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Engineering Properties of Onion Seeds for Sustainable Agricultural Machinery Design

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The engineering properties of the crop are an important factor in effectively designing agricultural machines. In terms of onion seeding or planting, various physical, mechanical, and frictional properties play a crucial role in the development of planting machines and performance assessment. The study on the engineering properties of onion seeds and their implications for agricultural machinery design supports the adoption of sustainable agricultural practices. Efficient and precise planting systems can optimize resource utilization, reduce wastage, and enhance overall agricultural productivity. This focus on engineering aspects in machinery design indirectly contributes to sustainable agriculture practices, which prioritize minimizing environmental impacts while ensuring food security. Ultimately, by emphasizing the importance of engineering properties, the study promotes the development of agricultural systems that align with sustainability goals. In this study, various engineering properties of onion seeds concerning the different soaking times have been studied. An experiment was performed to assess the change in engineering properties

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of onion seeds (Gavran, Puna fursungi, and KSP-117) by soaking them in water with a predefined duration (Dry seed, Day 1 and Day 2). The average moisture content of onion seeds varied from 9.44 to 40.87 % (d.b.). Sphericity, aspect ratio, geometric mean diameter, and thousand seed weight varied in the range from 0.72 to 0.77, 0.71 to 0.76, 2.05 to 2.18 mm, and 3.50 to 6.75 g, respectively. The bulk density of onion seeds was observed in the range of 489.64 to 526.24 kg/m^3. It was observed that there was a gradual increment in bulk density with an increase in soaking time. However, a gradually decreasing trend was observed in the case of true density. The true density of onion seeds varied from 1127.14 to 1245.64 kg/m^3. The coefficient of friction of onion seeds on a selected material (Wood, Plastic, Mild steel, and Aluminum) showed gradual growth concerning the soaking time.

Keywords: Onion seeds; engineering properties; planting; physical properties; mechanical properties; frictional properties.

1. INTRODUCTION

Onion is widely consumed as a vegetable in India and involves as a staple food. India is one of the largest producers of onions in the world after China. Due to the continually increasing demand for onion in foreign markets, onion export has jumped 64 % in volume. The country has exported 1.53 lakh MT of fresh onion to the world, worth Rs. 3.43 thousand crores during the year 2021-22. Major onion-producing states are Maharashtra, Madhya Pradesh, Karnataka, Gujrat, and Rajasthan, which contributed more than 75 % share in the production of onion. The cultivation area of the onion in 2022-23 was estimated to be 5.8 lakh hectares where production was found to be 318 lakh metric tons.

The demand for onion is also increasing with increasing the population, labor scarcity is one of the major issues due to the expansion of urbanization. Climate change poses risks to global food security, and onions are an important staple crop in many regions. Onion seeds selected for specific environmental conditions, such as drought tolerance or resistance to pests and diseases, can help mitigate the negative impacts of climate change. Onion seeds to improve their productivity, disease resistance, and nutritional content can contribute to ensuring food availability and stability, especially in areas vulnerable to climate-related disruptions in agriculture.

Mechanization is one of the important tools to address the above-said issues. Utilizing exact and heuristic algorithms [1,2] for the screen line problem empowers modern machines and robotics to efficiently perform a range of agricultural operations, including planting, navigation, harvesting, resource management, and data collection. By employing algorithms, farming processes are being enhanced with optimized operations, precision agriculture techniques, and improved overall efficiency. On the other hand, the engineering properties of the crop are an important factor in designing any machine effectively. Thus, the machine can perform effectively and enhance productivity and production. It's important to note that the specific climate effects of mechanized planting can vary depending on factors such as the scale of operations, machinery used, local agricultural practices, and the overall sustainability of the farming system. Nonetheless, by promoting efficiency, precision, conservation, and responsible resource management, mechanized planting techniques can contribute to more climate-friendly onion production practices.

