8	10	96.5	7.9	3.5	6
5	13	300	10	10	87	4.1	13	5.4
6	12	500	10	10	95.5	4.5	4.5	8.3
10	8	400	12	10	82.8	2.1	17.2	6.5
1	4	300	8	20	76	7.2	24	5.3
2	10	500	8	20	95	11.5	5	8.5
14	1	400	10	20	97.5	3.1	2.5	8
16	2	400	10	20	98	3	2	7.9
15	3	400	10	20	97.6	3	2.4	7.9
17	9	400	10	20	96.8	3.1	3.2	8.1
13	14	400	10	20	97.1	2.9	2.9	8
3	16	300	12	20	78.5	2.7	21.5	5.9
4	15	500	12	20	79	2.1	21	8.5
11	17	400	8	30	95	8.2	5	6.3
7	6	300	10	30	88	4.2	12	5.7
8	5	500	10	30	94	4.6	6	8.7
12	11	400	12	30	81.5	2.3	18.5	8.2

Table 2. Effects of Cylinder Speed on Dependent Parameters

Std	Run	A:Cylinder Speed RPM	Peeling Efficiency %	Triphal Damage %	Unpeeled Triphal %	Capacity of Peeling Machine kg/h
5	13	300	87	4.1	13	5.4
1	4	300	76	7.2	24	5.3
3	16	300	78.5	2.7	21.5	5.9
7	6	300	88	4.2	12	5.7
9	7	400	96.5	7.9	3.5	6
10	8	400	82.8	2.1	17.2	6.5
14	1	400	97.5	3.1	2.5	8
16	2	400	98	3	2	7.9
15	3	400	97.6	3	2.4	7.9
17	9	400	96.8	3.1	3.2	8.1
13	14	400	97.1	2.9	2.9	8
11	17	400	95	8.2	5	6.3
12	11	400	81.5	2.3	18.5	8.2
6	12	500	95.5	4.5	4.5	8.3
2	10	500	95	11.5	5	8.5
4	15	500	79	2.1	21	8.5
8	5	500	94	4.6	6	8.7

Table 3. Effects of Grate Clearance on Dependent Parameters

Std	Run	B:Grate Clearance mm	Peeling Efficiency %	Triphal Damage %	Unpeeled Triphal %	Capacity of Peeling Machine kg/h
1	4	8	76	7.2	24	5.3
9	7	8	96.5	7.9	3.5	6
11	17	8	95	8.2	5	6.3
2	10	8	95	11.5	5	8.5
5	13	10	87	4.1	13	5.4
7	6	10	88	4.2	12	5.7
14	1	10	97.5	3.1	2.5	8
16	2	10	98	3	2	7.9
15	3	10	97.6	3	2.4	7.9
17	9	10	96.8	3.1	3.2	8.1
13	14	10	97.1	2.9	2.9	8
6	12	10	95.5	4.5	4.5	8.3
8	5	10	94	4.6	6	8.7
3	16	12	78.5	2.7	21.5	5.9
10	8	12	82.8	2.1	17.2	6.5
12	11	12	81.5	2.3	18.5	8.2
4	15	12	79	2.1	21	8.5

Table 4. Effects of Sieve Stroke Length on Dependent Parameters

Std	Run	C:Sieve stroke length mm	Peeling Efficiency %	Triphal Damage %	Unpeeled Triphal %	Capacity of Peeling Machine kg/h
9	7	10	96.5	7.9	3.5	6
5	13	10	87	4.1	13	5.4
6	12	10	95.5	4.5	4.5	8.3
10	8	10	82.8	2.1	17.2	6.5
1	4	20	76	7.2	24	5.3
2	10	20	95	11.5	5	8.5
14	1	20	97.5	3.1	2.5	8
16	2	20	98	3	2	7.9
15	3	20	97.6	3	2.4	7.9
17	9	20	96.8	3.1	3.2	8.1
13	14	20	97.1	2.9	2.9	8
3	16	20	78.5	2.7	21.5	5.9
4	15	20	79	2.1	21	8.5
11	17	30	95	8.2	5	6.3
7	6	30	88	4.2	12	5.7
8	5	30	94	4.6	6	8.7
12	11	30	81.5	2.3	18.5	8.2

APPENDIX F

Operational Cost of Machine

Making some assumption for the calculation of the cost operation were as follows,

