

**DEVELOPMENT OF POWER OPERATED
DECORTICATOR FOR CONFECTIONERY
SUNFLOWER SEEDS (*Helianthus annuus* L.)**

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PALB 1279

**DEPARTMENT OF AGRICULTURAL ENGINEERING
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

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DECORTICATOR FOR CONFECTIONERY
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in

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AFFECTIONATELY DEDICATED

*To My
Beloved parents*

**Sri Thippeswamy.R &
Smt. Renuka. G. R**

*Brother Naveen &
Sister Smt. Sushma Jagdeesh*



**DEPARTMENT OF AGRICULTURAL ENGINEERING
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

CERTIFICATE

This is to certify that the thesis entitled “**DEVELOPMENT OF POWER OPERATED DECORTICATOR FOR CONFECTIONERY SUNFLOWER SEEDS (*Helianthus annuus L.*)**” Submitted by Ms. ASHWINI, T., ID No. PALB 1279, In the partial fulfilment of the requirements for award of the degree of **MASTER OF TECHNOLOGY (Agricultural Engineering)** in **PROCESSING AND FOOD ENGINEERING** to the University of Agricultural Sciences, Bangalore is a record of research work done by her during the period of her study in this University under my guidance and supervision, the thesis has not previously formed the basis of the award of any degree, diploma, associate-ship, fellowship or other similar titles.

Bangalore
July, 2013

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**“DEVELOPMENT OF POWER OPERATED DECORTICATOR FOR CONFECTIONERY
SUNFLOWER SEEDS (*Helianthus annuus L.*)”**

Department of Agricultural Engineering, UAS, GKVK, Bangalore-65

ABSTRACT

Sunflower (*Helianthus annuus L.*) seeds are commonly used to extract oil for consumption. Certain varieties of sunflower seeds are used in confectionery and are called confectionery sunflower seeds. They are also used as snack foods. The decortication of these seeds is done manually by hand. The traditional decortication process is time and labour consuming. Hence a power operated sunflower seed decorticator was developed and evaluated. The sunflower seed decorticator consists of a hopper at the top, cylinder, concave, blower and motor. The cylinder is made of dimple sheet. The cylinder is 65 cm long and, the diameter was 35cm. This has projections 2065/m². The concave made up of M.S. sheet with 4.5 mm holes to allow the seeds to fall. The clearance between the cylinder and concave was maintained at 4.5 mm. The decortication was done for two moisture contents (12 and 14 %), and for two cylinder speeds (75 and 90 rpm). During the trials, it was found that the pre-treated (sun dried) sunflower seeds of 14 % moisture content were better for decortication, when compared to other moisture levels. The rpm of the cylinder also effects the decortication. The efficiency was high at 75 rpm of the cylinder speed and was found to be 94.5 %, the capacity was 35 kg/h and the whole seed recovery was 43%. The cost of operation of the decortication was ₹ 1.70/kg of seeds or ₹ 59.5/h of operation and the advantage when compared with manual decortication works out to be 1:2.05.

Signature of student

(Ashwini. T)

Signature of Major advisor

(M. Ramachandra)

“ಶಕ್ತಿ ಚಾಲಿತ ಸೂರ್ಯಕಾಂತಿ ಬೀಜದ ಸಿಪ್ಪೆ ಸುಲಿಯುವ ಯಂತ್ರದ ಅಭಿವೃದ್ಧಿ”

ಅಶ್ವಿನಿ. ೮

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಸೂರ್ಯಕಾಂತಿ ಬೀಜವನ್ನು ಸಾಮಾನ್ಯವಾಗಿ ಎಣ್ಣೆಕಾಳಾಗಿ ಬಳಸುತ್ತಾರೆ. ಸೂರ್ಯಕಾಂತಿ ಬೀಜಗಳ ಕೆಲವು ಪ್ರಬೇದಗಳನ್ನು ಮಿಠಾಯಿ ಹಾಗೂ ಲಘು ಉಪಹಾರಗಳ ತಯಾರಿಕೆಯಲ್ಲಿ ಬಳಸುತ್ತಾರೆ. ಸೂರ್ಯಕಾಂತಿ ಬೀಜಗಳ ಸಿಪ್ಪೆಯನ್ನು ಕೈಗಳಿಂದ ಸುಲಿಯಲಾಗುವುದು. ಈ ಸಾಂಪ್ರದಾಯಿಕ ಸಿಪ್ಪೆ ಸುಲಿಯುವ ಕಾರ್ಯವು ಸಮಯ ಹಾಗೂ ಶ್ರಮವನ್ನು ಹೆಚ್ಚಾಗಿ ತೆಗೆದುಕೊಳ್ಳುತ್ತದೆ. ಆದ ಕಾರಣ ಶಕ್ತಿ ಚಾಲಿತ ಸೂರ್ಯಕಾಂತಿ ಬೀಜದ ಸಿಪ್ಪೆ ಸುಲಿಯುವ ಯಂತ್ರವನ್ನು ಅಭಿವೃದ್ಧಿ ಪಡಿಸಿ, ಇದರ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ಈ ಯಂತ್ರದ ಮೇಲ್ಭಾಗದಲ್ಲಿ ಬೀಜ ಹಾಕುವ ಪೆಟ್ಟಿಗೆ (hopper) ಇದ್ದು, ಅದರಿಂದ ಇಳಿಯುವ ಬೀಜಗಳು ಕೊಳವೆಯಾಕಾರದ ಬೀಜ ಬಿಡಿಸುವ ಕೊಳವೆ (cylinder) ಹಾಗೂ ಅದನ್ನು ಸುತ್ತಿರುವ ಅಂತರ್ಗೋಳದ (concave) ಕಾರ್ಯದಿಂದ ಸಿಪ್ಪೆ ಸುಲಿಯಲ್ಪಟ್ಟು ಕೆಳಗಿನ ರಂಧ್ರಗಳ ಮೂಲಕ ಬೀಳುತ್ತದೆ. ಗಾಳಿ ಬೀಸುವ ಯಂತ್ರದ ಮೂಲಕ ಸಿಪ್ಪೆಗಳು ಬೇರ್ಪಟ್ಟು ಸುಲಿದ ಬೀಜಗಳು ಕೆಳಗೆ ಬೀಳುತ್ತವೆ. ಇದು ಮೋಟರನ್ನು ಒಳಗೊಂಡಿದೆ. ಕೊಳವೆಯ ಉದ್ದ 65 ಸೆ.ಮೀ ಹಾಗೂ 35 ಸೆ.ಮೀ ವ್ಯಾಸ ಇದ್ದು, ಇದನ್ನು ಡಿಂಪಲ್ ಹಾಳೆಯಿಂದ ತಯಾರಿಸಲಾಗಿದೆ. ಈ ಹಾಳೆ ಒಂದು ಚದುರ ಮೀಟರಿನಲ್ಲಿ 2065 ಮುಂಬಾಗಿರುವ ರಂಧ್ರಗಳನ್ನು ಒಳಗೊಂಡಿದೆ. ಅಂತರ್ಗೋಳವನ್ನು 4.5 (mm) ರಂಧ್ರಗಳಿರುವ M.S. ಹಾಳೆಯಿಂದ ಮಾಡಲಾಗಿದೆ. ಕೊಳವೆ ಮತ್ತು ಅಂತರ್ಗೋಳ ನಡುವಿನ ಅಂತರವು 4.5 mm ಆಗಿದ್ದು, ಇದರಿಂದ ಬೀಜಗಳು ಕೆಳಗೆ ಬೀಳುತ್ತವೆ, ಈ ಯಂತ್ರವನ್ನು ವಿವಿಧ ತೇವಾಂಶ (12 ಮತ್ತು 14%) ಹಾಗೂ ವಿವಿಧ ಸುತ್ತುವ ವೇಗಗಳಲ್ಲಿ (75 ಮತ್ತು 90 rpm) ಪರೀಕ್ಷಿಸಲಾಯಿತು. ಇದರಿಂದ ತಿಳಿದು ಬಂದದ್ದೇನೆಂದರೆ ವಿವಿಧ ತೇವಾಂಶವಿರುವ ಬೀಜಗಳ ಜೊತೆ ತಾಳೆ ನೋಡಿದಾಗ, ಒಣಗಿಸಿದ 14% ತೇವಾಂಶವಿರುವ ಬೀಜವು ಸಿಪ್ಪೆ ಸುಲಿಯಲು ಯೋಗ್ಯವಾಗಿದೆ. ಸಿಪ್ಪೆ ಸುಲಿಯುವ ಕಾರ್ಯದಲ್ಲಿ ಕೊಳವೆಯ ವೇಗವು (rpm) ಸಹ ಪ್ರಭಾವ ಬೀರುತ್ತದೆ. ಯಂತ್ರದ ಅತ್ಯುತ್ತಮ ಪರಿಶೀಲನೆಯು, ಕೊಳವೆಯ ವೇಗ 75 rpm ಇದ್ದು, ತೇವಾಂಶ 14% ಇದ್ದಾಗ ದಕ್ಷತೆ 94.5%, ಸಾಮರ್ಥ್ಯ 35 ಕೆ.ಜಿ/ಘಂ, ಬಿಡಿಸಿದ ಬೀಜ 43% ಆಗಿರುತ್ತದೆ. ಈ ಕಾರ್ಯಕ್ಕೆ ರೂ.1.70/ ಕೆ.ಜಿ ಅಥವಾ ರೂ 59.5/ ಘಂ ವೆಚ್ಚ ತಗುಲಿದೆ, ಮತ್ತು ಈ ಯಂತ್ರದ ಹಾಗೂ ಕೈಯಲ್ಲಿ ಸಿಪ್ಪೆ ಸುಲಿಯುವ ಕಾರ್ಯಚರಣೆಯ ಪ್ರಯೋಜನಕಾರಿ ಅನುಪಾತವು 1:2.05 ರಷ್ಟಿದೆ.

ಪ್ರಧಾನ ಮಾರ್ಗದರ್ಶಕರು
(ಎಮ್. ರಾಮಚಂದ್ರ)

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LIST OF SIMBOLS AND ABBREVIATIONS

Abbreviations/ symbols	Description
%	percent
/	per
=	equal to
±	Plus or minus
°C	degree Celsius
cm	centimeter
d.b.	dry basis
w.b.	wet basis
Dia.	diameter
e.g.	Example graita (For example)
<i>et al.</i>	and others
Etc.	et cetera
Fig.	Figure
g	gram
h	hour
ha	hectare
hp	horse power
i.e.	id est. (That is)
kg	kilogram
m	meter
m.c.	moisture content
min.	minute
ml	milliliter
mm	millimeter
MT	metric tonnes
No.	Number
qtl	quintal
rpm	revolution per minute
₹	Rupees



Introduction

I. INTRODUCTION

Oilseed crops occupy an important position next to food grains in Indian agricultural economy. The oil not only forms an essential part in human diet but also an important raw material for manufacture of various products like flavor enhancers, lubricants, etc.

Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae. It is an annual, erect and herbaceous plant with leaves simple, alternate with stout petioles and lanceolate in shape. It is an important vegetable oilseed crop in the world, native to southern parts of USA and Mexico and ranks fourth after groundnut, soybean and rapeseed. In Greek "Helios" means sun and "anthos" means flower. In India it is popularly known as "Surajmukhi" or "Sooryakanthi". Sunflower is preferred by the consumers throughout the world due to its health appeal and in India also, sunflower oil is the largest selling oil in the branded oil segment. Seeds of sunflower contain 39-49 per cent edible oil, 14-19 per cent protein and 7.5-9.4 per cent soluble sugars (Nagaraja and Balasubramaniam, 1998). Sunflower oil is rich in PUFA (poly unsaturated fatty acids) which reduce the cholesterol content in blood and thereby help in reducing the chances of pulmonary diseases.

Sunflower ranks third, next to groundnut and soybean in total production. It is cultivated in an area of 18.12 million hectares with an annual production and productivity of 22.03 million tonnes and 1216 kg per hectare, respectively (Annon, 2012).

At present India has emerged as the second major sunflower producing country in Asia after China. In India, it is being grown in about 0.9 million hectares with annual production of 0.65 million tones and productivity of 696 kg per hectare (Anon, 2012).The cultivation of sunflower is largely confined to southern parts of the country comprising

the states of Karnataka, Maharashtra, Tamil Nadu and Andhra Pradesh. These four states contribute about 90 percent of the total acreage and 78 percent of total production.

Karnataka is a leading sunflower producing state in the country and contributes nearly 54 percent of the total area and 35.11 percent of total production in the country. It is grown over an area of 0.4 million hectares with a production and productivity of 0.35 million tonnes and 534 kg per hectare, respectively. In Karnataka, major sunflower production is concentrated in Bijapur, Bellary, Gulbarga, Raichur and Dharwad that accounts for nearly 85 percent of the total acreage (Anon, 2012).

In other parts of the world, the medium sized seeds are dehulled, roasted and sold as peanut substitutes and confectionary or snack item. Roasted and salted sunflower seeds either dehulled or whole are popular around the world as sweetmeat and savory. The broken or whole kernels with or without roasting are used in a variety of bakery products, salads, candies and some other food dishes. They are also used for sprinkling on syrup or pancakes and waffles, blended with honey, butter and salt to make a spread (Chakrapani, 1997).

Sunflower seed contains about 19.8 g of protein, 52.1 g of lipid, 17.9 g of carbohydrate, 1 g of crude fiber, 3.7 g of minerals, 280 mg of calcium, 5 mg of iron and it yields 620 Kcal of energy per 100 g of seeds (Gopalan *et al.*, 2007).

Shelling is the removal of outer seed coat namely hull/husk from the seed material. In general it is being done before the oil extraction. Very often, the term 'shelling' is replaced by the words hulling, dehulling and decortication. Shelling is done by shellers. Most shellers split the husks by the action of impact. Most of the oil seeds hulls are not fit for

direct oil expression and human consumption. Therefore, removal of hulls of the seeds is necessary. Hull content of the sunflower seeds varies between 20 and 30 percent depending on the variety. The hull contains crude fiber and insignificant quantity of fat.


Cultivated sunflower varieties are grouped into two distinct categories viz. oil type and non oil types. The oil type varieties are primarily of Russian origin and have small seeds with adhering seed coats and high oil percentage. Non oil types are of North American origin and produce large seeds. Stripped low oil content seeds are used extensively for human food and bird feed. The large size non oil seed type sunflower seeds are usually roasted and sold as snacks. The medium seeds are hulled, roasted and sold as peanut substitute and confectionery or snacks. Roasted and salted sunflower seeds either dehulled or whole are popular around the world as sweet meat and savory. The broken or whole kernels with or without roasting are used in a variety of bakery products, salads, candies and some other food dishes. They are also used for sprinkling on syrup or pancakes and waffles, blended with honey, butter and salt to make a spread. Sunflower seeds, flour and protein concentrate and isolates show promise and can be used in bakery products and infant formula as meat extenders. The non oil sunflower seeds enjoyed a constant market growth during last decade, particularly in the use of de-hulled and roasted or unroasted kernels for human consumption.

In the health conscious world today, nutrition helps in selling new products prepared from novel nutrient rich sources and sunflower is a power house of several nutrients. Roasted peanuts, almonds, cashew nuts, etc., are a few popular snack foods but are costly and sunflower seed kernels may be a cheaper substitute. Sunflower seed kernels are

rich source of many nutrients and can be used for the preparation of a variety of protein enriched food products at a lower cost.

The University of Agricultural Sciences, GKVK, Bangalore has developed a KBSH44 sunflower seed variety for confectionery purpose. A manually operated sunflower seed decorticator (capacity 6 kg/h) was developed (Vikas, 2012). To increase the capacity, there is a need to develop a power operated decorticator for removal of husk from the sunflower seeds which is suitable for confectionery purpose. This decorticator will reduce the labour requirement and also increase the extraction of oil in industries. Feeding the whole seeds to the expellers gives less percentage of oil due to the, presence of hulls covering the kernels or seeds. Hull absorbs some amount of oil in oil extraction. Keeping this in view, the research project on “Development of a power operated decorticator for confectionery sunflower seeds” was taken up with the following objectives:

1. To determine the physical properties of KBSH44 variety sunflower seeds.
2. To develop a power operated sunflower seeds decorticator.
3. To determine the power consumption at optimum speed of operation of the developed unit.
4. To evaluate the efficiency of decortication for the developed unit.
5. To calculate the economics of operation of the developed decorticator.



