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Engineering Properties of Fenugreek

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ABSTRACT: This study addresses the critical need for engineering properties essential in the design of agricultural machinery related to fenugreek cultivation, such as sowing machines, weeders, machinery related to fenugreek plant, and post-harvesting equipment. The research, conducted at the College of Agricultural Engineering, JNKVV, Jabalpur, focuses on gathering information about the engineering properties of fenugreek plants. The frictional properties of fenugreek were explored, revealing an angle of repose at 55.22°, an average angle of internal friction of 42°, and an average static coefficient of friction of 0.89. Additionally, the mechanical property of fenugreek, specifically the cutting force, was quantified at 0.686 N. These findings contribute valuable insights into the mechanical behaviour of fenugreek, providing essential data for the design and optimization of agricultural machinery tailored to fenugreek cultivation.

Keywords: Engineering properties, agricultural machinery, Fenugreek.

INTRODUCTION

Due to the limited availability of locally grown fresh vegetables, particularly during the winter months, there are seasonal variations in dietary habits. As fresh vegetable supplies diminish during this period, there arises a necessity for effective storage solutions, especially for leafy greens. To address this need, exploring the engineering properties of fenugreek becomes imperative. Understanding these properties can facilitate the development of storage methods tailored to prolong the shelf life of fenugreek and other leafy vegetables, ensuring their availability and nutritional value during periods of scarcity. Fenugreek (*Trigonella foenum-graecum* L.), a member of the Fabaceae family, is a seed spice widely recognized as 'methi' in Hindi and 'Menthya' in Kannada. Originating from South Eastern Europe and West Asia, this annual herbaceous plant is extensively cultivated in various regions, including India, Morocco, Bulgaria, Pakistan, Bangladesh, Egypt, China, France, Africa, and Lebanon. In India, Rajasthan and Gujarat emerge as the primary producing states, with Uttar Pradesh following suit (Anonymous, 2001). Covering an expansive area of 40,000 hectares, fenugreek boasts an average production of 50,000 tonnes in India. Notably, during the 2000-2001 period, India achieved a foreign exchange income of Rs. 1787.5 lakhs by exporting 9050 metric tonnes of fenugreek (Anonymous, 2001). The nation's rich flora encompasses 6000 plant species, with a notable one-third being green leafy vegetables, underscoring their significance in daily consumption (Garande *et al.*, 2019). Neglecting these essential mechanical properties during equipment design may lead to suboptimal results (Oluka *et al.*, 2010). Recognizing the importance of these engineering properties, this study focuses on fenugreek and aims to provide fundamental insights that can guide efficient process and equipment development. Notably, various researchers have extensively studied and determined engineering properties such as angle of repose, coefficient of static friction, coefficient of internal friction, hardness, for different millets under varying moisture content conditions (Balasubramanian and Vishwanathan 2010). The results underscore the vital role of engineering properties in machine and equipment design, showcasing their significance in examining and defining machinery efficacy. Furthermore, these properties play a crucial role in determining the quality and studying the behaviour of agricultural products during unit operations in processing. Recognizing the broader implications, it is evident that engineering properties of grains are not only pivotal for designing machines, processes, and structures but also instrumental in ensuring the efficiency and quality of agricultural processing operations.

MATERIALS AND METHODS

Frictional properties and mechanical properties are integral components of engineering properties. In the realm of materials and machinery design, these characteristics play crucial roles in determining how materials interact and respond to external forces. Frictional properties encompass aspects such as the angle of repose, internal friction, and static coefficient of friction, providing insights into how surfaces resist motion or sliding against each other. On the other hand, mechanical properties, including cutting force, hardness, and other measures, offer valuable information about a material's strength, durability, and response to applied forces. The consideration of both frictional and mechanical properties is essential in engineering, as it influences the design, functionality, and performance of various tools, machines, and structures across diverse applications. The comprehensive understanding of these engineering properties is vital for optimizing efficiency, reliability, and safety in engineering practices.