Initial cost (C) = Rs. 25,725/-

Life span (L) = 10 years

Annual use (H) = 720 h

Interest rate (I) = 10%

Salvage value (S) = 10%

Labour requirement = 1

Capacity of Machine = 8 kg/h

A. Fixed cost

a) Depreciation $=\frac{C-S}{L \text{ X } H}$

$=\frac{25725-2572}{10 \text{ X } 720}$

= **3.21 Rs/h**

b) Interest $= \frac{c+s}{2} \text{X} \frac{i}{H}$

$=\frac{25725 + 2572}{2} \text{X} \frac{10}{100 \text{ X } 720}$

= 1.96 Rs/h

c) Taxes, Insurance, housing $=\frac{3\ \%\ C}{H}$

$=\frac{3 \text{ X } 25725}{100 \text{ X } 720}$

= **1.07 Rs/h**

B. Variable cost

a) Repair &maintainance $=\frac{10\%\ C}{H}$

$= \frac{10}{100} \text{X} \frac{25725}{720}$

= **3.57 Rs/h**

b) Electricity consumption

Assume that electricity @ Rs. 10/unit (kWh)

= 0.125 x 10

= **1.25 Rs/h**

c) Labour charge = 350 Rs. /day

Day is considered as 8 hours working time.

$$= \frac{350}{8}$$

= **43.75 Rs/h**

Total Operational cost (A+B) Per Hour

Total cost = Fixed cost + Variable cost

= 1.515+1+0.505+1.68+4.59+43.75

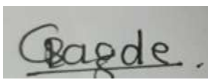
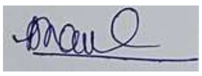
= **Rs. 53.04/h**

Operational cost of Machine Per kg = Total operational cost per hour/ capacity

= 6.84 Rs/kg

THESIS ABSTRACT

Triphal (*Xanthoxylum rhesta*) is the spice only produced in Konkan. No any processing machiney were developed for the triphal. Engineering properties of triphal were measured for development of triphal peeling unit. Engineering properties such as moisture content, dimension, size, bulk density, true density, porocity, angle of repose, coefficient of friction, seed detachment force etc were determined and utilized in design and development of the machine. Internal cylinder, grate, main frame, sieve, hopper were the parts of machine. Based on output the machine was tested for field performance and the results were obtained as peeling efficiency, triphal damage, unpeeled triphal and capacity of machine were observed as 98 per cent, 3.1 per cent, 3.2 per cent and 8 kg/h, respectively, which was obtained within 5 to 10 per cent variation over the field.

a)	Title of thesis	:	DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF TRIPHAL PEELING UNIT
b)	Full name of student	:	Mr. Bagde Chetan Shivprasad
c)	Name and address of Major Advisor	:	Dr. S. V. Pathak Professor (CAS) CAET Dr. BSKKV Dapoli
d)	Degree to be awarded	:	M Tech (Farm Machinery and Power Engineering)
e)	Year of award of degree	:	2023
f)	Major subject	:	Farm Machinery and Power Engineering
g)	Total number of pages in thesis	:	96
h)	Number of words in abstract	:	132
i)	Signature of student	:	
j)	Signature, Name and address of forwarding authority	:	

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Acceptance Letter

Dear,

Er. C.S. Bagde

Manuscript titled **"Production and Distribution of Triphal (** ***zanthoxylum rhesta.*****) in the Western Region of Maharashtra"** is very well written and has been accepted for publication.

Corresponding Author : Er. C. S. Bagde

Co - Author: Dr. S. V. Pathak, Dr. P. U. Shahare, Er. M. B. Patil, Dr. A. D. Rane

Ref No.: **S-11-7-96**
Date: **28-07-2023**

Yours Sincerely,

Akhil Gupta
Publisher :The Pharma Innovation Journal
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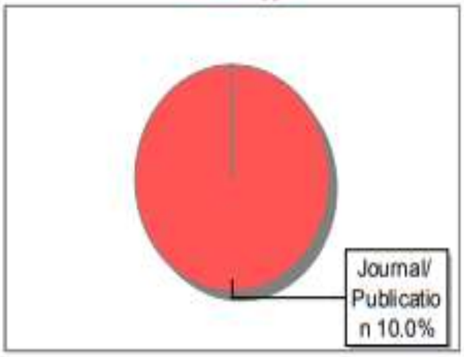

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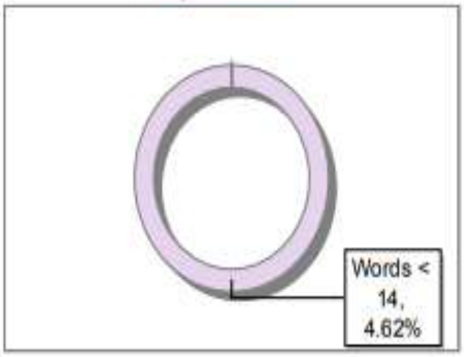

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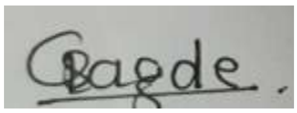
8. Research papers published / Paper submitted

Title of Paper:

Production and Distribution of Triphal (*Zanthoxylum rhesta*) in the western region of Maharashtra.



Place : Dapoli

Date: 02/08/2023 **Signature of Student**