To design a machine for onion seeding or planting, various physical, mechanical, and frictional properties play a major role and influence in the development of machines such as a pneumatic planting machines, inclined plate planting systems, seed cleaners, graders, sorting machines, transportation components, etc. There are various researchers studied the properties of onion and similar seeds for the design of various machines such as Punil et al. [3] analyzes the engineering properties of onion seed (Gujarat white onion-1) in the aspect of the design of various agricultural equipment such as precision planter. The planting device needs only one seed to be placed at a pre-specified distance. Due to the very small size of the onion seed, it is difficult to maintain uniformity with the metering device. The metering device is an essential factor that should be designed properly corresponding to the crop properties. Frictional, mechanical, and aerodynamic properties of onion seeds were determined by Pandiselvam et al [4] in the aspect of designing of onion thresher. All properties of onion seed were observed by varying the moisture content. Similarly, Yalcin et al. [5] also evaluated the various properties of onion seedlings where moisture content varied from 7.81 to 23.99 % (d.b.). the study revealed that the thousand seed weight varied from 3.85 to 4.33 g, and sphericity from 0.65 to 0.68. Bulk density and true density lay in the range of 550.18 kg/m^3 to 521.68 kg/m^3 and 1096.49 to 1083.46 kg/m^3, respectively. It was also reported that the coefficient of friction of onion seeds was increased linearly with the increase in moisture content. It varied from 0.16 to 0.23 and 0.15 to 0.19 for aluminum and galvanized material.

Jadhav et al. [6] conducted a study to analyze the engineering properties of paddy and wheat, in the aspect of designing of the pneumatic planting device. The size and shape of seeds are essential factors. Based on the size of the crop and its other properties, orifice sizes need to be optimized for the efficient performance of the planter. A study was performed by Gautam et al. [7] to study the engineering properties of pelleted onion seeds. Pelleted seeds were less stuck in mechanical planters, which allow growers to accurately and efficiently plant direct seeded crops. Evaluated properties were used to design the different components of the planter. Small and irregular seed size leads to affect the placement of the seed in the existing plant system. For effective mechanism development of onion seed, the study of engineering properties is primarily important. These properties change with a change in location and variety. Thus, this study focused to analyze the various engineering properties of onion seeds for particular locations and varieties.

2. MATERIALS AND METHODS

This study was conducted for three different varieties *i.e*., Light Red Gavran, Puna Fursungi, and KSP-117 of onion seeds, which most prevailed in different regions of India. To assess the physical, mechanical, and frictional properties of onion seeds, the study was conducted in the laboratory of ICAR-Central Institute of Agricultural Engineering, Bhopal. Different properties *viz*., size, sphericity, aspect ratio, weight, bulk density, true density, coefficient of friction, etc. were measured for dry, 1- day-soaked, and 2- day-soaked seeds of all three selected varieties.

2.1 Preparation of Sample

Onion seeds of all three varieties were taken in the laboratory. The seeds were separated into three parts, *i.e.,* one part is soaked for one day, the second part for 2 days and the third part was kept dry. The soaking process of seeds is an essential process, which breaks the dormancy of the seed, increases the germination process, and provides uniform growth. Thoroughly hydrated seeds before planting are mainly helpful for hard coated seed, as it helps to overcome any water-related germination barriers. Thus, all engineering properties were measured for dry, 1-day-soaked, and 2- day-soaked seeds of all three varieties.

2.2 Moisture Content of Onion Seeds

Various properties of the seeds majorly depend on the moisture content of seeds [6], such as seed weight, sphericity, the density of seed, coefficient of friction, etc. The change in moisture content significantly affects these properties. Therefore, the moisture content of onion seeds was determined by using the hot air oven method by maintaining the temperature at 105 ºC for 24 h [8]. Onion seed weight was measured before and after drying with the help of weighing balance (Model Citizen CY 304, least count of 0.0001 g). Moisture content was determined with the help of Equation 1.

$$\text{Moisture content (db), \%} = \frac{M_1 - M_2}{M_2} \times 100 \quad (1)$$

Where M_1 is the Weight of the sample before drying, g and M_2 is the Weight of the sample after drying, g.

2.3 Size

The Size of onion seeds is a prominent factor in deciding the metering mechanism which can influence the performance of the planting system. In the case of pneumatic planting, the orifice size of the pneumatic unit needs to be optimized to reduce the unnecessary losses and consequently reduced the germination due to the breakage of the seed. Thus, the length, width, and thickness of onion seed were measured by vernier caliper (make: Baker; model: SDN 30, least count: 0.01 mm).

2.3.1 Geometric mean diameter

The geometric mean diameter represents the size index of the seeds. It is a single representative of all three linear dimensions. The geometric mean diameter can be determined by Equation 2 (Mohsin, 1970).

$$\text{Geometric mean diameter} = (\text{LBT})^{1/3} \qquad (2)$$

Where, L is the maximum length of the onion seed, mm; B: the width of the onion seed, mm and T: the thickness of the onion seed, mm.