A. Frictional properties of selected leaf crops

Frictional properties of fenugreek are important in the context of cultivation machinery related to fenugreek because in conveying systems, the material generally moves or slides in direct contact with the conveyor belt, casing and other components of the machine, impacting the efficiency of harvesting and processing operations. Understanding the frictional properties of fenugreek helps in designing and optimizing cultivating equipment to minimize damage, reduce energy consumption, and improve overall handling efficiency.

Factors such as the surface texture of the fenugreek, moisture content, and the type of surfaces they come into contact with, influence their frictional behaviour. The study of frictional properties of fenugreek is crucial for designing efficient cultivating machinery related to fenugreeks that can gently and effectively harvest, transport, and process the vegetables without compromising their quality and appearance. The frictional properties like static coefficient of friction, and angle of repose were studied. These properties are very important in deciding the angle of conveyor.

(i) Angle of repose. The "angle of repose" refers to the angle formed between the base and the slope of a cone that is created when a material freely falls vertically and accumulates into a heap on a horizontal surface. Fig. 1 displays the measurement of the angle of repose for chosen fenugreek. In the context of the leafy crop machinery related to fenugreek, this angle was determined by conducting experiments. The process involved creating a heap of fenugreek through a free fall method, measuring the height and radius of the heap, and then using a specific equation 1 (Herderson and Perry 1976) to calculate the angle of repose. This experiment was repeated ten times to obtain a more reliable average value for the angle of repose. The goal was to understand how the fenugreek naturally flowed and assumed a slope when freely falling and accumulating.

$$\alpha = \tan^{-1}(h/L) \quad (1)$$

Where,

α = Angle of repose, degree;

h = Height of the heap, mm; and

L = Radius of the heap, mm.

Fig. 1. Measurement of sliding friction of selected fenugreek.

(ii) Static coefficient of friction. The sentence outlines a procedure for determining the coefficient of static friction (μs) for a crop using the inclined plane method. Fenugreek plants are positioned horizontally on an instrument's plate, and the slope is incrementally increased until the crop begins to slip. The angle at which this slip occurs is measured, as depicted in Fig. 2. Simultaneously, the angle of inclination between the test surface and the ground is measured using a bevel protractor, considering it as the angle of internal friction. The tangent of this angle serves as the coefficient of friction between the surface and the crop sample. The value of the coefficient of static friction (μs) is then calculated using equation 2, as specified in the work by Ghaffari *et al.* (2013). This comprehensive approach ensures a systematic determination of the crop's coefficient of static friction, crucial for understanding its interaction with surfaces.

$$\mu = \tan\varnothing \quad (2)$$

Where,

μ = Coefficient of static friction; and

∅= Angle of rolling resistance, degree.

Fig. 2. Texture analyzer with cutting and cutting probe.

B. Mechanical properties of fenugreek

Mechanical properties significantly impact the fenugreek cultivation process, equipment design, and overall crop yield. Moreover, knowledge of these properties aids in preventing crop damage during harvesting, ensuring the produce reaches consumers in fresh condition, and ultimately contributing to sustainable agricultural practices. The variation in the mechanical properties of plant stalks and the resistance of cutting have to be known in order to understand the behaviour of material with respect to different operating conditions of harvesting. Comparative performance of cutting elements applied in machinery related to fenugreek design can be judge by their cutting energy requirements, cutting force and stress applied (Chakraverty *et al.*, 2003). Hence, it is necessary to determine the cutting energy requirements for suitable cutting unit selection and also operational parameters (Yilma *et al.*, 2008). A thorough understanding of these mechanical properties is indispensable for engineering crop machinery related to fenugreeks that exert the right amount of force without causing excessive bruising or breakage.

(i) Measurement of cutting resistance of fenugreek. The cutting force of fenugreek plant emerges as a crucial mechanical parameter in the process of fenugreek cultivating machinery. It is employed to determine the force necessary for cutting fenugreek by the machinery related to fenugreek's cutting unit. The essential measure for selecting the cutting unit revolves around the cutting force of the fenugreek.