Review of Literature

II REVIEW OF LITERATURE

The literature was reviewed to understand the methods and equipment used for shelling of sunflower seeds and other seeds and nuts such as castor, soybean, groundnut, cocoa, cashew nut, etc., and are presented in this chapter.

2.1 Physical properties

Fraser *et al.* (1978) determined the physical properties of fababeans at different moisture contents. The angle of repose of fababeans varied from 0.36 rad at 8.5 per cent to 0.41rad at 2.9 per cent. For the moisture range of 50.5 to 21.6 per cent, the static coefficient of friction of fababeans ranged from 0.28 to 0.46 on plywood and from 0.32 to 0.38 on galvanized steel. Bulk density decreased with increase in moisture content. It decreased from 850kg/m³ at 8.5 per cent moisture content (w.b.) to 730kg/m³ at 34.8 per cent moisture content (w.b.). Thousand grain mass was 405g at 8.5 per cent moisture content (w.b.).

2.1.1 Size

Waziri and Mittal (1983) studied the design related physical parameters of selected agricultural products. The roundness and sphericity are important parameters that determined the geometric shape of agricultural products. The major, minor and intermediate diameters of agricultural products may be determined by the over head projection method for small seeds and grains by the vernier calipers/ micrometer screw gauge method for comparatively larger seeds, grains, fruits and vegetables. The thousand kernel weight (TKW) is a good parameter for describing the weight of small seeds like sorghum and millet.

Shepherd and Bhardwaj (1986) studied the moisture dependent physical properties of pigeon pea. A non-linear relationship was observed

between kernel volume and moisture content of pigeon pea. The best defined approximate shape was found to be prolate spheroid with an effective diameter of 4.83mm, mean surface area of 67.4mm², 1000 grain weight of 76g, and sphericity and roundness of about 80 per cent at 14.7 per cent moisture content (d.b). In the moisture range of 6.3 to 28.2 per cent (d.b), the bulk and true densities were found to decrease linearly from 806 to 745kg/m³ and from 1305 to 1251kg/m³, respectively and porosity decreased linearly with bulk density from 40.4 to 38.2 per cent. The angle of repose increased from 0.38 to 0.44rad in the moisture range of 5.8 to 14.7 per cent (db). The static coefficient of friction of pigeon pea against a galvanized steel surface increased from 0.26 to 0.37 in the moisture range of 6.4 to 28.5 per cent (d.b).

Muir and Sinha (1988) studied the physical properties of cereals and oil seeds grown in Western Canada. They reported that emptying angle of repose for sunflower seed was as high as 22 - 34° and 21 - 27° for wheat. An increase in moisture content of cereal grain from 12.9 to 16.4 per cent caused a 27 per cent increase in the coefficient of friction.

Sreenarayanan *et al.*, (1988) conducted experiments for the determination of various engineering properties of C0-1 variety soybean. The hardness and angle of repose at 7.5 per cent (w.b.) moisture content were found to be 8.1 kg and 22.5° respectively, The maximum value of static coefficient of friction was found to be with plywood surface and the minimum value with glass surface and the densities were found to decrease with the increase of moisture content.

Akcali and Guven (1990) determined the physical properties of peanut as per Turkish standards No. 310, (TS-310, 1972). They found that the shell thickness for varieties, such as Anamur, Antalya, Osmaniye and Silifke ranged from 0.75 to 1.06 mm. They also reported

that, the average number of kernels per peanut was 1.7-1.8mm and the critical voids in hulled peanuts were 4.5-5.9 mm.

Oje and Ugbor (1991) studied some physical properties of oil bean seed and found that oil bean seeds had a major diameter ranging from 60 to 70 mm and thickness from 9 to 19 mm. The average density was 1.12 g/cm³. The static coefficient of friction varied from 0.299 on glass to 0.4 against plywood and the angle of repose was 17°.

Oloso and Clarke (1993) reported that the cashew nut was generally kidney shaped and a mean size of 30 mm long, 22 mm wide and 17 mm thick. It corresponded to edible kernel which was covered by reddish brown testa and a shell. The kernel which fitted tightly into the shell had a mean size of about 24 mm long, 16 mm wide and 12 mm thick indicating a fairly uniform shell thickness of about 3 mm.

Kachru *et al.*, (1994) reported that the engineering properties of food grains were of great importance for analysis and behavior of grains during handling, drying, processing, storage and designing of processing machinery.

Baryeh (2001) evaluated the physical properties of bambara groundnuts as a function of grain moisture content varying from 5 per cent to 35 per cent (w.b). In this moisture range, grain length, width, thickness and geometric diameter increased from 10.5 to 14.65 mm, 9.48 to 11.65 mm, 8.50 to 10.9 mm and 9.65 to 12.55 mm, respectively; the grain surface area and volume increased from 304 to 495 mm² and from 425 to 900 mm³, respectively. The sphericity decreased from 0.90 to 0.87; the 1000 seed mass increased from 500.2 to 800.6 g;

Aydin (2003) evaluated several physical properties of almond nut and kernel as functions of moisture content. The average length, width,

thickness, geometric mean diameter, unit mass and volume of nuts were 25.49, 17.03, 13.12, 18.13 mm, 2.64g and 2.61 cm³, respectively. Corresponding values for kernel were 21.19, 14.34, 6.38, 11.42 mm, 0.69g and 0.71 cm³ respectively. The rupture strength of almond nut and kernel decreased with increasing moisture content.

2.1.2 100 seeds and kernels mass

Several scientists have studied the effect of moisture content on the mass of the grains. Some of the findings are presented below.

Fraser *et al.* (1978) found that the thousand grain mass of fababean was 405 g at 8.5 per cent moisture content (w.b.).

Balasubramanian (2001) reported that the 100 nut mass of raw cashew nuts varied from 610.6 to 735.1 g at a moisture content of 8.46 per cent and increased linearly with increase in moisture content.

Kaleemullah and Gunasekar (2002) found that 100 kernel mass of arecanuts were 1.159 and 0.594 kg at moisture content ranging from 88.91 and 10.51 per cent (d.b.), respectively.

Aviara *et al.* (2005) determined the physical properties of *Balanites aegyptiaca* nuts as a function of moisture content. For oblong nuts, in the moisture range of 4.72-26.35 per cent (d.b.), the one thousand nut mass of the oblong nuts increased from 2.39 to 3.33 kg. For spheroidal nuts, in the moisture range of 4.71-24.18 per cent (d.b.), the one thousand nut mass increased from 2.26 to 3.11kg.

2.1.3 True density and bulk density

Fraser *et al.* (1978) found that the bulk density of fababeans decreased with increase in moisture content. It decreased from 850kg/m³

at 8.5 per cent moisture content (w.b.) to 730 kg/m³ at 34.8 per cent moisture content (w.b.).

Shepherd and Bhardwaj (1986) found the bulk and true densities of pigeon pea at the moisture range of 6.3 to 28.2 per cent (d.b.) and observed that they decreased linearly from 806 to 745kg/m³ and from 1305 to 1251 kg/m³, respectively.

Balasubramanian (2001) observed that the bulk density of cashew nuts decreased from 624.2 to 591.9 kg/m³ as the moisture content increased from 3.15 to 20.06 per cent (d.b.). The true density of nuts followed a linear correlation with moisture content. It increased from 1201 to 1240kg/m³ as the moisture content increased from 3.15 to 20.06 per cent (d.b.).

Baryeh (2001) determined the true and bulk densities of Bambara groundnuts and found that they decreased from 1.285 to 1.160 g/cm³ and from 0.795 to 0.696 g/cm³ in the moisture range of 5 to 35 per cent (w.b.).

Aydin (2002) determined the physical properties of hazel nuts and kernels as function of moisture content. In the moisture range from 2.87 to 19.98 per cent (d.b.), for the rewetted nuts the bulk density decreased from 383 to 305 kg/m³, true density from 727 to 674 kg/m³, porosity increased from 47.23 to 48.85 per cent. The rupture strength of nuts and kernels decreased with increasing moisture content.

Aydin (2003) carried out studies on re-wetted almond nuts in the moisture range of 2.77 - 24.97 per cent (d.b.) and showed that the bulk density decreased from 655 to 525 kg/m³, true density increased from 1015 to 1115 kg/m³ and porosity increased from 35.32 to 53.21 per

cent. For the kernels, the corresponding values changed from 595 to 475 kg/m³, 900 to 995 kg/m³, 34.23 per cent to 50.29 per cent, respectively.

Omobuwajo *et al.* (2003) stated that true density and bulk density of calabash nutmeg seeds were 833.2 and 429.4 kg/m³, respectively.

Studies on rewetted peanuts showed that the bulk density decreased from 243 to 184 kg/m³ and the true density increased from 424 to 545 kg/m³, respectively as the moisture content increased from 4.85 per cent to 32.00 per cent (d.b); for the kernel, the corresponding values changed from 581 to 539 kg/m³ and 989 to 1088 kg/m³, respectively as the moisture content increased (Aydin, 2007).

2.1.4 Porosity

Shepherd and Bhardwaj (1986) found that the porosity of pigeon pea decreased linearly with bulk density from 40.4 to 38.2 per cent in the moisture range of 5.8 to 14.7 percent.

Baryeh (2001) studied the porosity and angle of repose of Bambara groundnuts and observed that both the values increased with increase in moisture content upto 4473.8 per cent and 23.5°, respectively, at 20 per cent moisture content.

Pliestic *et al.* (2005) determined various physical properties of filbert nuts and kernels as function of moisture content. In the moisture range from 6.19 to 28.71 per cent (w.b.), studies on the rewetted nuts showed that the porosity of nuts increased from 41.53 percent to 45.24 per cent, while porosity of kernels increased from 36.18 per cent to 39.44 per cent.

2.1.5 Frictional properties

2.1.5.1 Angle of repose

Fraser *et al.* (1978) found that the angle of repose of fababeans varied from 0.36 rad at 8.5 per cent to 0.41 rad at 2.9 per cent moisture content.

Shepherd and Bhardwaj (1986) found that the angle of repose of pigeon pea increased from 0.38 to 0.44 rad in the moisture range of 5.8 to 14.7 per cent (d.b.).

Omobuwajo *et al.* (2003) found that the dynamic angle of repose of Calabash nutmeg on four structural materials ranged from 28.10° to 32.22°.

Ozguven and Vursavus (2005) determined the selected physical properties of pine (*Pinus pinea*) nuts at a moisture content of 5.48 per cent (d.b.). The dynamic angle of repose of the nuts on three structural materials namely plywood, galvanized steel sheet and fiberglass were found to be 26.18°, 23.52° and 15.21°, respectively.

2.1.5.2 Co-efficient of static friction

Fraser *et al.* (1978) found that the static coefficient of friction for fababeans ranged from 0.28 to 0.46 on plywood and from 0.32 to 0.38 on galvanized steel, in the moisture range of 50.5 to 21.6 per cent.

Shepherd and Bhardwaj (1986) observed that the static coefficient of friction of pigeon pea against galvanized steel surface increased from 0.26 to 0.37 in the moisture range of 6.4 to 28.5 per cent (d.b.).

Balasubramanian (2001) observed that the static co-efficient of friction for cashewnuts increased linearly with moisture content

irrespective of surface employed, namely, glass (0.19-0.25), aluminium (0.25-0.30), galvanized iron (0.25-0.30) and cardboard (0.25-0.31).

Baryeh (2001) found that the co-efficient of static friction for Bambara groundnuts increased from 0.39 to 0.66, 0.29 to 0.58 and 0.25 to 0.49 for plywood, galvanized iron and aluminium, respectively.

Aviara *et al.* (2005) determined the physical properties of *Balanites aegyptiaca* nuts as a function of moisture content. For oblong nuts, in the moisture range of 4.72-26.35 per cent (d.b), the static co-efficient of friction on different structural surfaces increased from 0.194 to 0.577.

Ozguven and Vursavus (2005) determined the selected physical properties of pine (*Pinus pinea*) nuts at a moisture content of 5.48 per cent (d.b). The coefficient of static friction was 0.46 on plywood, 0.43 on galvanized steel and 0.35 on fiberglass.

Burubai *et al.* (2007) investigated the frictional properties of African nutmeg (*Monodora myristica*), a wild perennial edible plant, at a moisture content level of 4.93 per cent (d.b). The average values for coefficient of static friction on four test surfaces ranged from 0.502 (for galvanized iron sheet) to 0.702 (for rubber).

2.2. Effect of pre-treatments

Pominski *et al.* (1952) developed a new method for the removal of skin from peanut kernels by water-treatment, drying, and blanching in a standard split-nut blancher developed on a pilot-plant scale. Optimum conditions for approximately 98 per cent skin removal from U.S. No. 1 shelled Spanish peanuts were water-treatment at room temperature, drying with forced circulated air at 48.89°C to 51.67°C, to approximately 4.5 per cent moisture content in the peanuts, and blanching.

Thivavarnvongs (1981) reported that the cashew nut pre-shelling treatment of 30 minutes boiling time and then 24 hours drying, produced an average whole kernel recovery of 82.7 per cent.

Sachan *et al.* (1993) studied preconditioning of seeds before processing to make decortication easier for many pulses, and work was undertaken to study the effect of grain physical characteristics and preconditioning on dehulling efficiency of Australian field peas.

Chattopadhyay (1996) observed that steam roasting was commonly used by most of the cashew processing units. Raw cashew nuts were steam roasted at about 7.03 kg/cm² pressure for 25-30 minutes. The cashew nuts were allowed to cool for 24 hours and then shelled.

Nagaraja and Balasubramaniam (1998) reported that the steam boiling was followed as preliminary conditioning process with steam pressure of 2.11- 10.55kg/cm² and duration of 30-90 minutes. It differed from industry to industry. It was further reported that 7.03 kg/cm² pressure for 30 minutes was generally recommended for recovery of higher percentage of whole cashew kernel recovery.

Anonymous (1999) evaluated three different methods viz., hot oil bath, steam roasting and drum roasting of cashew nuts. All methods produced satisfactory results as indicated by the percent recovery of whole kernels after shelling. Based upon the results of the initial evaluation, the process that would best satisfy the above criteria was drum roasting. Although the steam roasting was the most modern and convenient to use, the equipment cost was too high even if it was fabricated locally. The oil bath method was not convenient to use, as it required accurate measurement of oil temperature and time of roasting to produce the best results. Roasting time of 30 minutes with a capacity

of 10kg per batch would produce the best quality nuts and would match the capacity of mechanized cashew nut sheller.

Chadha (2001) mentioned that steam-boiling method was adopted in Indian factories where hand and leg operated shelling machines were employed. After conditioning, the cashew nuts were given mild roasting for 20 to 25 minutes at 7.03-8.43 kg/cm² pressure to loosen kernel from shell in order to make its removal easy.

Dandekar and Salvi (2003) found the treatment 1.406 kg/cm² pressure for 15 min exposure of the Cashewnuts in an autoclave was better for higher recovery up to 83 per cent. The treatment was accepted for its best sensory evaluation and drying behavior.

Oluwole *et al.* (2007) conducted a study to determine the effect of moisture content on shelling efficiency of Bambara groundnuts using a centrifugal cracker. The cracker was evaluated at three different moisture contents of 5.3, 9.6, and 12.2 per cent (d.b). Results showed that both moisture contents and impeller angulations had a significant effect on the performance indices. The most effective performance was obtained at moisture content of 5.3 per cent (d.b), at which the shelling efficiency, percentage of damaged seeds, percentage of partially shelled pods and percentage of unshelled pods were 96, 3.4, 0.6 and 0 per cent respectively.

