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Sarbani Padhi
M. Tech. (Farm Machinery and Power Engineering), Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Dr. SC Bhangare
Assistant Professor, ICAR-AICRP on Farm Implements and Machinery, Dr Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra, India

Dr. SM Nalawade
Professor and Head, Department of Farm Machinery and Power Engineering, Dr Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra, India

Dr. TB Bastewad
Professor and Principal Investigator, ICAR-AICRP on Farm Implements and Machinery, Dr Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra, India

Dr. MR Patil
Professor and Head, Department of Statistics, Post Graduate Institute, MPKV, Rahuri, Maharashtra, India

MM Pacharne
Assistant Professor, ICAR-AICRP on Farm Implements and Machinery, Dr Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra, India

Dr. RK Rathod
Assistant Professor, ICAR-AICRP on Farm Implements and Machinery, Dr Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra, India

Corresponding Author:

Sarbani Padhi
M. Tech. (Farm Machinery and Power Engineering), Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Engineering properties of MPKV sunflower varieties

Sarbani Padhi, SC Bhangare, SM Nalawade, TB Bastewad, MR Patil, MM Pacharne and RK Rathod

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Abstract

Engineering properties of sunflower are important for the design and development of harvesting, threshing, handling, transportation, and storage equipment. The research work was carried out at Annasaheb Shinde Government College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra. In this study to evaluate the engineering properties of three varieties of sunflower viz., Phule Kalsubai, Phule Bhaskar and Raviraj. The properties evaluated includes the physical, mechanical, frictional and other engineering properties of the sunflower heads. The experimental data showed that the head diameter of the varieties ranged from 7.92-23.46 cm; 6.62-25.24 cm; 4.75-21.34 cm for Phule Kalsubai, Phule Bhaskar, and Raviraj, respectively. The head thickness of these experimental materials were 3.27 cm; 3.06 cm; 3.01 cm respectively. The determined moisture content were 57.91%, 71.20%, and 80.48% respectively, while the Phule Bhaskar variety had the highest average head weight, which was more than 160 g. Such differences in yield component characteristics of sunflower varieties present the basics to develop and calibrate specialized machinery that would improve processing quality and minimize grain losses due to inefficient harvesting technologies.

Keywords: *Helianthus annuus*, moisture content, head diameter, mechanical properties

Introduction

Sunflower (*Helianthus annuus* L.) is a multipurpose annual crop, which is primarily cultivated for its high-quality edible oil, healthy properties, and adaptability to different agro-climatic conditions. It plays an important role in the Republic of Moldova vegetable oil sector (Singh *et al.*, 2010). Beyond primary oil extraction, the seeds are widely utilized in the bakery, confectionery, snack, and bird feed industries, owing to their substantial protein and oil content. The design and development of agricultural machinery require accurate knowledge of the engineering properties of the crop. The engineering properties of sunflower heads and seeds are fundamental for the design, optimization, and performance evaluation of post-harvest machinery used in handling, processing, and storage operations (Mohsenin, 1986; Sahay and Singh, 1994). Several researchers have reported the engineering properties of sunflower seeds and heads, evaluating them under varying moisture conditions and used different hybrids for their experiments. For example, (Gupta & Das, 1997) studied the physical properties of sunflower seeds, (Gupta & Das, 2000) examined the compression characteristics of sunflower seeds, determining their fracture resistance to compression. Furthermore, (Figueiredo *et al.*, 2010) and (Li *et al.*, 2024) reported the effect of moisture content and variety on the studied properties. Collectively, these studies have contributed significantly to the design and development of post-harvest machinery.

Although several studies have reported the engineering properties of sunflower under different varieties and moisture conditions, comparable information for the MPKV sunflower varieties like Phule Bhaskar, Phule Kalsubai, and Raviraj are limited. It approximately takes 3-4 months for the sunflower to reach maturity for harvesting. Therefore, the present study was conducted after the harvesting, at the beginning of October to evaluate their engineering properties and generate a baseline data for the design and development of sunflower seed removal machines and other post-harvest equipment. (BHISE *et al.*, 2013) [26, 27, 9, 8, 16, 6].

1. Materials and methods

1.1 Experimental Site

The present investigation was conducted in the Department of Farm Machinery and Power Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Ahilyanagar, Maharashtra, India. Fully matured sunflower heads of three MPKV varieties, namely Phule Bhaskar, Phule Kalsubai and Raviraj, were collected from the MPKV Research Farm. The heads were harvested in the beginning of October after complete maturity, and stored under ambient conditions.