To quantify the cutting force of fenugreek, a computer-controlled texture analyser (Stable Micro Systems, United Kingdom, machine model number TA-XT Plus) available at the Department of Post Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur was utilized. The measurement process involved randomly selecting three samples with varying stem diameters from fenugreek stems.

Fig. 3, clearly shows texture analyser. The heavy-duty platform served as the base for various attachments fitted to the texture analyser, including a base plate fixed at the lower end. The fenugreek plant was positioned horizontally on the base plate, ensuring the cutting point was at the centre of the sample. The probe carrier at the top of the texture analyser accommodated a highly sensitive load cell. The force was measured by affixing the load cell to the movable bar of the texture analyser. A weight was suspended on the load cell using a hanger, with the measuring base left free from attachments, providing sufficient clearance for the weights to hang freely, ensuring the probe was free.

For the cutting force test, the HDP/WBR; Warner Bratzler rectangular notch blade probe set was employed, as illustrated in Fig. 4. This set ensured precise adjustment of probes and product samples. After configuring the machine, the crop sample was placed on the base plate, and the cutting probe moves, cutting at the sample's center.

The maximum force required to cutting the fenugreek plant testing procedure, the cutting probe steadily moves from the top portion to the bottom, fracturing the fenugreek samples at specified distances. The testing involved distinct speeds: a pre-test speed of 2.0 mm/s, a test speed of 1.0 mm/s, and a post-test speed of 10.0 mm/s, as outlined by (More *et al.*, 2014).

Once the probe made contact with the sample, the peak force required for rupturing the fenugreek plant was observed and compared across the samples. The computer recorded the peak force, and upon completion of all tests, a data sheet was generated in graph format setting the machine, the crop sample was kept on the base plate; the cutting probe moved in the downward direction and crushed at the center of the sample. The peak force was obtained with the help of the computer attached to the texture analyzer. The experiment was repeated 10 times for cutting of the crop and average value was calculated.

Understanding these engineering properties of plants is essential for designing and optimizing machinery, equipment, and processes related to fenugreek cultivating machinery and processing. By considering these properties, engineers and agricultural professionals can develop efficient and effective systems for handling and utilizing fenugreek in various industries, such as agriculture, food processing, and biomass utilization.

Fig. 3. Measurement of cutting fore of fenugreek by texture analyzer.

Fig. 4. Rectangular notch blade probe set.

DETERMINATION OF ENGINEERING PROPERTIES

The engineering properties of most common variety of central part of India i.e. fenugreek (Bombay bold**)** variety are angle of repose, cutting force and coefficient of friction were determined for the selected crops. These values were used for designing and fabricating of the fenugreek cultivation machinery.

A. Frictional properties of various treatments

(i) Angle of repose. The angle of repose is a critical parameter in designing agricultural machinery, particularly for related to fenugreek. From the provided data in Fig. 5 and Table 1, the angle of repose of fenugreek was 55.22°. This indicates that fenugreek has a moderate angle of repose, suggesting that the harvested fenugreek leaves can be relatively stable on the machinery related to fenugreek platform even on moderately sloped surfaces. The observed angle of repose values for the fenugreek closely aligned with those reported by Tarighi *et al.* (2011). Showing a high degree of similarity within the selected range. The design can take advantage of this characteristic to ensure efficient harvesting on various terrains.

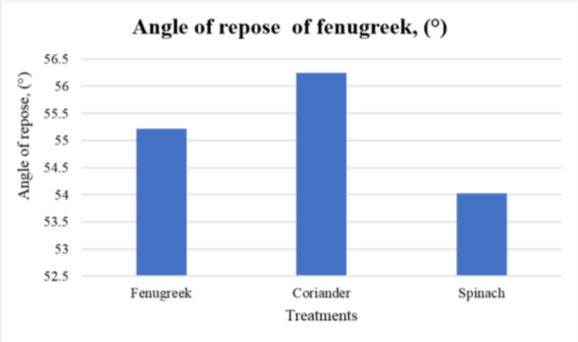

Fig. 5. Angle of repose of selected crops.