2.3 Type of cylinder, cylinder speed and feed rate

Channaveeraswami *et al.* (1986) conducted studies to determine the effect of seed moisture content, cylinder speed and retardable gate opening on seed breakage during maize shelling. Minimum seed breakage was found at 16.47 per cent seed moisture content, 15.30 m/s cylinder speed and 22.5 mm retardable gate opening.

Okokon *et al.* (2007) analysed the impact forces on melon seeds during shelling. Melon seeds are shelled in a rotating impeller type machine to obtain the cotyledons. The analysis showed that the factors affecting the impact force were impeller speed, seed cross-sectional area at impact and mass ratio. The mean forces to break melon seeds were 13.14×10^{-3} , 19.62×10^{-3} and 19.55×10^{-3} N for orientations breadth wise, lengthwise with tip up and lengthwise with tip down, respectively.

2.4 Evaluation of decorticator or sheller

Sharp (1957) reported that an all purpose hand operated decorticator was developed in 1957 under the Indian University of Technical Assistance Programme, which consisted of vertically mounted discs faced with 0.94 cm sheet rubber. The roasting disc had curved radial feed grooves cut into the rubber facing. Feeding was effected at the center above the discs through the hopper and handle. The unit decorticated 34 kg of castor seeds or 23 kg of mahua seeds in an hour.

Singh and Shrivastava (1978) designed and fabricated different components of groundnut decorticator. The various parameters such as blower speed, airflow rate, eccentric speed, cylinder speed and feed rate were studied during the experiments. The highest decorticating efficiency (98 per cent) was obtained at cylinder speed of 100 rpm, feed rate of 150 kg/h at 15 per cent moisture content with a clearance of 1.5 cm.

Kittachi (1984) developed a power-operated groundnut sheller at AIT, Bangkok. The sheller cylinder consisted of 12 sets of 10 x 20 cm rubber tire shoes which were 30 degrees apart. The diameter and width of shelling bar were 54 cm and 22 cm, respectively. For the optimum performance of shelling, the blower settings were blower shaft speed of 1000 rpm and 30 degree blower chute angle. The best performance of the sheller was achieved at 20 mm clearance and shelling bar speed of 180

rpm. At these settings, capacity, shelling efficiency and percentage breakage were 210.5 kg kernels/h, 98 percent and 5.3 percent respectively. The power consumption of the sheller was about 1.0 to 1.1 kW.

Singh *et al.*, (1985) developed and tested a ground nut decorticator to recommend the values of selected operational variables. The decorticating efficiency was very high (99.6 per cent), at 180 kg/h feed rate, 200 rpm (197.4 m/min peripheral speed) of cylinder and 16 mm cylinder concave clearance. The breakage was 12.67 per cent. The maximum cleaning efficiency of 80 per cent was achieved at 300 rpm (292.0 m/min peripheral speed) of cylinder and 14 mm cylinder concave clearance with 150 kg/h feed rate.

Gore *et al.* (1990) suggested that the best performance of the power operated groundnut sheller was achieved at 180 rpm cylinder speed and 18 mm concave clearance, with a feed rate of 400 kg/h of pods at 13 per cent m.c. (w.b). The shelling capacity, shelling efficiency and breakage were 280 kg/h, 98.05 and 4.53 per cent, respectively.

A foot operated groundnut sheller was developed by Hindsons Private Ltd., Punjab. It was fitted with a flywheel for easier operation and a blower to separate shells from kernels. It was operated by one person and had a capacity of 25 kg/h (Singh and Shukla, 1991).

2.5 Soybean dehulling

Ren and Hou (1992) examined the physical properties relating to the hulling of soybeans, e.g., compression and shear tests of the soyabean, tensile and relaxation tests of the soybean seed coat, and analysis of movement and dynamics of the soybean between 2 rollers.

CIAE (Central Institute of Agricultural Engineering), Bhopal developed manually operated soybean dehuller consisting of two concentric cylinders, on driving mechanism, and a blower or a fan to remove the hulls from split kernels (dal). A perforated deflector was provided in front of the fan to separate the brokens. The overall length, width and height were 1700 mm, 620 mm and 1330 mm respectively. Diameter and length were 286 mm and 860 mm for inner cylinder and 300 mm and 910 mm for outer cylinder respectively. The speed of rotation of the inner cylinder was 100-150 rpm. The capacity was 31-35 kg/h with dehulling per cent of 98(Singh and Shukla, 1991).

Mbuvi and Litchfield (1994) investigated two green pea shellers for their effectiveness in shelling of green soybeans. The two shellers are a rubber roller-type (Taylor) and a rotary drum-beater type (Sinclair-Scott). Shelling efficiency using the Taylor sheller was 95 per cent and seed damage was 3 per cent. Use of the Sinclair-Scott sheller resulted in 77 per cent shelling efficiency and 7 per cent seed damage.

2.6 Cocoa and Castor dehulling

Adenosun (1993) described a medium scale cocoa dehulling and winnowing machine. The machine was rugged and easy to operate and maintain. The only adjustment required on the machine was, the roller clearance. The quantity of cocoa nibs dehulled increased rapidly as the roller clearance decreased from 14 to 8 mm. The dehulling efficiency of the machine was 98.36 per cent and the winnowing efficiency was approximately 45.5 per cent.

Sharp (1957) reported that an all purpose hand operated decorticator was developed in 1957, which had vertically mounted discs faced with 0.94 cm sheet rubber. The roasting disc had curved radial feed grooves cut into the rubber facing. Feeding was effected at the

center above the discs through the hopper and handle. The unit decorticated 34 kg of castor seeds or 23 kg of mahua seeds in an hour.

Duraisamy and Manian (1990) developed and evaluated a hand/power operated castor bean sheller. It consisted of a feeding hopper a screw auger, shelling discs, flywheel and blower. The unit was operated by a 0.5 hp electric motor with blower. The output and shelling efficiency of power/hand operated castor bean sheller was 163.00 and 52.65 kg, 97.29 per cent and 98.72 per cent with a kernel breakage of 0.82 per cent and 0.88 per cent, respectively.

Castor could be decorticated with slight modification in existing TNAU (Tamil Nadu Agricultural University) groundnut decorticators. With power operated decorticator with sieves containing 20x6 mm slots perpendicular to the direction of oscillation, the shelling capacity was 230 kg pods/h with a shelling efficiency of 97.65 per cent and breakage of 2.27 per cent kernels. The equipment had 99.17 per cent cleaning efficiency (Singh and Shukla, 1991).

In case of hand operated decorticator, fitted with sieves of 20 x 6 mm perpendicular slots, a shelling capacity of 76 kg pods/h, shelling efficiency of 95.5 per cent and breakage of 1.26 per cent kernels was obtained while the shelling rate by conventional method of rubbing was only 11.7 kg pod/h with 97 per cent shelling efficiency. (Singh and Shukla, 1991).

2.7 Sunflower seed shelling

Pierce (1970) has discussed the sunflower processing techniques and made comparisons with the processing of other oil seeds. Sunflower seeds are nearly 30 percent hulls and these hulls are high in crude fiber content. For this reason dehulling and hull separation practices are important aspects in processing of sunflower.

Galloway (1976) described techniques and equipment for cleaning, craking, dehulling, decorticating and flaking of oil-bearing materials. Particular methods and calculations for unusual materials were discussed.

Hussian *et al.*, (1980) designed and developed a manually operated castor bean – cum sunflower seed dehuller. The device consisted of a hopper, rotary drum feeder and 2 horizontal discs faced with 1/4 inch thick rubber, one of which rotated when manually driven; the clearance between the discs was adjustable. The optimum speed for the rotating disc was found to be 120-150 rev/min, the capacity was 1 lb/min for sunflower seed, 1 lb for castor bean at 20 per cent moisture content 70 and 60 per cent of the seed being hulled respectively from samples containing 20-35 per cent immature seed.

Nag *et al.*, (1983) developed a centrifugal impeller-type of decorticating machine for sunflower seeds. The decortication was done by subjecting the seeds to a high centrifugal force and then striking them on a hard surface. The performance of the machine was evaluated at different moisture contents of seeds and feed rates, and peripheral speeds of the impeller.

Luan and Liang (1983) developed macadamia nut husker which gave improved husking efficiency (96 per cent) and reduced the number of damaged nuts to 0.2 per cent or less in weight. Energy consumption of the machine was also lower. Separation of husks and nuts was satisfactory. Performance was affected little by nut variety, nut size, and husk moisture content. A capacity of 340 kg/h of nuts in shell was obtained from this husker.

Tranchino *et al.*, (1984) dehulled the high oil sunflower seeds with an air jet impact huller. The effectiveness of dehulling was evaluated as a

function of characteristics of the seed (variety, moisture etc.) and of operative parameters like impact velocity, etc. The use of proper seed momentum, which was a function of the characteristic of the seed could allow selective hull breaking with minimum kernel breakage. Almost complete hull-free kernels from high oil sunflower seeds were obtained by means of a continuous dehuller-separator pilot plant.

Kachru *et al.*, (1986) described the details of various sunflower seed shellers developed throughout the country. It included disc huller developed at OTRI, Anantpur, hand operated sunflower decorticator developed at CIAE, Bhopal and power operated sheller for sunflower developed at TNAU, Coimbatore.

Ishitani (1987) dehulled the non-oil sunflower seeds with an impact type rice huller. The flow of hulls and kernels was disrupted at the outlet of the separating device because of the smaller angle of inclination of the flowing pans. All other parts worked well with sunflower seeds. The total power requirement was about 2.2 kW. For an impeller shaft speed of 1700 rev/min (peripheral velocity of about 45 m/s), the dehulling efficiency was 200 kg/h with a shutter opening of 1/2 and 700 kg/h with a shutter opening of 5/6. Peripheral impeller fan velocity of about 40m/s and single impact of the sunflower seeds with 12 per cent moisture content (w.b.) gives about 80 per cent undamaged kernels, 2 per cent crushed, 8 per cent damaged and the remainder were unhulled.

CIAE, Bhopal had modified the hand operated bar and disc mill developed at Tropical Product Institute, U. K. The modification made was the change of oscillator with a rubber lined shoe and sieve. The modified decorticator had an output of 12 kg/ h with 49 per cent head yield, 22 percent hull, 6 percent broken and 23 percent undecorticated seed.

Based on the design concept of a hand operated sunflower seed decorticator developed at TPI, U.K., a power operated multi oil seed decorticator was developed at CIAE, Bhopal. The equipment consisted mainly of a high speed fluted rotor, stator, hopper, blower and sieve assembly. Rotor made of mild steel was 200 mm long and 100 mm in diameter. Stator was also made of mild steel with 200 mm long and half breadth diameter of 45 mm. Fluted rollers were provided in hopper for uniform feeding of the seed. An arrangement was made for separation of hulls, kernels, and undecorticated seeds. Decortication took place due to abrasive and shearing action between stator and rotor.

The disc huller developed at OTRI, Anantpur is made of emery discs, one of the discs was static and the other rotates at a speed of 600 rpm by a 15 HP electric motor. The clearance between the discs could be varied. A shaker separator was with the machine to get a continuous performance. The capacity of the machine was 8 t-seed/d. The cost of the machine was about Rs. 60000 (Singh and Shukla, 1991).

TNAU, Coimbatore had developed a power operated sheller for sunflower which was of centrifugal type, consisting of a high speed rotor, rubber lined stator, blower, elevator and sieves. Shelling was done by impact. The equipment was operated by a 3 HP electric motor and its capacity was 1.25 q/h (Singh and Shukla, 1991).

2.8 Cost

Tastra (2009) studied three types of local maize shellers at three levels of grain moisture contents and cylinder speeds. The results indicated that the optimum moisture content of maize for shelling, using sheller types SLM, KWT and TMO, was 32.5%, 35.0% and 35.0% w.b, respectively. The minimum total costs of shelling and drying were ₹

.3,573/t, ₹.3,176/t and ₹.3,315/t while the optimum grain mechanical damage was 18.4%, 17.8% and 21.1%.

Hussain *et al.* (2009) reported that the horizontal maize cob sheller, very usefull to the farmers of hilly region, was evaluated for three varities, namely, local collection Kashmir, North Dakota Pop-1 and composite Almora to study the different parameters like shelling capacity (kg/h), labour requirement (manhours), shelling efficiency (%), grain recovery (%) and grain damage (%). The results were compared with traditional methods of maize cob shelling (beating by sticks and hand rubbing). When the shelling capacity and labour requirement were compared, the horizontal maize cob sheller was significantly superior over both traditional methods. Regarding shelling efficiency, the difference between mechanical maize cob shelling and shelling by hand rubbing was found to be non-significant.



Material and Methods

III. MATERIAL AND METHODS

This chapter describes the procedures employed for determination of the properties of sunflower seed, and constructional details of the sunflower seed decorticator. The pretreatments employed to improve decortication efficiency are described. A power operated decorticator was fabricated in the Department of Agricultural Engineering work shop, University of Agricultural Sciences, GKVK, Bangalore during the years 2012 - 2013.

3.1. Principle of decortication

The decortication is accomplished by the shearing action of the rotating cylinder drum on the concave. A dimple sheet covers the surface of the cylinder which helps to increase the shearing of the husk from the sunflower seeds. The concave consists of perforated M.S. sheet with hole diameter of 4.5 mm. A blower separates the husk.

3.2 Raw material

Fully matured, good quality sunflower seeds (Variety: KBSH-44) which are suitable for confectionary products were procured from AICRP on Sunflower, UAS, GKVK, Bangalore for conducting the studies. Well dried raw sunflower seeds were stored in plastic bags to avoid the possible moisture migration into the seeds and also to prevent insect attack. The seeds were graded manually to get uniform sized seeds of 5mm, 4.5mm thickness using the sieves of respective sizes (Plate 3.1).

3.3 Physical and mechanical properties

3.3.1 Size

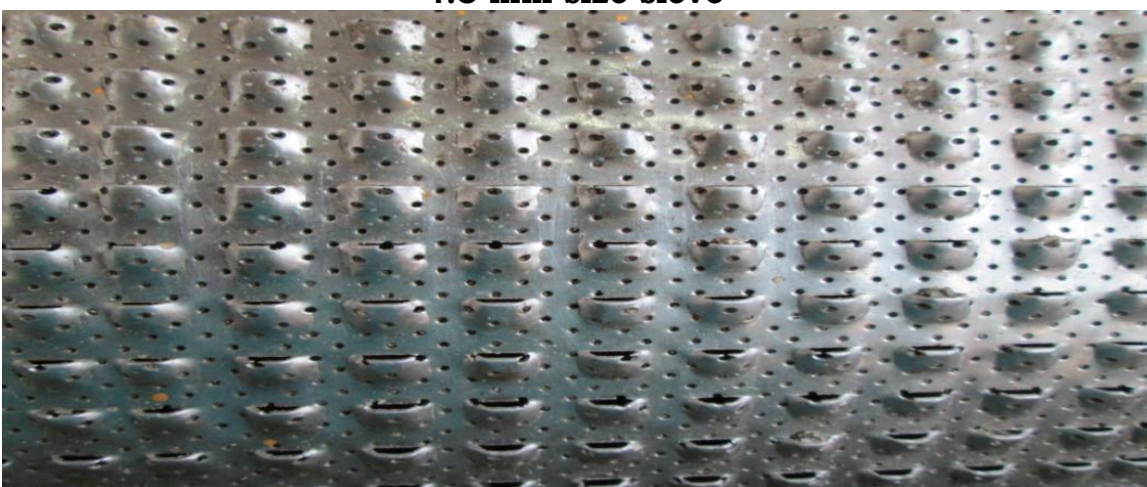
To determine the average size of the seeds, a sample of 100 seeds was randomly picked and their three major dimensions namely, length



4 mm size sieve



4.5 mm size sieve



Dimple sheet

Plate 3.1: Perforated M.S. sheet and dimple sheet used for concave and cylinder of sunflower seed decorticator

(*l*), width (*b*) and thickness (*t*) were measured using a digital vernier calipers (Model CD-6BS-Mitutoyo Corporation, Japan) with an accuracy of ±0.01 mm.