1.2 Sample Preparation

The sunflower heads- Phule Kalsubai, Phule Bhaskar and Raviraj of MPKV were harvested and collected from the fields and were manually cleaned to remove foreign matters, broken components, or immature seeds. Samples were stored under ambient conditions. Observations were taken on the day of harvest and after storage.

1.3 Moisture Content

The moisture content of sunflower heads was determined by the oven drying method. Samples of each variety were weighed and then dried in a hot-air oven at $104 \pm 1^\circ\text{C}$ for 24 h. The moisture content of the samples was calculated by the following equation:

$$\text{MC}\% = \frac{W_i - W_d}{W_i} \times 100 \quad (1)$$

Where,

- W_i = Initial weight of sample (g)
- W_d = Oven-dry weight of sample (g) (Dorrell and Vick (1997), Bhise *et al.*, Seifi (2011))^[6, 28]

1.4 Determination of Physical Properties of Sunflower Heads and Seeds:

The physical properties of sunflower heads and seeds were determined using standard methods. The head diameters were measured using a Measuring tape (Fig 2), while the head thickness was measured using a Vernier caliper (least count: 0.02 cm). Head weight was recorded using an electronic weighing balance (least count: 0.01 g). (Gupta and Das (1997), Joshi *et al.* (1993)). Healthy seeds from each variety were randomly selected, and their length, width and thickness were measured using a Vernier caliper (least count: 0.02 mm). Ten observations were recorded for each variety, and the measured dimensions were used to calculate the properties using standard equations. (Seifi (2011), Li *et al.* (2024))^[9, 13, 16].

The derived properties were calculated as follows

1.4.1 Surface area

$$(S) = \pi \times Dg^2 \quad (2)$$

(Jafari *et al.*, 2011; Lj. *et al.*, 2012)^[11]

1.4.2 Area

$$(A) = \left(\frac{\pi}{4}\right) L \times W \quad (3)$$

Jafari *et al.*, 2011; Lj. *et al.*, 2012)^[13]

1.4.3 Volume

$$(V) = \frac{\pi}{6} Dg^3 \quad (4)$$

(Jafari *et al.*, 2011; Lj. *et al.*, 2012)^[13]

1.4.4 Geometric mean diameter

$$(G.M.D) = (LWT)^{\frac{1}{3}} \quad (5)$$

(Bhise *et al.*, 2013; Malik & Saini, 2016)^[6]

1.4.5 Sphericity

$$(S) = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (6)$$

(Bhise *et al.*; 2013; Malik & Saini, 2016, Mohsenin 1986 and Sahay and Singh 1994)^[6, 17, 26, 27]

Where L, W and T are length, width and thickness respectively.

1.5 Determination of Frictional properties

1.5.1 Angle of Repose

The angle of repose was measured by using the fixed funnel method (Fig 1). A funnel was placed at a certain height from a horizontal wooden surface. (Gupta and Das (1997), Seifi (2011), Chavoshgoli *et al.* (2015))^[9, 13]. The angle of repose was calculated by using the following equation:

$$(\theta_f) = \tan^{-1} \left(\frac{2H}{D} \right) \quad (7)$$

(Chavoshgoli *et al.*, 2015)^[7]



Fig 1: Fixed Funnel Method

1.5.2 Coefficient of Static Friction

The coefficient of static friction was determined on a wooden (plywood) surface using the inclined plane method. (Gupta and Das (1997), Seifi (2011), Chavoshgoli *et al.* (2015))^[9, 7]. Five replications were conducted, and the coefficient of static friction was calculated using the following equation:

$$(\mu) = \tan(\phi) \quad (9)$$

(Chavoshgoli *et al.*, 2015)^[7].

1.6 Determination of Gravimetric properties

1.6.1 Thousand Seed Weight

The thousand seed weight was determined by counting one thousand healthy seeds from each variety by seed counter machine and weighing them using an electronic weighing balance. (Gupta and Das (1997), Reddy *et al.* (2010) ^[9, 21].

1.7 Determination of Mechanical Properties

1.7.1 Initial cracking force of seeds

The hardness of sunflower seeds was determined using a Texture Analyzer (Model: TMS-PRO) available in the Department of Agricultural Process Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri. The maximum compressive force required to initiate rupture was recorded. Ten

observations were recorded for each variety, and the average hardness was calculated. (Jafari *et al.*, 2011) ^[11].

2. Results and discussion: 2.1 Physical properties of sunflower heads: The physical properties of sunflower heads differed among the three selected varieties. Phule Kalsubai recorded the highest head diameter and head weight, Raviraj had comparatively smaller head dimensions. These differences were mainly due to varietal nature and its moisture content. The average head thickness was found to be 2.87 ± 0.23 cm for Raviraj while 3.11 ± 0.43 cm for Phule Kalsubai. Phule Kalsubai exhibited the highest mean head volume and surface area, whereas Raviraj recorded the lowest values. Similar varietal differences in sunflower head characteristics have been reported by Reddy *et al.* (2010) and Li *et al.* (2024), indicating that genotype plays an important role in determining the engineering characteristics of sunflower heads.