2.3.2 Sphericity

Sphericity is representative of the shape of the seed. The sphericity of the onion seed can be determined by dividing the geometric mean diameter by the maximum axial length of the seed (Mohsin, 1970).

2.3.3 Aspect ratio

It is also representative of the shape parameter. It is the ratio of width to axial length of the seed (B/L).

2.4 Weight of Seed

Thousand seed weight is the significant parameter for seed quality assessment and, its commercialization and cultivation practices. It, directly and indirectly, influences the growth and yield of crops. Thousand seed weights were calculated by collecting randomly 1000 seeds of onion and weighted using weighing balance (Model Citizen CY 304). It was replicated five times.

2.5 Bulk Density

The bulk density of seeds was calculated using a circular container where the volume of the container was known. The circular container is filled with seeds and gently tapped to compact it [9]. The weight of filled seeds was measured and bulk density was measured by taking the ratio of the mass of the seed to the volume of the circular container. It was replicated five times.

2.6 True Density

The true density (ρ_t) of onion seed was calculated using the toluene displacement method [10]. The toluene was filled in a measuring cylinder and a selected quantity of seeds (fixed weight) were filled into the liquid. The displacement volume of liquid (true volume) due to pouring seeds were measured and true density was calculated by taking the ratio of the mass of the onion seeds and the true volume of onion seeds. Each treatment was replicated five times.

2.7 Coefficient of Friction

The fictional force (F) to the normal force (N) ratio is used to express the coefficient of friction (Bajpai *et al.* 2019). It is expressed by 'μ'. The coefficient of friction varied with the material used to design the different components of the planting machine. Thus, the coefficient of friction was measured for different selected platforms namely, wood, plastic, and mild steel sheet for all three varieties.

2.8 Statistical Analysis

SPSS software was used to perform the analysis of variance using full factorial in a completely randomized design. Tukey's (b) test was performed for pairwise comparison of the mean of variables [11]. All data were assessed and examined at a 5 % level of significance.

3. RESULTS AND DISCUSSIONS

3.1 Moisture Content

Moisture content of onion seed is an important factor insight to healthy growth and better yield of onion. The level of moisture affects every aspect of the physical characteristics of seeds. All the properties are affected by the moisture content [9,5].

Fig. 1 showed that the moisture content (d.b.) of onion seeds for all selected varieties varied from 9.44 ± 0.57 % to 40.87 ± 0.67 %. Due to the soaking process, the moisture content of onion seeds was increased from zero days to the second day. Moisture absorption percent was observed to be higher for the KSP 117 variety, however, the minimum moisture content for dry onion seed (7.50%) was also reported in the KSP 117 variety. the Puna fungi variety showed a higher moisture content (13.25%) for dry seed. In the same manner, the maximum percent of moisture for two days-soaked onion seed was found for KSP 117 variety, whereas, for the light red and Puna fungi variety this was observed to be similar at par as 34.71 % and 34.34 % respectively. Observed findings were in agreement with the study conducted by Pandiselvam et al [4].

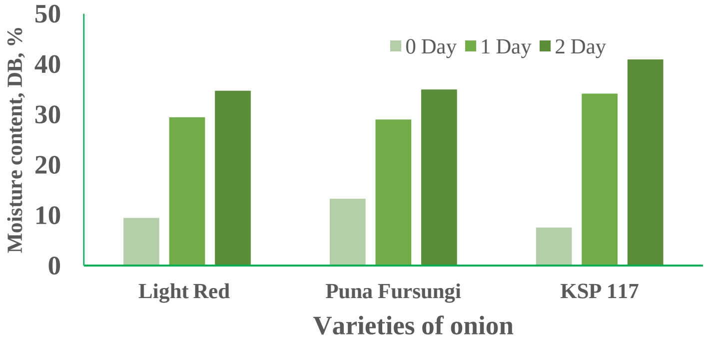

Fig. 1. Variation of moisture content of onion seeds during the soaking period

3.1.1 Geometric mean diameter

The geometric mean diameter was determined using primary linear dimensions. The minimum value of GMD was observed as 2.05 mm for the Gavran variety (dry seed), while the maximum GMD was reported as 2.18 mm for the 2-day-soaked seed for the KSP-117 variety (Table 1). A gradual increase in geometrical diameter concerning the soaking time was observed. The increase in GMD with the increase in the soaking period might be due to the absorption of moisture by the seeds leading to the elongation of linear dimension. Due to the hygroscopic nature of the onion seed, water molecules were absorbed by the seed and held in the cellular structure of the seeds. Through the process of water absorption, seeds swelled which led to an increase in the size of the seeds. Similar results were reported by Sunitha et al. [12] and Punil et al. [3].