The geometric mean diameter (*D*) was determined using the following equation (Mohsenin, 1970):

$$D = (lbt)^{\frac{1}{3}} \quad \dots\dots\dots 3.1$$

- l = length (mm),
- b = width (mm),
- t = thickness (mm).

3.3.2 Shape

The shape of the sunflower seeds was determined through visual observation and by comparing with standard shapes. The procedure for recording the shapes of the seeds is given by Kachru, *et al* (1994).

3.3.3 100 seeds mass

The mass of 100 seeds was measured using an electronic balance (Model PS200/2000/C/2- RADWAG, Poland) with an accuracy of ± 0.001 g.

3.3.4 True density

The true density of sunflower seeds was measured using toluene displacement method. 50 ml of toluene was taken in a 100 ml measuring jar and weighed, the sample seeds were poured into the jar. The change in the level of toluene in the jar was recorded. The true densities of the samples were calculated using the formula (Mohsenin, 1970).

$$\text{True density (kg/m}^3\text{)} = \frac{\text{Weight of seeds (kg)}}{\text{Volume of seeds (m}^3\text{)}} \quad \dots\dots\dots 3.2$$

$$\text{Volume of seeds} = \left\{ \begin{array}{l} \text{Final toluene level} \\ \text{in measuring jar} \end{array} \right\} - \left\{ \begin{array}{l} \text{Initial toluene level} \\ \text{in measuring jar} \end{array} \right\} \dots\dots\dots 3.3$$

3.3.5 Bulk density

The bulk density was determined as per the method described by Mohsenin (1970). The seeds were filled into a container of standard size 10×10×10 cm upto the top level. The excess seeds were removed so that the top surface was perfectly level and even. Then the seeds in the container were weighed by using an electronic balance. The bulk density was calculated using the following formula:

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{Weight of seeds (kg)}}{\text{Volume of seeds (m}^3\text{)}} \dots\dots\dots 3.4$$

3.3.6 Porosity

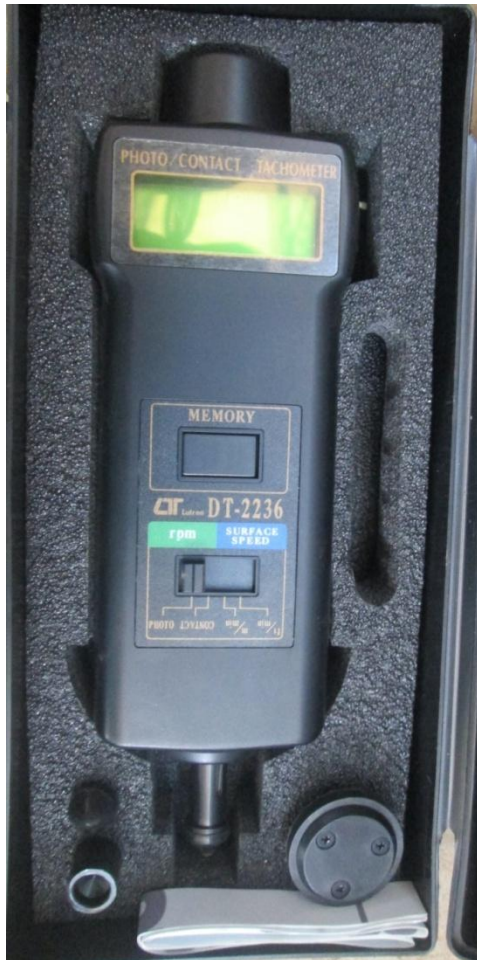
The porosity is also known as the packing factor and it was determined from bulk density and true density of grains and expressed by the following expression (Mohsenin, 1970)

$$\text{Porosity (\%)} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100 \dots\dots\dots 3.5$$

3.3.7 Frictional properties

3.3.7.1 Angle of repose

The angle of repose indicates the cohesion among the individual units of a material. Higher the cohesion, higher is the angle of repose. The dynamic angle of repose of sunflower seeds was measured by the emptying method. For the emptying method, a bottomless cylinder was used. The cylinder was placed over a plain surface and sunflower seeds were filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope. The dynamic angle of repose was calculated from the height and diameter of the pile as:



Tachometer



Anemometer

Plate 3.2. Instruments used to check speed and blower velocity of decorticator



Sun flower seeds



Dehusked whole seeds



Husk



Broken seeds

Plate 3.3 Portions of sun dried sunflower seeds after decortication



Sunflower seeds



Dehusked whole seeds



Husk



Broken seeds

Plate 3.4 Portion of hot water soaked sunflower seeds after decortication

$$\theta = \tan^{-1} \frac{2h}{D} \quad \dots\dots\dots 3.6$$

Where, θ = Angle of repose ($^{\circ}$),

h = Height of the pile (cm) and

D = Diameter of the pile (cm).

3.3.7.2 Co-efficient of static friction

The coefficient of static friction (μ_s) was measured on different material surfaces such as plywood, galvanized iron sheet, and glass. The seeds were placed on the surfaces and raised gradually at one end by screw until the seeds began to slide. The angle that the inclined surface made with the horizontal when the sliding of the seeds began was measured. The coefficient of static friction was calculated by using:

$$\mu_s = \tan \theta \quad \dots\dots\dots 3.7$$

Where,

μ_s = Co-efficient of static friction

θ = Angle of inclination of material surface

3.4 Moisture content

The moisture content of the seeds was determined using ASAE Standard (ASAE, 1993). The seeds were dried in an air ventilated oven at 90°C for 48 h, then the moisture content (wet basis) was calculated as:

$$\text{Moisture content, \% (w.b.)} = \frac{\left(\text{Initial weight of seed / kernel} \right) - \left(\text{Final weight of seed / kernel} \right)}{\text{Initial weight of seed / kernel}} \times 100 \quad \dots\dots\dots 3.8$$

3.4.1 Pretreatments of sunflower seeds

Pre-treatments such as sun drying and hot water soaking were given to soften the husk and to increase the efficiency of decortication.

3.4.2 Sun drying

In order to determine the proper moisture level for better decortication, four different moisture levels were studied.

In sun drying process, the sunflower seeds (Plate 3.3) were dried for about 30 min to moisture levels of 10 and 12. To obtain seeds of 14 and 16 percent moisture content, the seeds were rehydrated and then dried to the required moisture level. These seeds were packed immediately to avoid the absorption of moisture from the atmosphere.

3.4.3 Hot water soaking

In this treatment, sunflower seeds were soaked in hot water for 6 hours at 74°C temperature and later the seeds were dried under sun for 24 hours. These seeds were used for decortication, by the developed decorticator (Plate 3.4).

3.4.4 Treatment details

The performance of the decorticator was tested for sun dried and hot water soaked sunflower seeds. The tests were carried out at 10,12, 14 and 16 per cent (w.b.) moisture content at two cylinder speeds (75 rpm / 1.38 m/s and 90 rpm / 1.65 m/s).

3.5 Development of decorticator

The power operated decorticator was developed and fabricated (Plate 3.6) in the workshop of Department of Agricultural Engineering, University of Agricultural Sciences, GKVK, Bangalore.

The traditional method of decortication of sunflower seeds was studied. One labourer was able remove the husk of sunflower seeds of 350-400 g/h. This method was very time and labour consuming, resulting in little interest for the farmers and processors to process



Plate 3.5 Fabrication of frame

sunflower seeds for oil extraction and seed purpose. The following factors were considered while developing the decorticator for sunflower seeds.

Attempts was made to develop a power operated decorticator with the following objectives

1. Suitability of machine for decortication of sunflower seeds
2. Ease of operation and maintenance
3. Low cost of operation and high energy efficiency
4. Minimum damage to kernels

The various physical properties of sunflowers seeds, affecting the design, like physical dimensions, angle of repose and co-efficient of friction were measured.

3.5.1 Materials for fabrication

The materials used for the fabrication of the decorticator, the quantity and cost of materials used are presented in Appendix I.

3.5.2 Instrumentation

a) Tachometer: A tachometer was used to measure the speed of the cylinder and blower in rpm. The range of the instrument was 10-10000 rpm.

b) Vernier calipers: A digital vernier calipers was used to measure the physical dimensions of the sunflower seeds viz., length, width and thickness, as well as diameter of rotor shaft, drum shaft, thickness of M.S. sheet, flat, M.S. angle, etc. It had the least count of 0.01mm.

c) Measuring tape and scale: A measuring tape and a metal scale were used for measuring length of flats, angles, shaft, pulley, belt, etc.,

d) Anemometer: A digital anemometer was used to measure the velocity of air blown by the blower.

3.5.3 Design details

The schematic diagram of the developed machine is shown in Fig 3.1. The important machine parts are described below:

3.5.3.1 Rotor shaft

The shaft is the central part on which the cylinder is mounted on two bearings (7 cm). The shaft is made of high carbon steel of grade 40C8 which has ultimate strength of 320 MPa and tensile strength of 560-670 MPa. The length of the cylinder shaft is 80cm and diameter is 20mm. A pulley is mounted on one end of the shaft which is connected to the motor pulley by a v-belt.

3.5.3.2 Shaft design

The shaft is subjected to torque force and the diameter of the shaft was determined by using the equation.

$$\frac{\pi}{16} \times F_s \times d^3 = T \quad \text{.....3.9}$$

Where, F_s = maximum allowable stress for high carbon steel (MPa)

Taking, yield stress = 320MPa (Lingaiah, 1989)

F_s = 160 MPa

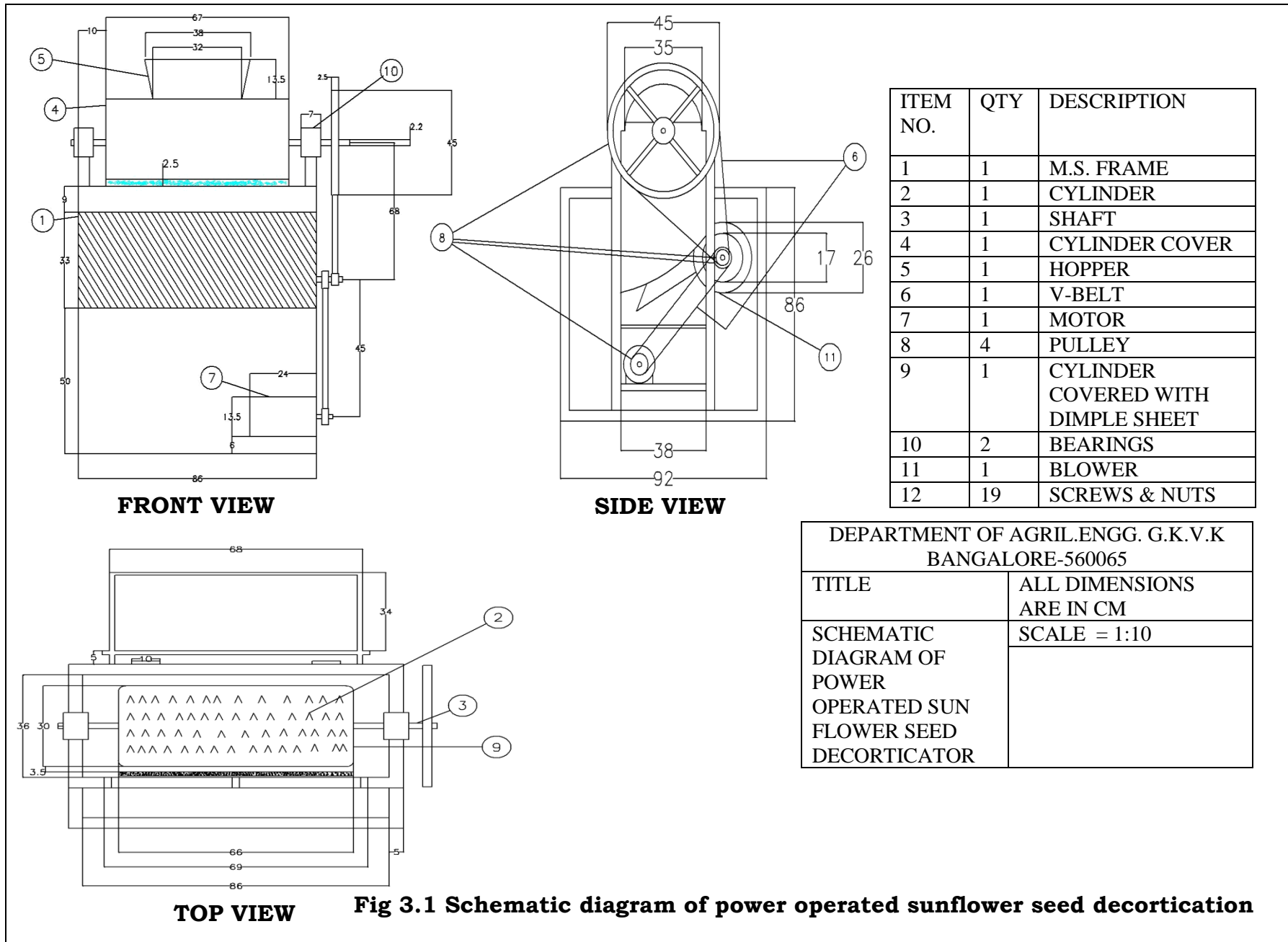
d = diameter of shaft required (cm)

T = torque developed on the shaft (kg-cm)

3.5.3.3 Power requirement

The horsepower was calculated by using the formula:

$$hp = \frac{2\pi NT}{4500} \quad \text{.....3.10}$$



ITEM NO.	QTY	DESCRIPTION
1	1	M.S. FRAME
2	1	CYLINDER
3	1	SHAFT
4	1	CYLINDER COVER
5	1	HOPPER
6	1	V-BELT
7	1	MOTOR
8	4	PULLEY
9	1	CYLINDER COVERED WITH DIMPLE SHEET
10	2	BEARINGS
11	1	BLOWER
12	19	SCREWS & NUTS

DEPARTMENT OF AGRIL.ENGG. G.K.V.K BANGALORE-560065	
TITLE	ALL DIMENSIONS ARE IN CM
SCHEMATIC DIAGRAM OF POWER OPERATED SUN FLOWER SEED DECORTICATOR	SCALE = 1:10

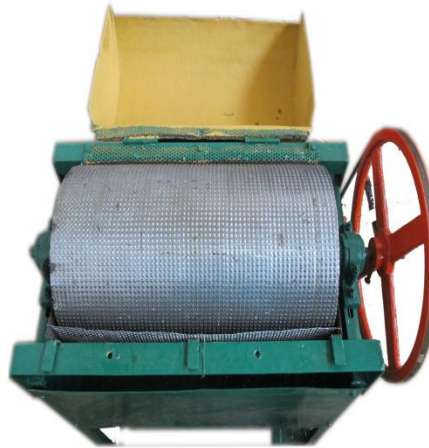
Fig 3.1 Schematic diagram of power operated sunflower seed decortication



Front view



Side view



Top view

Plate 3.6 View of power operated sunflower seed decorticator

Where, $N = \text{speed (rpm)} = 75 \text{ rpm}$
 $T = \text{torque (kg m)} = 9.6 \text{ kgm}$
 $\text{hp} = 1.00\text{hp}$
Hence, 1 hp motor was used.

3.5.3.3 Pulleys

The diameter of pulley shaft was obtained from the velocity relationship, (Murgesan and Tajuddin, 1997).

As the motor speed was 1400 rpm and the required speed of the cylinder was 75 rpm, an intermediate shaft (blower shaft) was used and the required speed reduction was obtained.