Fig 2: Sunflower head diameter

Table 1: Physical properties of sunflower heads

Physical properties of sunflower heads					
Variety	Moisture content (%)	Diameter (cm)	Thickness (cm)	Volume (cm ³)	Surface area (cm ²)
Phule Bhaskar	71.62±1.691	15.874±3.522	3.044±0.507	2374.178±1578.779	824.938±368.726
Phule Kalsubai	56.472±5.204	17.039±4.927	3.11±0.43	3194.189±2596.527	980.715±555.661
Raviraj	80.778±1.189	9.48±1.396	2.871±0.23	472.264±202.83	287.844±83.69

Table 1: Values are mean ±SD

2.2 Moisture content

Moisture content varied among the selected sunflower head varieties, the higher moisture content of Raviraj indicates greater water retention at the time of experimentation, whereas Phule Kalsubai exhibited comparatively drier heads. Moisture content influences the physical strength of the head and affects handling and seed removal during post-harvest operations, which agrees with the observations of (Figueiredo *et al.* (2011) ^[1].

2.3 Physical properties of sunflower seeds

The physical properties of the sunflower seeds are given in Table 3. The table shows that the geometric mean diameter ranged from 0.501 ± 0.009 cm in Raviraj to 0.566 ± 0.014 cm in Phule Kalsubai (larger seeds in Kalsubai). Among the varieties, Phule Kalsubai had a higher dimension, followed by Raviraj variety,

while Phule Bhaskar had lower dimensions than the other two varieties. Phule Kalsubai exhibited the highest mean surface area and volume, while the surface area and volume of Raviraj were the lowest. The sphericity of the varieties varied from 0.500 ± 0.012 to 0.526 ± 0.014 . Thus, the sunflower seeds are not spherical in shape. Phule Bhaskar showed the highest sphericity and Raviraj showed the lowest. Seed shape influences rolling behaviour, flow characteristics, and separation efficiency. Comparable variations in the engineering properties of sunflower seeds have also been reported by Gupta and Das (1997), Işık and İzli (2007), Seifi (2011), Khodabakhshian *et al.* (2010), Voća *et al.* (2008), Figueiredo *et al.* (2011), and Li *et al.* (2024), confirming that seed dimensions and associated engineering properties are strongly influenced by varietal characteristics and moisture content ^[9, 14, 25, 1].

2.4 Initial cracking force of sunflower seeds

Seed hardness was determined using a Texture Analyzer (TMS-PRO). The graph (Fig. 4) showed that Phule Bhaskar generally required higher cracking force than the other varieties in most replications, indicating comparatively greater resistance to fracture. Phule Kalsubai exhibited lower cracking force, while Raviraj showed intermediate to higher values. Similarly, the mechanical behavior of sunflower seeds was evaluated by Gupta and Das (2000); Voča *et al.* (2008); Babić *et al.* (2012); Jafari *et al.* (2011); Khodabakhshian *et al.* (2010) [25, 11, 14] with the results confirming the effect of moisture content, size, shell properties, and variety on rupture force and other mechanical features.

2.5 Angle of repose

The angle of repose indicated differences in the flow characteristics of sunflower seeds. The angle of repose of Phule Kalsubai is lower than Raviraj, indicating that Phule Kalsubai is more flowable. The results of Khodabakhshian *et al.* (2010) and Seifi (2011) also had similar findings. Increased moisture content in an environment decreases inter-particle adhesion which may lead to an increase in the angle of repose and decrease flowability. According to Chavoshgoli *et al.* (2015) [14], the angle of repose is a design factor for storage bins, hoppers and conveying machines, as it influences the flowability of the sunflower seeds.