3.1.2 Sphericity

The onion shape was presented by using the sphericity and aspect ratio. The sphericity of seeds can impact their flow characteristics within a machine or conveyor system. Seeds with higher sphericity tend to roll more easily, promoting smoother and more predictable material flow. The average sphericity of onion seeds under different soaking conditions varied from 0.72 to 0.76 from zero days (Dry seed) to 2 days of soaking period. Punil et al. [3] also reported average sphericity of 0.75 for GWO-1 onion variety, which was similar at par with the findings of the study. Table 1 showed that sphericity remained unaffected by the sowing period.

3.1.3 Aspect ratio

Based on the primary linear dimensions, the aspect ratio of onion seed was determined for all selected varieties for dry, 1-day, and 2-day soaking periods. Table 1 showed that the aspect ratio of onion seeds varied from 0.71 to 0.76. A maximum aspect ratio (0.76) was observed for the KSP-117 variety, whereas, a minimum aspect ratio (0.71) was observed in the Gavran variety. Punil *et al.,* 2019 reported that the average aspect ratio of onion seed was 0.74, It was in agreement with the finding of this study.

3.2 Thousand Seed Weight

Thousand seed weights of onion seed samples were assessed. Thousand seed weights of onion seeds were gradually increased concerning the soaking time. This was due to the absorption of moisture by the seed with time. It was observed that thousand seed weight of onion seeds varied from 3.50 to 6.75 g. thousand seed weight was the minimum for the dry seed of the Puna fungi variety. It was revealed that the thousand seed weight followed an increasing trend with the increase in the soaking period. Table 2 showed that the thousand seed weight was significantly affected by the variety and soaking period. It was also revealed that the interaction of variety and soaking period also significantly affected the thousand seed weight. It might be due to the varietal effect and moisture absorption of onion seeds leading to changes in linear dimensions. Table 3 showed that there was a significant difference between the mean of thousand seed weights for the variety Gavran and Puna fursungi with KSP-117. Whereas, thousand seed weights were significantly different for all three soaking treatments. It might be due to the variation in moisture content in all three soaking treatments.

3.3 Bulk Density

Gravimetric properties were a principal factor in the theoretical design and effective calculation for optimum suction required to seed picking, holding the pneumatic metering unit, and hopper size calculation for mechanized plantation [13,14]. Thus, Bulk density for the selected varieties was recorded concerning the soaking time and assessed the factor accordingly to the effect of moisture content. The bulk density varied from 481.57 to 597.94 kg/m^3 (Table 1). Table 2 revealed that the bulk density was significantly affected by the variety and soaking period. The first-order interaction of variety and soaking period was also found significant. The bulk density was significantly increased with the increase in the soaking period. Sunitha et al. [12] and Pandiselvam et al. [9] also reported similar findings. Tukey's (b) analysis showed that there was a significant difference in the bulk density of all three varieties (Table 3). This might be due to variations in linear dimensions of all three varieties and absorption of moisture. The bulk density was also significantly different for all three soaking treatments. The increase in the bulk density by soaking treatments might be due to a reduction in intergranular pore space [9].

3.4 True Density

The true density of onion seed was also evaluated with different soaking times for all three verities. Table 1 showed that the true density varied from 1113.96 to 1245.64 kg/m^3. The true density was significantly affected by the variety and soaking period (Table 2). Tukey's (b) analysis showed that the true density of the Gavraan variety had a significant difference with the Puna fungi and KSP-117 Variety. Whereas, there was no significant difference between the true density of Puna fungi and the KSP-117 Variety. It might be due to variations in the linear dimensions of all three varieties. The true density of dry seed was significantly different with the soaking period of one and two days. However, there was no significant difference in true density by soaking for one and two days (Table 3). It was observed that the true density decreased with the soaking of one day thereafter, it further increased for the soaking of two days.

The observed trend was found to be similar to the study reported by Bajpai et al. [15]. When onion seeds absorb moisture, they tend to swell and increase in size. This swelling increases in volume while the mass remains relatively constant, causing the true density to decrease. The soaking period of one or two days had no significant difference in true density might be due to less variation in the weight and volume of the seed as most of the pores filled with water after one day of soaking (Table 3).