The diameter of the pulleys was determined by the relationship

$$N_1 D_1 = N_2 D_2 \quad \dots\dots\dots 3.11$$

Where, $N_1 = \text{speed of blower pulley} = 780 \text{ rpm}$

$N_2 = \text{speed of drum shaft} = 75 \text{ rpm}$

$D_1 = \text{diameter of blower pulley} = 4.44\text{cm}$

$D_2 = \text{diameter of cylinder pulley, (cm)}$

Therefore, from equation 3.11

$$D_2 = 45\text{cm}$$

3.5.3.4 Length of belt

The length of the belt was obtained by using the formula (Gopalkrishna, 2002).

$$L = \frac{2C + \frac{\pi}{2}(d_1 + d_2) + (d_1 + d_2)^2}{4C} \quad \dots\dots\dots 3.11$$

Where, $C = \text{distance between the centers (cm)}$

$d_1 = \text{diameter of large size pulley (cm)}$

$d_2 = \text{diameter of small size pulley (cm)}$

Therefore, length of belt $L = 68 \text{ cm}$

3.5.3.5 Horsepower required

The calculated horsepower of the machine was 1.00 hp; the motor efficiency and belt efficiency of the machine were calculated as 70% and 75%, respectively. The recommended horsepower of machine was calculated by using the formula

$$\text{Required hp} = \frac{\text{Actual power required (hp)}}{\text{Motor (efficiency)} \times \text{belt (efficiency)}} \quad \dots\dots\dots 3.12$$

The horsepower of machine was 1.0 hp.

Hence, an electric motor of 1.0 hp was selected.

3.6 Constructional features

3.6.1 Frame

The M.S frame of the machine was fabricated in a trapezoidal shape to provide strength and firmness to the machine. The frame was made of M.S. angle iron section 88×46× 88 cm. The size of top portion of frame was 67× (height 20) × 34 cm, bottom portion of frame was 35 cm and height was 22 cm. The frame was well braced to mount and support other parts of the machine and also withstand the vibrations during operation.

3.6.2 Hopper

The hopper (Plate 3.6) was fabricated, using mild steel sheet of 18 gauge thickness. The base size was 32 cm, and the top was of size 38 cm, with a height of 13.5 cm. The hopper was used for feeding the seeds manually.

3.6.3 Cylinder

The cylinder is made up of M.S. sheet with perforations (2065 projections/ m², 4mm dia) which is commercially known as dimple sheet. The dimple sheet was bent into a cylindrical shape (dia 35 cm) having a

length of 65 cm. The sheet was supported inside by M. S. plates for support and strength. Linear speed of the cylinder was determined using the formula

$$LS \text{ (m/min)} = \pi \times D \times N \quad \dots\dots\dots 3.13$$

Where, D =Diameter of the cylinder

N =Number of rotations (p/m)

3.6.4 Perforated concave

The concave was made of the perforated M.S. sheet. It had 4mm holes. The diameter of the holes were increased to 4.5 mm by drilling. The whole size of 4.5 mm was found suitable for the passage of decorticated seeds. The concave was strengthened by M.S. frame. A concave clearance of 0.5 cm was maintained between the cylinder and concave.

3.6.5 Cylinder cover

The cover is made of 18 gauge M.S. sheet and was bent to a semicircular shape (Plate 3.6) of diameter 34 cm and is rigidly fixed to give protection to the cylinder and avoid the spilling of seeds and has a provision for attaching to the hopper.

3.6.6 Blower

It is made of 18 gauge sheet M.S sheet of length 104 cm and diameter of 28cm having a shaft of 20 mm diameter and 3 blades are welded to that shaft. The blades are of 60cm length and width of 8 cm.

3.6.7 Outlet

The outlet is provided at the opposite end of the hopper and below the concave. The outlet is wide open in order to have a free fall of the kernels and husk.

3.7 Operation of decorticator

The developed decorticator was tested as per standard procedures for combination of various treatments as described earlier. Before starting operation, belt tension, and direction of rotation of pulley were checked. The clearance between cylinder and the concave were measured using a vernier calipers. The cylinder speed was recorded using a tachometer.

The cylinder speed was set at the required rpm. The sunflower seeds were fed manually through the hopper (Plate 3.7).

The rotating cylinder forces like impact and shearing caused the outer layer of the seeds to be (husk) removed. The kernels and the husk started to fall down through the concave opening which was collected in a tray at the bottom. The husk and the broken seeds separated in the main outlet and did not require to be separated later. Two laborers were required for these operations, one for feeding the seeds at hopper and the other for collecting the de-husked materials at the outlet. weight of kernels, broken kernels and husk (Plate 3.3) were measured (separately), and time of operation was noticed.

The procedure was repeated for all the treatments and data was recorded. The following parameters were recorded during testing:

- 1) Speed of cylinder (rpm)
- 2) Weight of seeds fed through the hopper (kg)
- 3) Weight of kernels after decortication (kg)
- 4) Weight of broken kernels (kg)
- 5) Weight of un-decorticated seeds (kg)
- 6) Weight of husk (kg)
- 7) Time of operation (h)
- 8) Clearance between cylinder and concave.

9) Moisture content of whole seeds

The following parameters were then computed:

$$\text{Decorticator capacity (kg/h)} = \frac{\text{Weight of seeds decorticated (kg)}}{\text{Time taken(h)}} \dots\dots\dots 3.14$$

$$\text{Unhusked seeds (\% by weight)} = \frac{\text{Weight of unhusked seeds (kg)}}{\text{Weight of total seeds fed (kg)}} \times 100 \dots\dots\dots 3.15$$

$$\text{Decortication efficiency (\%)} = \frac{\text{Weight of seeds decorticated (kg)}}{\text{Total weight of seeds fed (kg)}} \times 100 \dots\dots\dots 3.16$$

$$\text{Kernal damage by mass (\% by weight)} = \frac{\text{Weight of broken kernals (kg)}}{\text{Weight of total seeds(h)}} \times 100 \dots\dots\dots 3.17$$

3.8 Statistical analysis

The results of the machine performance for different treatments of decortication were analysed using Fisher's Factorial Completely Randomized Design to determine the significant differences among the treatments. Levels of significance was used in F-test at (P=0.05) for the statistical conclusion.

3.9 Cost economics

The economics of sunflower seed decorticator was determined taking into account the fixed (capital, depreciation, etc) and variable costs (energy consumed, labour, raw materials, etc.). Cost of operation for decorticating seeds per hour and per kilogram was calculated.



Plate 3.7 Power operated sunflower seed decorticator in operation



Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the present study entitled “Development of power operated Decorticator for Confectionary sunflower seeds (*Helianthus anus* L.)” conducted in the Department of Agricultural Engineering, University of Agricultural Sciences, Bangalore are presented under the following headings:

4.1 Physical and mechanical properties of sunflower seeds

4.2 Frictional properties of sunflower seeds

4.3 Evaluation of developed decorticator

4.1 Physical and mechanical properties of sunflower seeds

4.1.1 Size

The size of sunflower seeds at 10 to 12 per cent moisture content (w.b) were lower than the size of seeds at 14 to 16 per cent moisture content (w.b) (Table 4.1). The average dimensions of seeds at moisture contents between 10 and 16 percent viz., length, width and thickness varied from 12.54 to 13.19, 5.75 to 6.40, 3.88 to 5.91 mm, respectively.

4.1.2 Shape

By visual observation and standard chart of shapes, the seed shapes were recorded. The shapes of seeds were identical and were oblong shaped (Mohsenin 1986).

4.1.3 100 seeds mass

The mass of 100 seeds at different percentages of moisture content are presented in Table 4.1. The mass of 100 seeds at 10, 12, 14 and 16 percent moisture content were found to be 6.08, 6.28, 6.36, and 6.38 g respectively.

Table 4.1 Physical dimensions of sunflower seeds

Dimension	Moisture content, % (w.b.)				S.Ed. ±	F- test	CD (0.01)
	10	12	14	16			
Length, mm	12.54	12.71	12.91	13.19	0.0365	100.45**	0.1225
Width, mm	05.57	05.75	05.93	06.40	0.0337	228.42**	0.1130
Thickness, mm	03.88	04.02	04.36	05.19	0.0516	257.35**	0.1733
100 seeds mass, g	06.08	06.28	06.36	06.38	0.0564	11.99**	0.1892

**Significant at 1% level

4.1.4 True density

The true density of seeds at 10 per cent moisture content (769.2 kg/m³) was found to be lower than the true density of seeds at 12 per cent moisture content (772.3 kg/m³) and the true density at 14 per cent moisture content was found to be 806.5 kg/m³. The experimental data is shown in Table 4.2.

4.1.5 Bulk density

The bulk density of seeds significantly varied with moisture content. The bulk density of seeds at 10, 12 and 14 per cent moisture contents were found to be 435 kg/m³, 434 kg/m³ and 432 kg/m³ respectively (Table 4.2).

4.1.6 Porosity

The porosity of seeds at different moisture contents are presented in Table 4.2. The porosity of seeds at 10 per cent moisture content was found to be 43.5 %, whereas porosity values at 12 and 14 per cent moisture contents were found to be 41.0 and 38.7 per cent, respectively.

4.2 Frictional properties

4.2.1 Angle of repose

The angle of repose of seeds at 10, 12 and 14 per cent moisture content are presented in Table 4.3. The angle of repose of seeds at 10 per cent moisture content was found to be 23.9° and the values at 12 and 14 per cent moisture contents were found to be 25.50° and 26.80°, respectively.

4.2.2 Co-efficient of static friction

The co-efficient of friction on different surfaces of materials like wood (ply-wood), galvanized iron sheet, and glass were measured using

Table 4.2 Physical properties of sunflower seeds

Trials	Moisture Content (% w.b.)	Volume (ml)	True Density (kg/m³)	Bulk Density (kg/m³)	Porosity (%)
T1	10.0	65	769.2	435	43.5
T2	12.0	68	772.3	434	41.0
T3	14.0	69	806.5	432	38.7
	S.Ed.	3.6124	28.2830	16.6508	1.5773
	CD (0.05)	9.33	6.92	40.74	3.85

Table 4.3. Frictional properties of sunflower seeds

Trials	Moisture Content, % (w.b.)	Coefficient of static Friction (degrees)			Angle of Repose (degrees)
		Plywood	G.I. Sheet	Glass Sheet	Filling
T1	10.0	22	19	16	23.9
T2	12.0	20	19	15	25.5
T3	14.0	22	18	15	26.8
Mean	13.1	21.3	18.6	15.3	25.4
	S.Ed.	0.80	0.75	0.57	0.98
	CD (0.05)	1.96	1.84	1.40	2.40

standard techniques and procedures; analyzed statistically and presented in Table 4.3. The co-efficient of friction for plywood sheet was 22, 20 and 22, for galvanized iron 19, 19 and 18 and glass 16, 15 and 15 at 10, 12 and 14 percent moisture content, respectively.

4.3 Evaluation of developed power operated decorticator

The power operated decorticator was tested for its performance. The tests were conducted using seeds subjected different pre-treatments. The two pre-treatments were sun drying and hot water soaking. The sunflower seeds at 10 and 16 percent moisture contents were tested at 75 and 90 rpm. The results are presented in Table 4.6. The clearance (5 cm) of the decorticator was constant for all the trials.

4.4 Effect of pre-treatments, cylinder speeds and moisture contents on the performance of decorticator

The results of the decortication of sunflower seeds for two pre-treatments, two cylinder speeds and two moisture content levels are presented in Tables 4.7 and 4.8.

The statistical analysis was conducted for both sun dried and hot water soaked sunflower seeds to evaluate the effect of cylinder speed and moisture content on the decortication efficiency (Table 4.5), capacity (Table 4.8), whole kernel recovery (Table 4.9), broken grains (Table 4.10) and unshelled grains (Table 4.11).

4.5. Cost economics

The cost economics of the sunflower decorticator was calculated. The details are presented in Appendix II. The cost of decorticator is ₹ 18,700/- which includes the cost of materials used, motor and fabrication. The fixed cost is calculated considering the cost of the machine, depreciation, interest and maintenance. The variable costs include power cost and labour charges.

Table 4.4: Performance of power operated sunflower seed decorticator

Moisture content	Pre-treatments	Speed of rotor (rpm)	Whole seeds recovery (%)	Brokens (%)	Unshelled seeds (%)	Efficiency (%)	Capacity (Kg/h)
12%	Sun dried	75	42.00	7.17	7.84	92.30	24.0
		90	39.76	8.63	8.72	91.23	30.0
	Hot water soaked	75	42.00	7.13	7.64	92.33	16.22
		90	38.28	8.30	8.65	91.35	17.22
14%	Sun dried	75	43.08	3.25	5.59	94.50	35.31
		90	43.01	5.15	6.72	93.30	35.23
	Hot water soaked	75	43.05	6.62	7.22	92.74	18.65
		90	37.04	8.56	9.14	90.80	21.56

Table 4.5. ANOVA for effect of different cylinder speeds and moisture contents on decortication efficiency of sun dried and hot water soaked sunflower seeds

Pre-treatments	Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Sun drying (a)	Total	11	17.986667	1.635152	100.1143**
	Treatment	3	17.520000	5.840000	
	Error	8	0.466667	0.058333	
Hot water soaking (b)	Total	11	7.293867	0.663079	27.2685**
	Treatment	3	7.099333	2.366444	
	Error	8	0.194533	0.024317	

**Significant at 1% level

(a) S.E.D: 0.13944 LSD (5%): 0.32156 LSD (1%): 0.46790 CV (%):0.21

(b) S.E.D: 0.09003 LSD (5%): 0.20761 LSD (1%): 0.30210 CV(%): 0.13

Table 4.6. Performance of decorticator at 10 % and 16 % moisture contents and speeds of 75 and 90 rpm.

Moisture content (%) (W.b.)	Speed of cylinder (rpm)	Weight of seeds (g)	Weight of dehusked seeds (g)	Weight of broken seeds (g)	Weight of unshelled seed (g)	Weight of husk (g)	Whole seeds recovery (%)	Broken (%)	Unshelled kernels (%)	Efficiency (%)
10	75	5000	1015.0	780.0	1250.0	2298.0	20.30	15.60	25.0	75.0
	90	5000	920.0	670.0	1350.0	2060.0	18.40	13.40	27.0	73.0
16	75	5000	850	770.0	1550.0	1830.0	17.00	15.40	31.0	69.0
	90	5000	850	770.0	1550.0	1830.0	16.40	21.80	39.8	60.02

Contd...

Moisture content, % (W.b.)	Speed of cylinder (rpm)	Time (min)	Capacity (Kg/h)
10	75	14.83	20.68
	90	15.88	27.00
16	75	16.00	31.00
	90	18.00	39.80

Table 4.7 Performance of decorticator for pre-treatment of sun dried and hot water soaked seeds at 12 and 14 % moisture contents and cylinder speeds of 75 and 90 rpm.

Moisture contents (%) (W.b.)	Pre-treatments	Speed of cylinder (rpm)	Weight of seeds (g)	Weight of dehusked seeds (g)	Weight of broken seeds (g)	Weight of unshelled seeds (g)	Weight of husk (g)	Whole seeds recovery (%)	Broken (%)	Unshelled kernels (%)	Efficiency (%)
12	Sun dried	75	5000	2100.3	358.67	382.00	2159.00	42.00	7.17	7.64	92.30
		90	5000	1988.3	413.33	438.33	2142.00	39.76	8.63	8.72	91.23
	Hot water soaked	75	5000	2100.3	357.00	382.00	2159.00	42.00	7.13	7.64	92.33
		90	5000	1914.2	415.17	432.67	2238.00	38.28	8.30	8.65	91.35
14	Sun dried	75	5000	2154.3	163.33	270.33	1189.00	43.08	3.25	5.59	94.50
		90	5000	2150.7	257.33	336.00	2239.33	43.01	5.15	6.72	93.30
	Hot water soaked	75	5000	2234.0	329.50	363.00	2073.50	43.05	6.62	7.22	92.74
		90	5000	1852.3	428.17	457.83	2260.67	37.04	8.56	9.14	90.80

Contd...

Pre-Treatment	Speed of cylinder (rpm)	Time (min)	Capacity (Kg/h)
Sun dried	75	11.55	25.78
	90	9.55	30.59
Hot water soaked	75	18.28	16.22
	90	17.70	17.22
Sun dried	75	8.83	35.31
	90	8.24	35.63
Hot water soaked	75	16.01	18.65
	90	14.41	21.56

Table 4.8. ANOVA for effect of different cylinder speeds and moisture contents on decortication capacity of sun dried and hot water soaked sunflower seeds.