Table 2: Frictional Properties of sunflower seeds

Frictional Properties of sunflower seeds		
Varieties	Co- efficient of friction	Angle of repose
Phule Bhaskar	0.765±0.085	13.15±0.412
Phule Kalsubai	0.7±0.089	12.397±0.544
Raviraj	0.8±0.056	14.96±0.302

Table 2: Values are mean ± SD

Table 3: Values are mean ± SD

Physical Properties of sunflower seeds					
Varieties	Geometric mean diameter (cm)	Surface Area (cm ²)	Area (cm ²)	Volume(cm ³)	Sphericity
Phule Bhaskar	0.539±0.009	0.914±0.031	0.387±0.013	0.082±0.004	0.526±0.014
Phule Kalsubai	0.566±0.014	1.008±0.05	0.366±0.02	0.095±0.007	0.508±0.006
Raviraj	0.501±0.009	0.788±0.027	0.319±0.012	0.066±0.003	0.5±0.012

2.6 Coefficient of friction

The coefficient of friction of sunflower seeds was determined on a wooden surface. The higher coefficient of friction was observed in Raviraj, indicates greater resistance to movement on the wooden surface, whereas Phule Kalsubai exhibited smoother sliding behaviour. Similar observations were reported by Khodabakhshian *et al.* (2010) [14], who founded that the coefficient

of friction increased with moisture content and varied with the contact surface.

2.7 Thousand seed weight: The thousand-seed weight graph (Fig. 3) showed relatively small variation among the three replications for each variety. Phule Kalsubai recorded the highest thousand seed weight because of its comparatively larger and heavier seeds, whereas Raviraj had the lowest value and Phule Bhaskar had intermediate values.

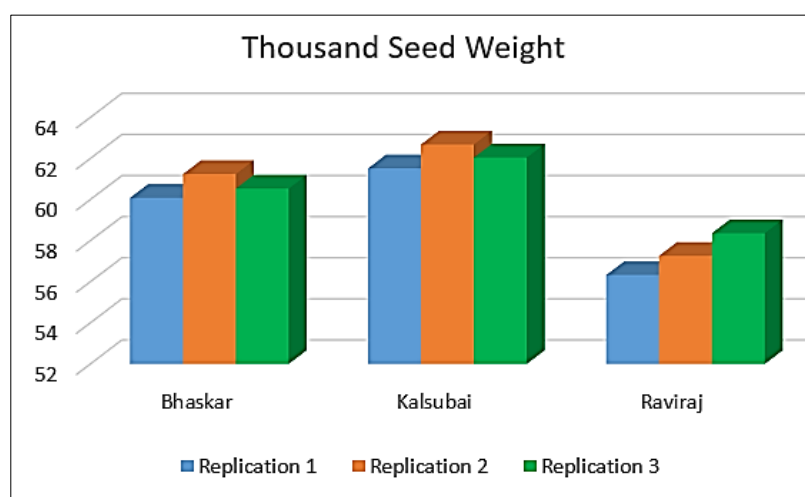


Fig 3: Thousand seed weight

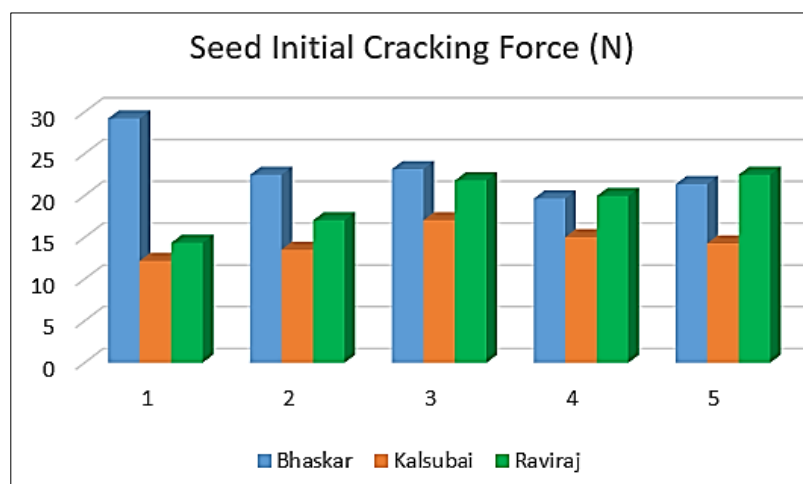


Fig 4: Seed Initial Cracking Force

Conclusion

The present study evaluated the engineering properties of three sunflower (*Helianthus annuus* L.) varieties, namely Phule Bhaskar, Phule Kalsubai, and Raviraj, to generate engineering data for the design and development of sunflower processing equipment. The results revealed distinct varietal differences in the physical, frictional, and mechanical properties of both sunflower heads and seeds. Phule Kalsubai exhibited comparatively higher values for most physical properties and thousand-seed weight, while Raviraj recorded the highest moisture content, coefficient of friction, and angle of repose. Phule Bhaskar showed higher projected area, sphericity, and greater resistance to initial cracking. These findings demonstrate that varietal characteristics significantly influence the engineering behaviour of sunflower. The data generated in this study provide a reliable basis for the design and optimization of sunflower seed removal machines and other post-harvest equipment, thereby improving processing efficiency, minimizing seed damage, and supporting the mechanization of sunflower production.

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