(ii) Static coefficient of friction

Angle of internal friction of treatments. The angle of internal friction is a critical parameter in the design of cultivating machinery related to fenugreek plant for to efficiently handle and transport of fenugreek. In the context of fenugreek, the average replication angles of internal friction, as obtained from Fig. 6, were 42°, 43° and 41 °respectively. The obtained angle of internal friction values exhibited a comparable trend when contrasted with the angle of internal friction values reported by Ehiem *et al.* (2015). These values represent the frictional resistance within the crop material and are essential for optimizing the machinery related to fenugreek's performance. Notably, from three replications of treatments. This information is crucial for the design and calibration of machinery related to fenugreeks. This additional information provides insights into the consistency and reliability of the observed frictional characteristics, aiding in the refinement of machinery related to fenugreek cultivating machinery.

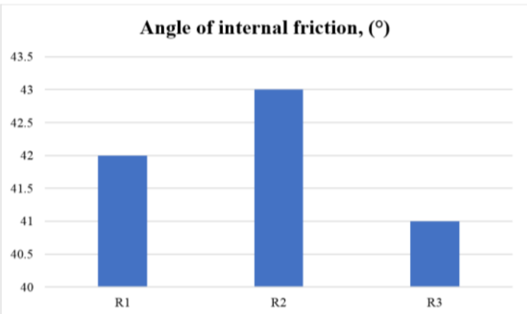

Fig. 6. Angle of internal friction, (°).

Static coefficient of friction of treatments. The static coefficient of friction was a key parameter in the design of cultivating machinery related to fenugreeks, as it influences the machinery's ability to grip and transport fenugreek effectively on conveyor. In the specific context of leafy vegetables such as fenugreek, the average static coefficients of friction Table 1, was 0.89, respectively. From Fig. 7 represents the replications of static coefficient friction of fenugreek that are 0.9, 0.86 and 0.93.The obtained static coefficient of friction values exhibited a comparable trend when contrasted with the static coefficient of friction values reported by Ehiem *et al.* (2015). These values represent the ratio of the force required to initiate sliding to the force pressing the surfaces together, and they play a critical role in determining the performance of conveyor. Understanding these variations in the static coefficient of friction is crucial for the design and optimization of cultivation machinery related to fenugreeks. Lower static coefficients may require adjustments in the machinery related to fenugreek's grip mechanisms to ensure proper engagement and prevent slippage during harvesting operations.

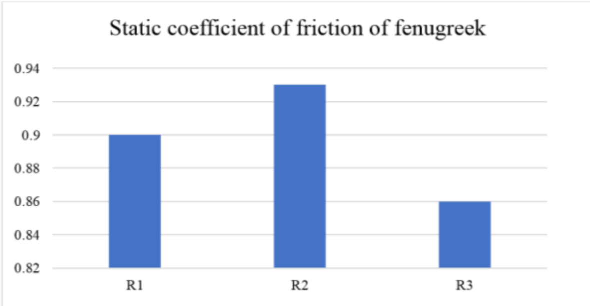

Fig. 7. Static coefficient of friction of fenugreek.

B. Mechanical properties of treatments

In the conducted study, variations in the force required for cutting fenugreek stem were examined, revealing distinctive characteristics. The maximum force requirement for cutting of fenugreek plant illustrated in Fig. 8 and Table 1. The cutting force required for fenugreek was 0.686 N, a higher force value reported by Rathod *et al.* (2020). This discrepancy can be attributed to variations in cutting force requirements, influenced by factors such as the diameter of the stem and the maturity of the plant. The force required for rupturing the samples was thoroughly analysed, and average values were recorded. This analysis demonstrated a range from 0.08 to 1.3 kg concerning time, indicating fluctuations in the cutting force. Notably, the fenugreek cutting process exhibited a sudden occurrence once it reached its peak, emphasizing the criticality of understanding these variations for efficient fenugreek cultivating and processing practices.