Pre-treatments	Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Sun drying (a)	Total	11	264.589167	24.053561	7.33 NS
	Treatment	3	194.051367	64.683789	
	Error	8	70.537800	8.817225	
Hot water soaking (b)	Total	11	49.713025	4.519366	110.2277**
	Treatment	3	48.538758	16.179586	
	Error	8	1.174267	0.146783	

NS : Non Significant, **Significant at 1% level

(a) S.E.D: 1.71437 CV (%): 9.91

(b) S.E.D: 0.22120 LSD (5%): 0.51009 LSD (1%): 0.74222 CV (%):2.35

Table 4.9. ANOVA for effect of different cylinder speeds and moisture contents on whole kernel recovery of sun dried and hot water soaked sunflower seeds

Pre-treatments	Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Sun drying (a)	Total	11	26.849967	2.440906	6.755 NS
	Treatment	3	19.250500	6.416833	
	Error	8	7.599467	0.949933	
Hot water soaking (b)	Total	11	111.314692	10.119517	51.5579**
	Treatment	3	109.744492	36.581497	
	Error	8	1.570200	0.196275	

NS – Non significant , **Significant at 1% level

(a) S.E.D: 0.79579 CV (%): 2.74

(b) S.E.D: 0.25578 LSD (5%): 0.58984 LSD (1%): 0.85827 CV (%):0.33

Table 4.10. ANOVA for effect of different cylinder speeds and moisture contents on broken grains of sun dried and hot water soaked sunflower seeds

Pre-treatments	Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Sun drying (a)	Total	11	50.530767	4.593706	165.0425**
	Treatment	3	49.727300	16.575767	
	Error	8	0.803467	0.100433	
Hot water soaking (b)	Total	11	7.926900	0.720627	0.335**
	Treatment	3	7.766300	2.588767	
	Error	8	0.160600	0.020075	

**Significant at 1% level

(a) S.E.D: 0.18297LSD (5%): 0.42193 LSD (1%): 0.61395 CV(%):5.54

(b) S.E.D: 0.08180 LSD (5%): 0.18864 LSD (1%): 0.27449 CV(%):2.01

Table 4.11. ANOVA for effect of different cylinder speeds and moisture contents of unshelled grains of sun dried and hot water soaked sunflower seeds

Pre-treatments	Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Sun drying (a)	Total	11	2656.273167	241.479379	0.585**
	Treatment	3	2655.173700	885.057900	
	Error	8	1.099467	0.137433	
Hot water soaking (b)	Total	11	7.178667	0.652606	0.585**
	Treatment	3	7.034867	2.344956	
	Error	8	0.143800	0.017975	

**Significant at 1% level

(a) S.E.D: 0.30269 LSD (5%): 0.69802 LSD (1%): 1.01567 CV(%):2.65
(b) S.E.D: 0.07741 LSD (5%): 0.17850 LSD (1%): 0.25973 CV(%):0.99



Discussion

V. DISCUSSION

The results obtained in the investigation are critically discussed under the following headings:

- 5.1 Physical and mechanical properties of sunflower seeds at 12% and 14 % moisture contents.
- 5.2 Development of the power operated decorticator for sunflower seeds.
- 5.3 Performance evaluation of the developed decorticator.
- 5.4 Economics of decortication process of sunflower seeds.

5.1 Physical and mechanical properties of sunflower seeds

The physical properties of sunflower seeds studied, as these properties have an effect on the performance of a decorticator and are presented in Tables 4.1 and 4.2.

It is observed from the results, that the moisture content has an effect on the physical properties. The length, width, thickness, and mass of 100 seeds increased with the increase in moisture content.

5.1.1 Size

It was observed that the length of sunflower seeds was found to be 13.19 mm at 16 percent moisture content which was higher than the length of 12.54 mm found at 10 percent moisture content. Similar observations were observed in case of the width and thickness of sunflower seeds, i.e., the width increased from 5.57 mm to 6.40mm and the thickness increased from 3.88 mm to 5.19 mm which might be due to the absorption of moisture content. The moisture content has caused significant difference among the different dimensions of the sunflower seeds (Figure 5.1). The mass of 100 seeds also increased with increase in

moisture content (Figure 5.4). This proves the influence of moisture absorption on the changes in length width, thickness and mass of the seeds.

5.1.2 True density and bulk density

Analysis of physical properties of sunflower seeds shows that the true density increased from 769.2 kg/m^3 to 806.5 kg/m^3 (Fig.5.5) with increase in moisture content from 10 to 14 percent. The increase was found to be 4.48 %. The bulk density decreased from 435 kg/m^3 to 432 kg/m^3 (Fig 5.5), which was 0.68%. This is in agreement with the results of Aydin(2003).

The moisture content had effect on porosity (Fig. 5.2) also. It was high at 10 percent moisture content and low at 14 per cent moisture content. This might be due to the increase in the size of the seeds due to absorption of moisture. This was also observed that the size of the seeds which was higher at 14 percent moisture compared to 10 percent moisture content (fig 5.1). Statistically no significant difference was found among in the values of (43.5, 41.0, and 38.7 %) at different moisture contents of the sunflower seeds.

5.1.3 Frictional properties

The frictional properties of sunflower seeds indicated that there was a change in the angle of repose and static co-efficient of friction on different materials. The change in the moisture content of sunflower seeds had a negligible effect on the frictional properties. The co-efficient of friction for plywood, GI sheet and glass sheet, are presented in the Fig 5.3. The angle of repose of seeds at 10 per cent moisture content was found to be 23.9° and the values at 12 and 14 per cent moisture contents were found to be 25.50° and 26.80° , respectively.

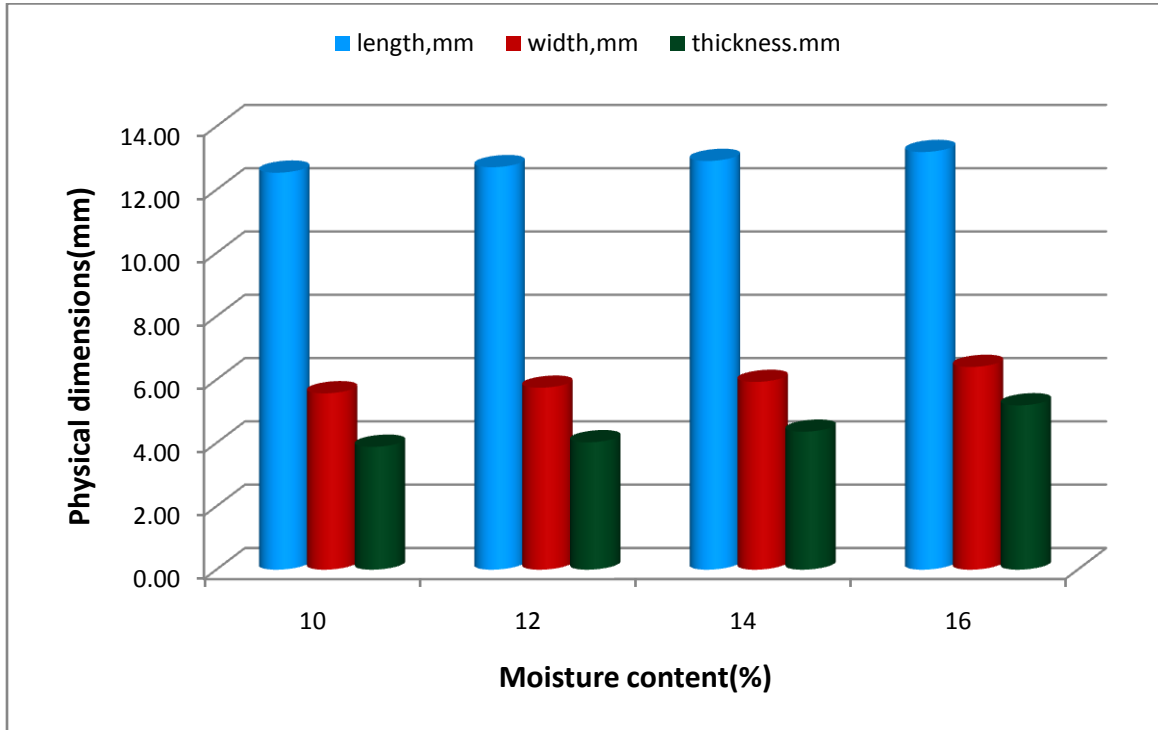


Fig. 5.1 Size at different moisture contents of sunflower seeds

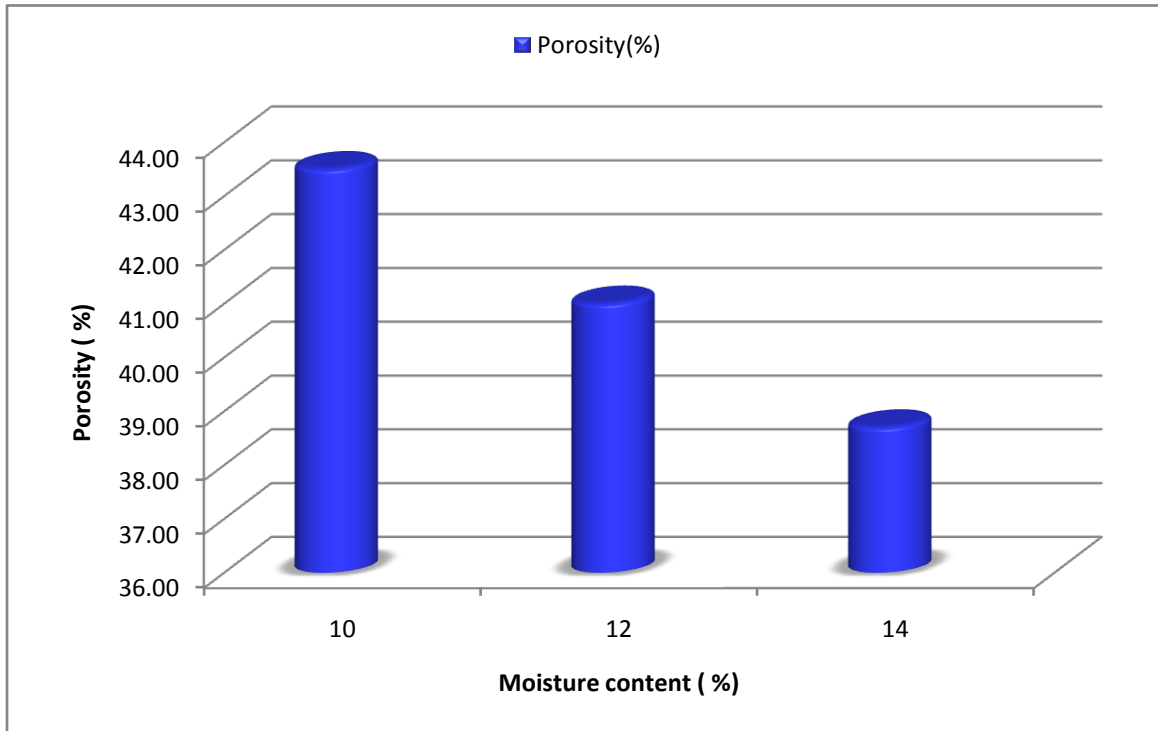


Fig. 5.2 Porosity of sunflower seeds at different moisture contents

Similar observations were recorded by Balasubramaniam (2001). The variation in the co-efficient of friction values for different frictional surfaces indicates the behavior of the surface texture of sunflower seeds. Statistically no significant difference was found for the co-efficient of seeds at different among the different moisture contents on different surfaces.

5.2 Development of sunflower seed decorticator

As mentioned in Chapter III, the power operated sunflower seed decorticator was fabricated in the workshop of Department of Agricultural Engineering, University of Agricultural Sciences, Bangalore. The machine parameters were standardized by taking various trials at different cylinder speeds and pre-treatments. During the trials it was observed that at 12 and 14 % moisture contents, the efficiency was found to be better (Fig 5.8). Hence further trials were concentrated on these two moisture contents.

The decorticator was later tested for two cylinder speeds (75 and 90 rpm) and two pre-treatments (sun-dried and hot water soaked seeds) for sunflower seeds at two moisture contents (12 and 14 %), with a 4.5cm clearance between the cylinder and concave. The cylinder was made of dimple sheet. The performance of the decorticator was found to be efficient at a cylinder speed of 75 rpm for seeds of 14 % moisture content. The seed breakage was also minimum.

5.3 Performance evaluation of sunflower decorticator

5.3.1 Decortication efficiency

The decorticator was operated for decorticating the sun flower seeds at four different moisture contents of 10, 12, 14, and 16 % (w.b) and at two cylinder speeds of 75 and 90 rpm to determine the most