3.5 Coefficient of Friction

The coefficient of friction (μ) of onion seeds was observed for the selected platform materials (Wood, Plastic, Mild steel, and Aluminum) and depicted in Fig. 2. The study revealed that the 'μ' varied from 0.55 to 0.64, 0.25 to 0.56, 0.36 to 0.66, and 0.36 to 0.63 for wood, plastic, mild steel, and aluminum material respectively. The coefficient of friction was gradually increased during the soaking period. Pradhan et al. (2009) and Garnayak et al. [16,17,18] also revealed that the coefficient of friction was increased by increasing the moisture content. A similar trend was observed for all the platform materials except the plastic surface.

Table 1. Engineering properties of onion seeds for different varieties with soaking time

Particulars		Gavran			Puna Fursungi			KSP-117		
		Dry	1 Day	2 Days	Dry	1 Day	2 Days	Dry	1 Day	2 Days
Sp	Mean	0.72	0.73	0.75	0.75	0.75	0.74	0.76	0.76	0.76
	SD	0.81	0.90	0.94	0.06	0.06	0.05	0.07	0.06	0.04
	CV, %	7.67	8.93	10.4	7.67	8.20	7.09	9.04	7.78	4.78
AR	Mean	0.71	0.74	0.74	0.74	0.76	0.72	0.75	0.76	0.76
	SD	0.07	0.07	0.09	0.08	0.08	0.08	0.09	0.08	0.07
	CV, %	9.64	9.15	12.65	10.91	12.40	10.85	12.84	10.44	9.20
GMD, mm	Mean	2.05	2.17	2.15	2.12	2.24	2.19	2.08	2.25	2.18
	SD	0.17	0.11	0.17	0.14	0.21	0.16	0.14	0.15	0.11
	CV, %	7.69	5.24	8.11	6.85	9.42	7.21	6.87	6.51	4.93
BD, kg/m^3	Mean	497.83	565.62	597.94	481.57	553.29	570.51	483.24	547.47	549.69
	SD	5.41	7.58	6.58	8.86	4.19	15.75	6.71	14.10	23.05
	CV, %	1.09	1.34	1.10	1.84	0.76	2.76	1.39	2.60	4.19
TD, kg/m^3	Mean	1245.64	1179.71	1195.98	1160.15	1127.14	1130.11	1194.71	1113.96	1146.72
	SD	65.12	10.19	75.38	60.19	33.27	27.47	30.94	24.10	62.35
	CV, %	5.23	0.86	6.30	5.19	2.95	2.43	2.59	2.16	5.44

Table 2. Analysis of variance for selected engineering properties of onion seeds

SOV	Bulk density	True density	1000 seed weight	Coefficient of friction			
				Wood	Plastic	Mild Steel	Aluminum
Model	<0.0001**	<0.002**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Variety	<0.0001**	<0.001**	<0.0001**	<0.0001**	<0.0001**	<0.019*	<0.0001**
Days	<0.0001**	<0.005**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Variety × Days	<0.033*	<0.846^{NS}	<0.004**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Mean	537.90	1166.02	5.55	0.54	0.42	0.51	0.52
R^2	0.93	0.96	0.94	0.99	0.98	0.97	0.97