Table 1: Engineering properties of fenugreek.

Sr. No.	Particulars	Fenugreek
1.	Avg. of angle of internal friction, (°)	42
2.	Avg. of static coefficient of friction	0.89
3.	Avg. of angle of repose, (°)	54.45
4.	Cutting force, (N)	0.686

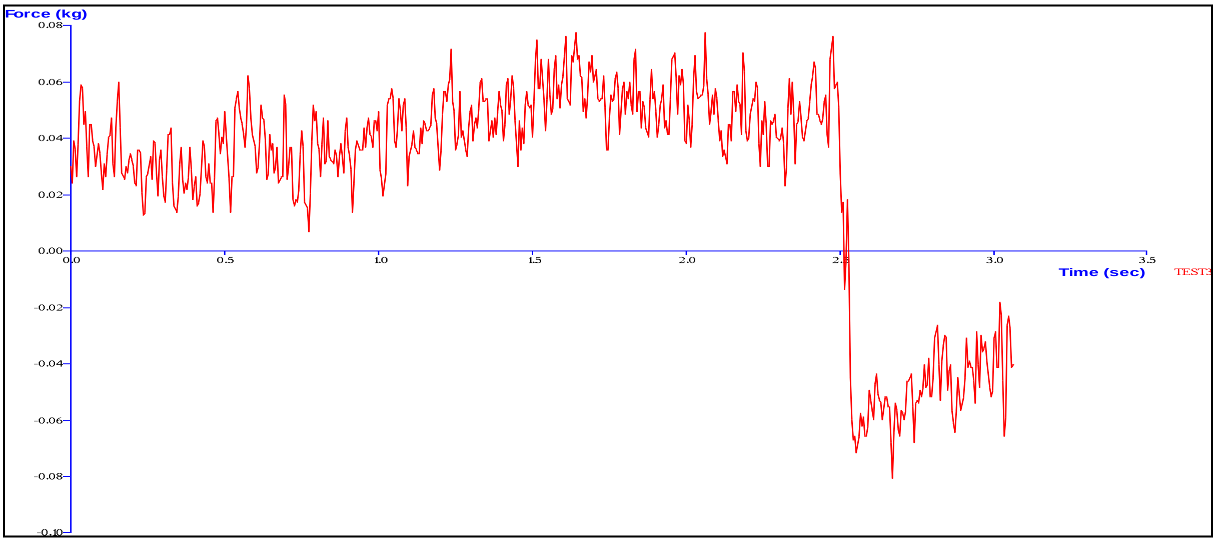

Fig. 8. Force required for cutting of fenugreek plant.

CONCLUSIONS

In conclusion, this study delves into the engineering properties of fenugreek leaves, shedding light on both frictional and mechanical characteristics. The investigation revealed specific frictional properties, showcasing an angle of repose at 55.22°, an average angle of internal friction of 42°, and an average static coefficient of friction amounting to 0.89. Complementing these findings, the mechanical property analysis focused on the cutting force, which was quantified at 0.686 N. These results provide valuable insights into the behavior of fenugreek leaves, offering essential data for the design and optimization of processes and equipment within the agricultural and food industries. The comprehension of these engineering properties not only contributes to the scientific understanding of fenugreek but also holds practical implications for enhancing the efficiency, safety, and overall performance of related technologies and applications.

FUTURE SCOPE

Investigating the engineering properties of fenugreek holds considerable potential across diverse industries. Understanding the physical and mechanical characteristics of fenugreek seeds and plants can revolutionize food processing, agricultural practices, pharmaceutical formulations, material science applications, environmental management strategies, biomedical innovations, cosmetic formulations, and chemical processing techniques. By delving into fenugreek's properties, including its composition, texture, and behavior under various conditions, researchers can unlock new insights into efficient production methods, sustainable agricultural practices, therapeutic applications, and eco-friendly solutions. Ultimately, this interdisciplinary approach to studying fenugreek's engineering properties promises to drive innovation, improve product quality, and contribute to sustainable development in multiple sectors.

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