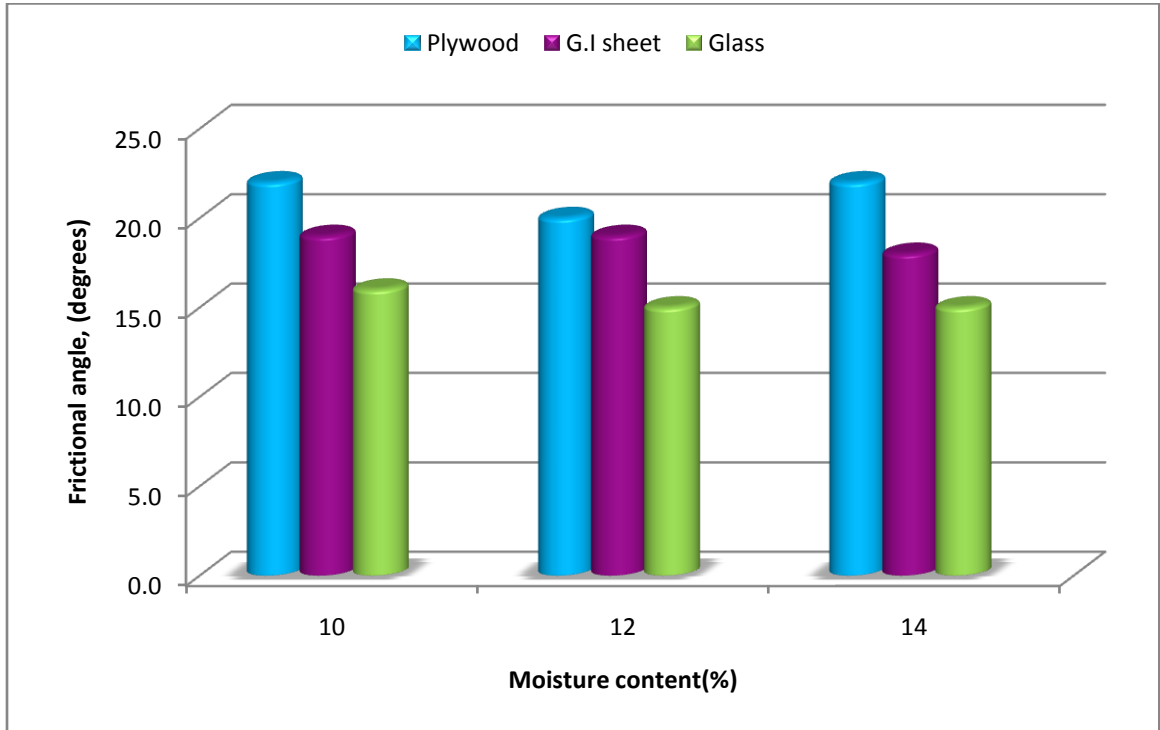


Fig. 5.3 Co-efficient of friction of sunflower seeds on different surfaces

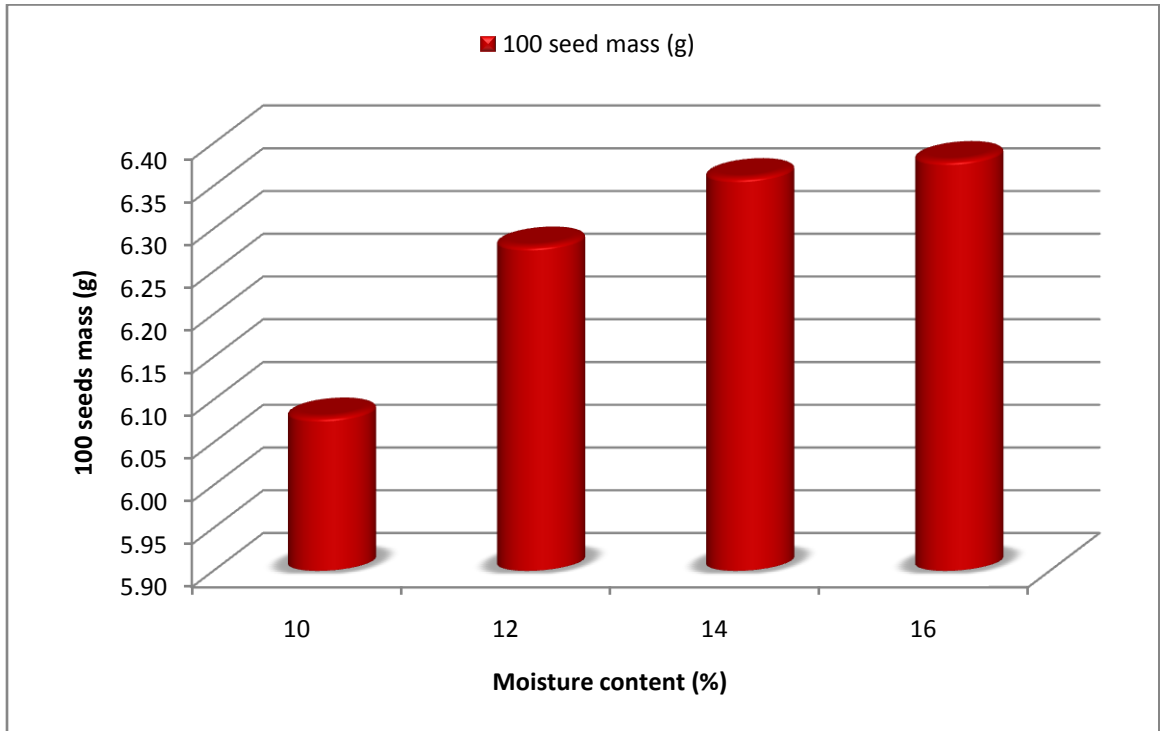


Fig. 5.4 100 seed weight of sunflower seeds at different moisture contents

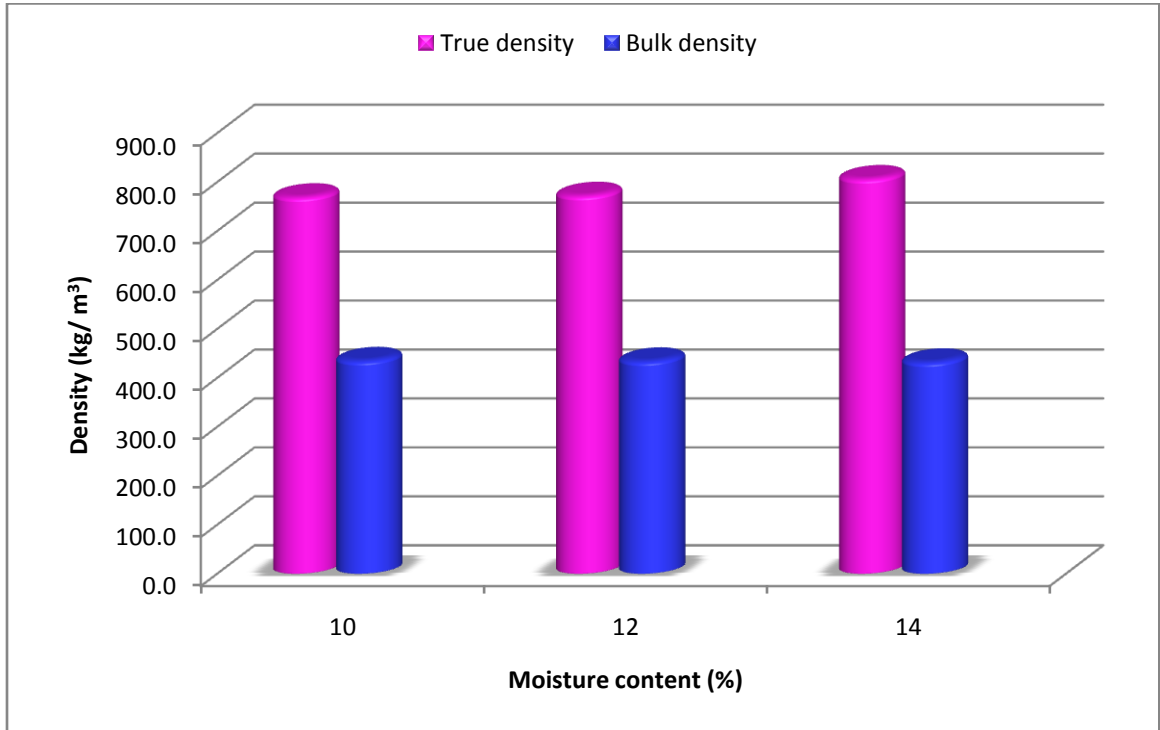


Fig. 5.5 Density of sunflower seeds at different moisture contents

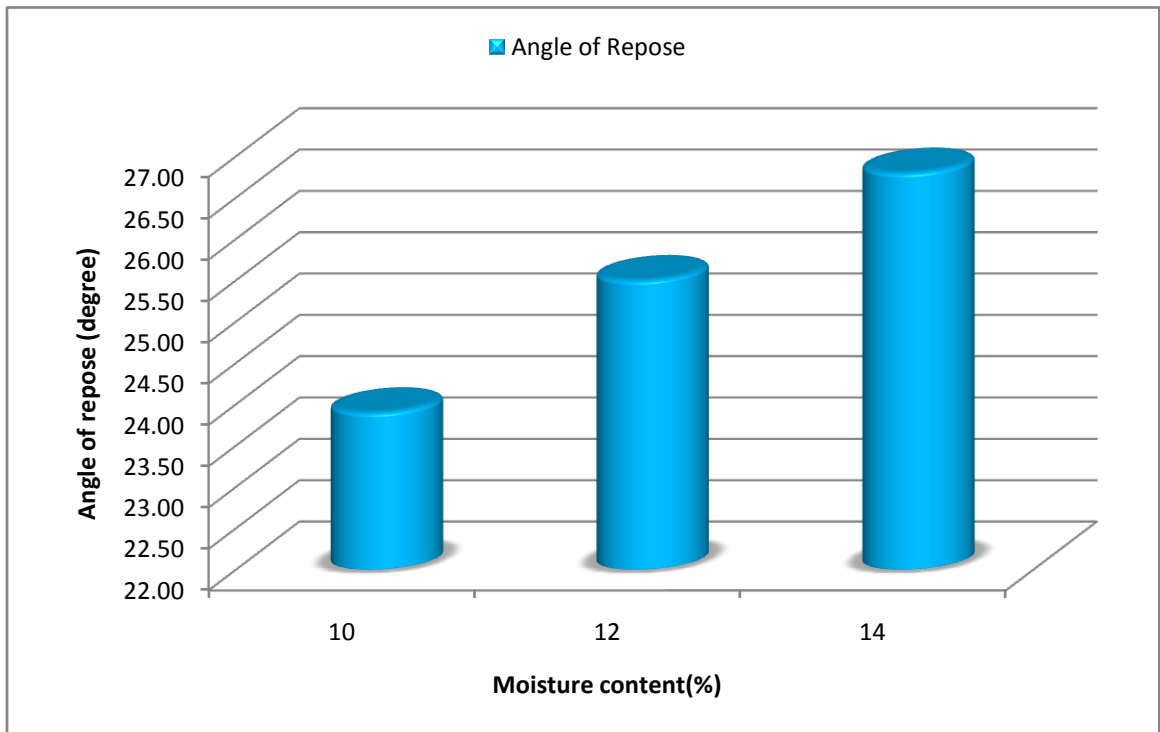


Fig. 5.6 Angle of repose of sunflower seeds at different moisture contents

suitable moisture content. The decorticating efficiencies at these moisture levels are presented in Fig 5.7.

From the results, it was found that the decorticating efficiencies were higher at 12 and 14% moisture contents compared to 10 and 16 % moisture contents (w.b).

Hence, further studies were conducted using seeds at 12 and 14 % moisture content. The results of the decortication at these moisture contents, with the pre-treatments of sun drying and hot water soaking, at cylinder speed of 75 and 90 rpm are presented in Figure 5.8.

The results show that the decortication efficiency was higher (94.50 percent) for sun dried seeds of 14 per cent moisture content at 75 rpm compared to other treatments. This indicates that the moisture content and the cylinder speed play important role in the decortication. It was also observed (Fig 5.9) that the breakage was higher 8.56% and decortication efficiency was 90.80%, for hot water soaked seeds of moisture content 14 % and at 90 rpm. This indicates that the speed of the cylinder has an effect on decortication. Again it indicates that the sun dried seeds are better compared to hot water soaked seeds for decortication.

It might be due to the drying to the proper level, which made the material to retain the strength required for easy peel of the husk from the seeds. The treatment cost was higher in case of hot water soaked seeds as compared to sun dried seeds. However, the higher efficiency was observed with the sun dried seeds fed to decorticator (Fig 5.8).

It was also observed that the efficiency was lower at 90 rpm compared to 75 rpm cylinder speed for both sun dried and water soaked treatments.

The statistical analysis was conducted to measure the effect of treatments on the decorticating efficiency and found that there was a significant difference among the two pre-treatments. Higher decortication efficiencies were observed at the cylinder speed of 75 rpm. The second best efficiency (93.30 percent) was observed with a combination of sun dried seeds of 14 % moisture content and cylinder speed of 90 rpm.

5.3.3 Percentage of broken kernels

The percentage of broken kernels was found to be lower (3.25 %) in sun dried sun flower seeds of 14 per cent moisture content at a cylinder speed of 75 rpm.

The breakage percentage in case of hot water soaked seeds was high (8.56%) at 14 % moisture content and 90 rpm, which might be due to softening of the seed coat (Fig.5.9). Statistically it was found that there was a significant difference among pre-treatments the sunflower seeds due to softening of husk and increase in speed of drum rotation.

5.3.4 Percentage recovery of whole seeds

The whole seeds recovery was significantly affected by the pretreatments and moisture contents at two different cylinder speeds (Fig 5.10). Higher percentage of whole kernels (43.08per cent) were obtained for hot water soaked sun flower seeds at 14 per cent moisture content and 75 rpm and lowest whole seeds recovery (37.04%) was obtained at 14% moisture content at 90 rpm for hot water soaked seeds (Table 4.7). Statistically it was found that there was no significant difference for sun dried seeds but in case of hot water soaked seeds, a significant difference on whole seeds recovery was noted.

5.3.5 Decorticator capacity

The results indicate, high capacity of decortication (35.31kg/h) was observed for sun dried sun flower seeds at 14 per cent moisture at cylinder speed of 90 rpm, followed by the sun dried seeds (capacity 35.23 kg/h) at 14% moisture content at cylinder speed of 75 rpm. This was perhaps due to the fact that the duration of decortication process was minimum (Fig 5.11). Statistically it was found that there was no significant difference in sun dried treated seeds but in case of hot water soaked seeds, there was a significant difference in decorticator capacity.

By analyzing all the factors such as percentage of whole seeds recovery, broken seeds, unshelled seeds, decortication efficiency and capacity, it was found that the sun dried seeds at 14 percent moisture content and cylinder speed of 75 rpm gave the best results.

5.4 Economics of decortication process

The cost incurred in decorticating one kilogram of raw sun flower seeds of 14 per cent moisture content in the power operated decorticator was only ₹ 1.67/- which was comparatively lower than the manual decortication process. The electricity and labour costs accounted for 96.0 per cent of the total operational cost (Appendix II).

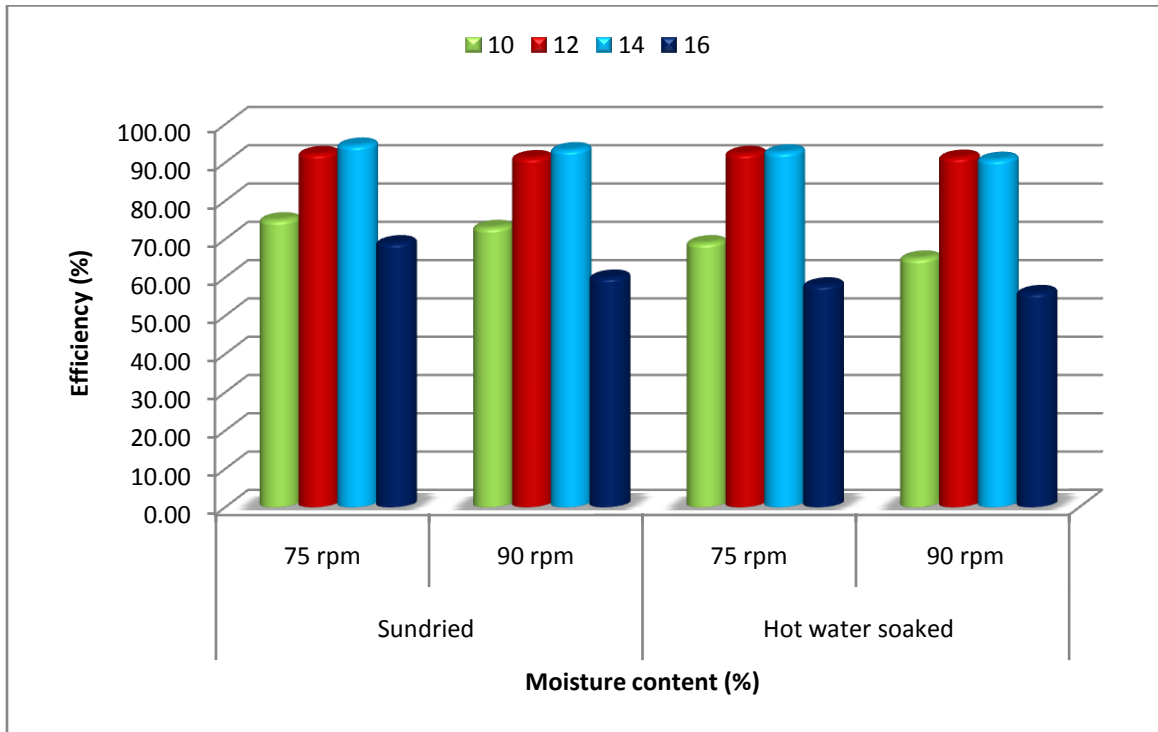


Fig. 5.7 Efficiency of decorticator using seeds of different moisture contents

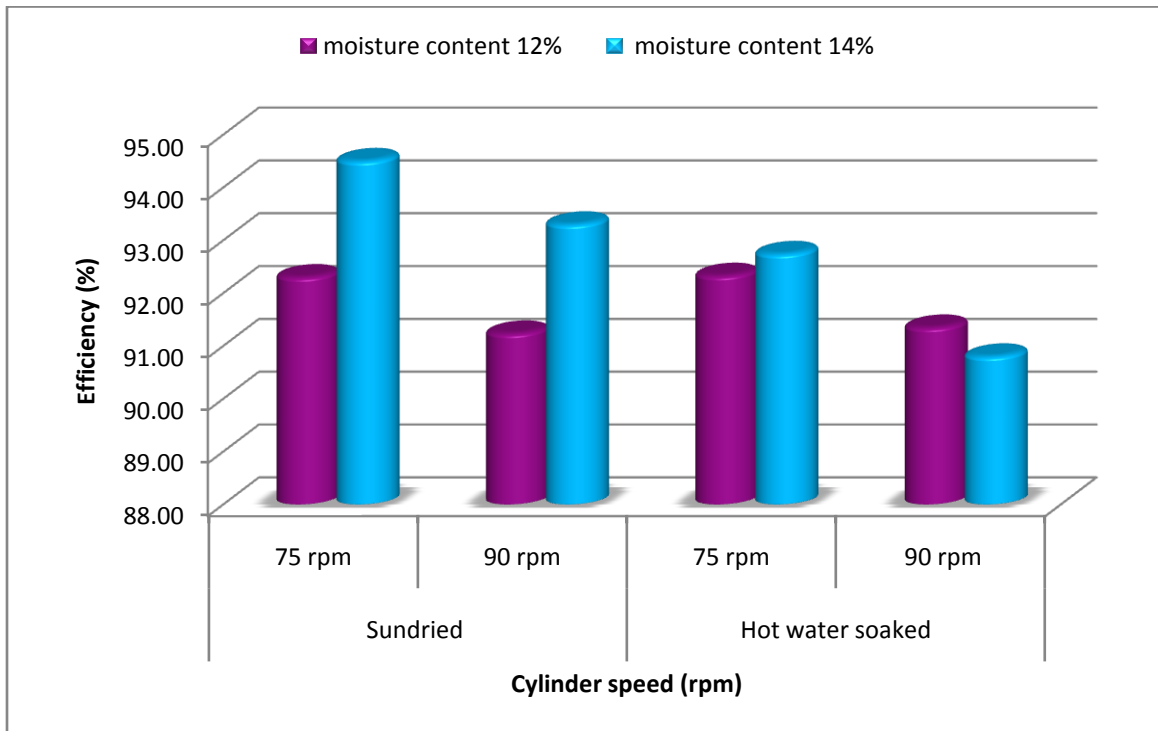


Fig. 5.8 Efficiency of the decorticator using different moisture content seeds at different cylinder