*** Significant at 1 % level of significance; * Significant at 5 % level of significance; NS Non-significant*

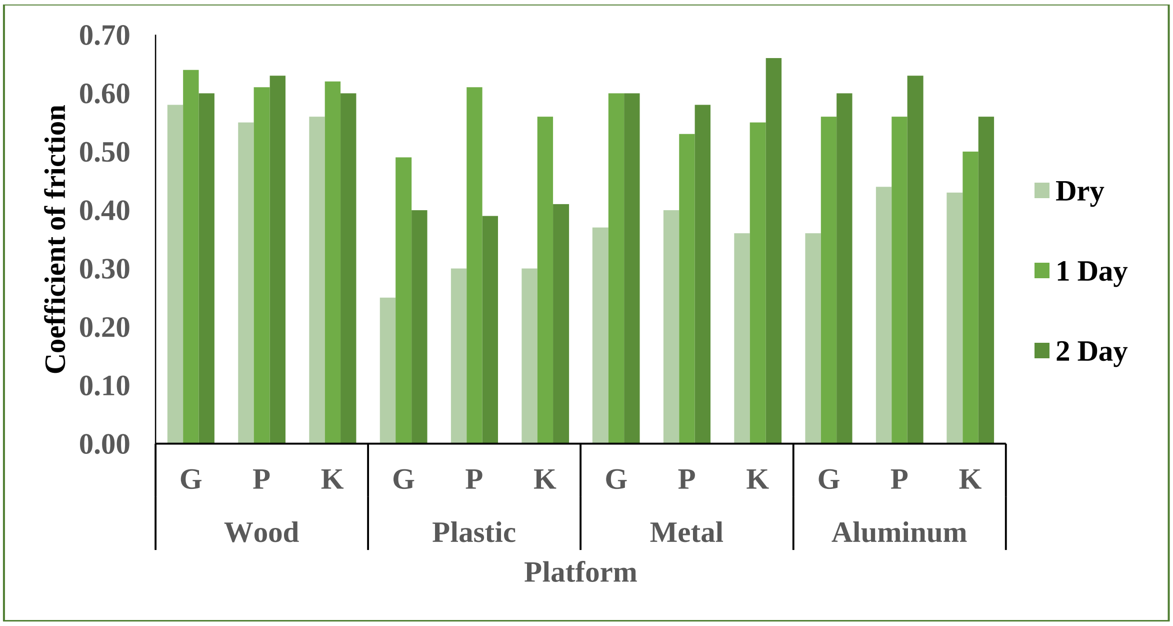

Fig. 2. Coefficient of friction under different platforms for different varieties (G- Gavran; P- Puna Fursungi; K- KSP-117)

Table 3. Tukey's b comparison least squares mean (LSM) of dimensional properties

Particulars	Varieties			Soaking time		
	Gavraan	Puna fursungi	KSP-117	Dry	One day	Two days
LSM of BD, kg/m^3	524.80^a	535.12^b	553.79^c	487.54^a	553.46^b	572.71^c
LSM of TD, kg/m^3	1207.10^b	1139.12^a	1151.79^a	1200.16^b	1140.26^a	1157.60^a
LSM of 1000 seed weight, g	5.02^a	5.02^a	5.55^b	3.75^a	5.63^b	6.21^c
LSM of CF Wood	0.60^b	0.51^a	0.51^a	0.39^a	0.61^b	0.62^c
LSM of CF plastic	0.38^a	0.43^b	0.43^b	0.29^a	0.40^b	0.55^c
LSM of CF MS	0.51^a	0.53^b	0.53^b	0.37^a	0.56^b	0.62^c
LSM of CF Aluminum	0.51^a	0.52^b	0.54^c	0.41^a	0.56^b	0.59^c

However, in the case of plastic material, µ was gradually reduced after the first day of soaking time. Similar findings were reported by Pandiselvam et al. [9]. It might be due to more smoothness of the plastic surface and less moisture absorption capacity. Plywood surface offered maximum coefficient of friction even in case of dry seed also. Jadhav et al. [6] also reported the µ for paddy and wheat on wood, plastic, and mild steel material.

Analysis of variance depicted that the coefficient of friction was significantly affected by the variety and soaking period for all the platform materials. The first-order interaction of variety and soaking period was also found significant at a 1% level of significance (Table 2). For all of the platform materials selected, the coefficient of determination was also found to be higher than 0.90 which showed that the model predicted adequately. Tukey's (b) mean comparison showed that there was a significant difference in the coefficient of friction with the soaking treatment for all the platform materials. Whereas, the coefficient of friction for the Gavraan variety was significantly different from the Puna fungi and KSP 117 variety for wood plastic and MS material. Whereas, in the case of aluminium it was different for all three varieties.

4. CONCLUSIONS

This study focused on analyzing the engineering properties of onion seeds about different soaking times and their implications for sustainable agricultural machinery design. The engineering properties of onion seeds were highly influenced by the moisture content of onion seeds which was varied by soaking the seeds. It revealed that the moisture content plays an important role by which the other essential properties of seeds were also affected. All linear dimensions were gradually increased with the increase in moisture content. Gravimetric properties are an important factor in terms of design consideration of any machine development. Variations in the moisture also influenced the gravimetric properties. Bulk density was linearly increased concerning the soaking time and varied from 481.57 to 597.94 kg/m^3. However, a declining trend was observed for true density. The study also revealed that the coefficient of friction was also affected significantly by the variety and soaking period for different platform materials. Thus, the variety and moisture content played a significant role in the engineering properties of onion seed. This study actively contributes to the promotion of environmentally friendly and resource-efficient farming practices through the optimization of resource utilization, minimization of wastage, and improvement of agricultural productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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