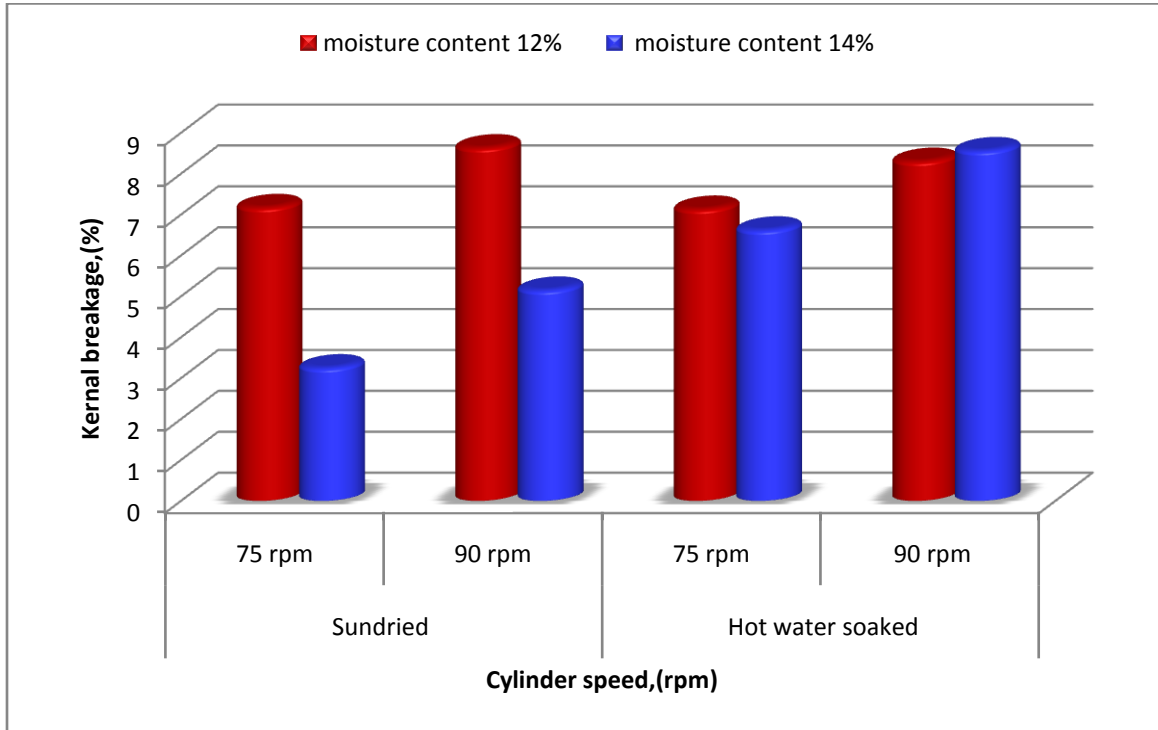


Fig. 5.9 Broken grains of decorticator using seeds of different moisture contents

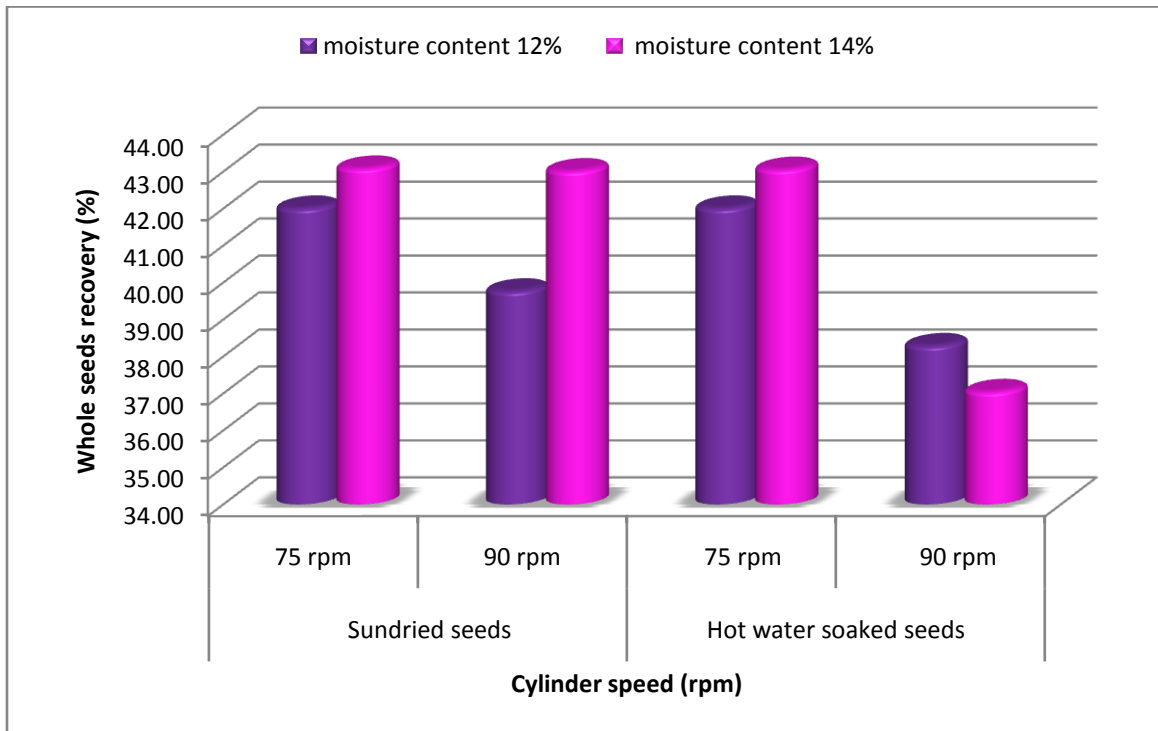


Fig. 5.10 Whole seeds recovery of decorticator using Seeds of different moisture contents

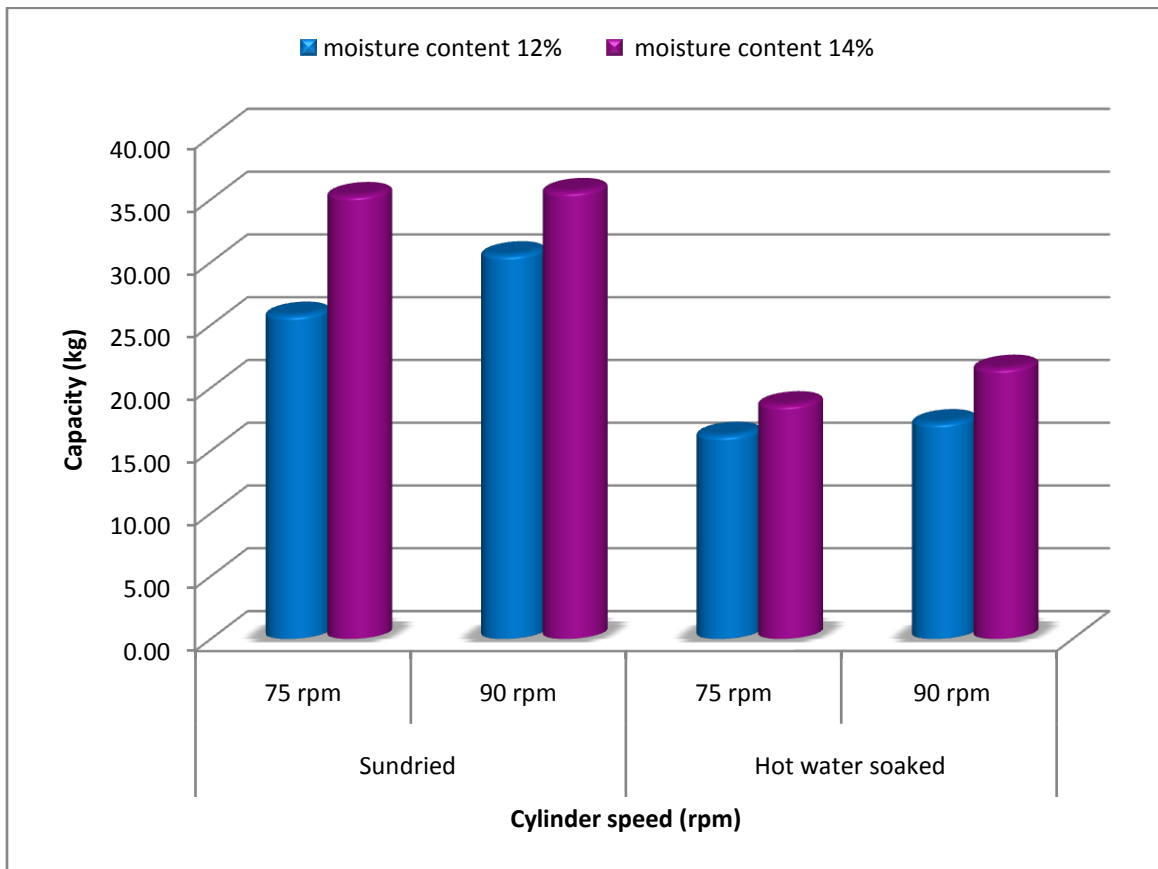


Fig. 5.11 Dehusking capacity of decorticator using seeds of different moisture contents



Summary

VI. SUMMARY

Sunflower (*Helianthus annuus* L.) originated from Southern USA and Mexico. It belongs to Asteraceae family and is one of the four major oilseed crops of the world. Flower and Seeds are two major economical parts of sunflower crop. Sunflower is adapted well to major agro-climatic conditions of India. The seed cake is a rich source of protein for animals and birds (Gopalan *et al.*, 2007). Certain varieties of sunflower seeds are used in confectionery and are called confectionery sunflower seeds

The sunflower is cultivated largely in southern parts of the country comprising the states of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu.

Shelling is done by shellers, which split the husks by the action of impact. Most of the oil seeds hulls are not fit for direct oil expression and human consumption, therefore, removal of hulls of seeds is necessary for better yield.

There is a good scope for the development of a new machine (decorticator) as at present the decorticating process is time and labour consuming. Hence, this study entitled "Development of power operated decorticator for confectionary sunflower seeds" was undertaken.

The physical properties of sunflower seeds at different moisture contents were studied by using standard procedures given by Mohsenin (1986). The results were statistically analyzed. Moisture content has an effect on size, shape, 100 seeds mass, true density, bulk density, porosity and frictional properties like angle of repose and co-efficient of static friction.

The power operated sunflower seed decorticator was tested for two pre-treatments (sun drying and hot water soaking) moisture contents (12 and 14 %) and two speeds of cylinder (75 and 90 rpm).

1. Sunflower seeds at 16 % moisture content had the highest dimensions in terms of length, width and thickness with values 13.9, 6.40 and 5.19 mm respectively.
2. Sun flower seeds of 14 % moisture content (sun dried seeds) had higher decortication efficiency (94.50%).
3. Seeds recovery was also higher for sun flower seeds having 14 % moisture content and at cylinder speed of 75 rpm.
4. Maximum whole seeds recovery with minimum kernel breakage and higher capacity was observed when sun dried seeds with 14 % moisture content were fed to the decorticator at 75 rpm.

Finally, it is concluded that the decortication was effective for sunflower seeds of 14 % moisture content with a cylinder speed of 75 rpm (35.70 m/s).

Future line of work

1. Sieves may be attached to have graded seeds.
2. Efficiency of the blower needs to be improved.



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Appendices

APPENDIX-I

Materials and cost of power operated sunflower seed decorticator

Sl. No.	Material	Size	Quantity	Total cost of materials (₹)
1.	MS sheet for Cylinder	60×30cm	4 kg	1000
2.	Dimple sheet	100×100cm	0.8kg	500
3.	Mild steel flats	2.54cm	2 kg	250
4.	Bearings	7 cm	0.8kg or (4)	800
5.	Mild steel sheet (4×6 ft)	18 gage	2 kg	2500
6.	Mild steel shaft (EN-8)	2.2cm	2	300
7.	L-angles	1×0.4"	15kg	600
8.	Sieves	60×35.5 cm	0.35kg	250
9.	Motor	1.0 hp	1	4500
10.	Pulley's	45, 3, 2.0 and 1.75 cm	4	900
11.	V- belt	68 and 45 cm	2	300
12.	Inges	5×2 cm	3	15
13.	Miscellaneous	-	-	150
14.	Paint	-	500 ml	350
15.	Total cost	-	-	12,415
16.	Labor cost (50%)	-	-	6207
	Total cost of machine			Rounded off- 18,700

APPENDIX II

COST ECONOMICS OF POWER OPERATED SUNFLOWER SEED DECORTICATOR

1. Fixed cost

- a. Machine cost = Material cost + Fabrication cost = ₹.18,700
- b. Salvage value (S) @ 10% of total cost of decortications = ₹.1870
- c. Annual use (U) (Expected operational hours) = 1000 h
- d. Expected life of decorticator (L), years = 10 years
- e. Rent and insurance are not included
- i. Depreciation (D)

$$D = \frac{C - S}{UL}$$
$$= ₹.1.69 /h$$

D= Depreciation

C= Machine cost

S= Salvage value

U= Annual use

L= Expected life

- ii. Interest(I) on capital @ 12 % per annum on fixed price (i)

$$I = \frac{C + S}{2U} \times i$$
$$= ₹.1.23/h$$

- iii. Repairs/ maintenance cost (R) @ 2% (r)

$$R = \frac{C}{UL} \times R$$
$$= ₹.0.04/h$$

Total fixed cost (D+I+R) = 1.69+1.23+0.04=₹. 2.96/h

2. Operational cost / Variable cost

i. Power consumption = 1.5 kw/h

(Energy cost @ 4.20/units) (P) = ₹. 6.3/h

ii. Labour cost @ Rs. 200/day (8h) per person

(2 labours i.e., Rs 25/h = 2×25) (b) = ₹. 50.00/h

Total variable cost (P+b) = 6.3+50 = ₹. 56.3/h

Total cost of operation (A) = Total fixed cost + Total variable cost

= ₹. (2.96+56.3)/h

= ₹. 59.5/h

- The capacity is 35.5 kg/h (observed during operations)
- Therefore cost of operation is ₹ 1.67/kg .
- The cost operation of manual decortication of sunflower seeds is about ₹ 3.5/kg (observed in field operations).

By comparing the manual decortications and power operated decortication the cost of operation is low in power operated decortication.

Cost benefit ratio = 1:2.05