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Development of a Disc Blade Cutting System for Sesame Harvesting: Determination of Operating Criteria and Energy Requirements

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This study aimed to explore the use of rotary disc blades in cutting, since the mowing units used in sesame harvesting contain many parts, require frequent lubrication, and have vibration problems. An experimental setup with a disc blade working on a cut-mowing system based from harvesting methods of sesame plants was designed and fabricated. The most suitable cutting criteria which are blade edge types (30°-30°, 30°-Flat, 45°-45°, 45°-Flat) and disc blade diameters (150, 180, and 210 mm) were determined for shearing and disc cutting action. The lowest cutting energy was consumed by the disc blade with a 30°-wedge angle at all stem thicknesses and by the disc blade with a diameter of 180 mm for large stem thicknesses. In all pairs of edge, as the disc diameter increased, the energy spent for cutting the stems decreased. There was a significant difference between the two methods in terms of energy consumption only when cutting stems with a diameter of 10 mm. These results show that disc cutting can be recommended as a method for sesame harvesting.

Keywords: sesame harvesting, disc blade cutting, shear cutting, cutting energy

INTRODUCTION

Sesame (*Sesamum indicum* L.) is an annual herbaceous oil plant belonging to the Sesamum genus of the Pedaliaceae family of the Personatae order (Salunkhe et al. 1992; Baydar and Turgut 2000; Baydar 2005; Arıoğlu 2007). It is widely consumed in pastries such as bagels, cakes, donuts, and confectionery. Its oil is also used in the soap and cosmetics industries (Atakişi 1999). Sesame is planted in main crop agriculture as well as in secondary crop agriculture due to its short growing period and its ability to enter crop rotation with almost any cultivated plant (Tan 2015). In 2021, the world's total sesame cultivation area was calculated at 12.5 million ha and 6.4 Mt, with Sudan, India, and the United Republic of Tanzania as the plant's top producers (FAO 2022).

Sesame that has reached harvest maturity should be harvested quickly and on time, since delays in harvest time cause a decrease in the moisture content of the sesame capsules and induce opening of the capsule mouth. This causes a considerable increase in losses during harvest (Uğurluay and Özcan 2001).

Machine harvesting of agricultural products is generally done by applying cutting-sawing, plucking-harvesting, shaking, or plucking-picking methods in many ways. Although human labor is generally used in sesame harvest, when partial mechanization is concerned, reaper harvesters or similar machines with some modifications are also used (Uğurluay and Özcan 2001; Vurarak and Bilgili 2014). Direct harvesting is also done (Öztürk and Yaldız 1995). Mowing units are used in all the aforementioned harvesting methods. A shearing-based mowing unit contains many parts; however, due to the high inertia forces with which they alternate motion, vibrations occur that damage the machine. This causes working speeds to be limited and some parts to require continuous tuning. Excessive friction forces occur and the machine must be lubricated at frequent intervals, hence making it very difficult for the machine to be operated for a long time without encountering any problems (Yıldız et al. 2008).

Such issues may be addressed by using a rotating disc blade in the cutting unit. Therefore, this study aimed to: (1)

design and manufacture a cutting-based experimental setup with disc blades for sesame plants; (2) determine the most suitable cutting criteria (blade type, disc blade diameter) for sesame plant stems; and (3) compare the amount of energy consumed in cutting with disc blades and shearing.

MATERIALS AND METHODS

Plants of the sesame variety Muganlı-57 were grown in the trial areas of the Faculty of Agriculture, Hatay Mustafa Kemal University, Turkey. A caliper with 0.05-mm precision was used to measure the diameters of the sesame plants. The amount of energy consumed by the disc blade cutting system was measured using an Energy Consumption Meter (TT T-ECHI-C brand, China). The test device used in shear cutting (Lloyd brand, England) has three main components: a fixed and movable plate, a driving unit, and a data acquisition system. The inclined plane method was used to determine the friction coefficient between the plant stem and the blade material. Several stems were placed together on a plane covered with blade material (St-37) to avoid rolling. The plane was lifted to make an angle of "φ" at a slow and constant speed (Fig. 1). The tangent of the angle of inclination (Eq. 1) that brings the plant to the beginning of movement gives the critical friction angle (Uğurluay et al. 2010; Ugurluay and Cardak 2020).

After finding the friction coefficient, the friction force can be calculated using Eq. 1 (Mohsenin 1971).

$$Tan\ \varphi = \frac{F_f}{F_N} \quad (1)$$

Here;
F_f : Frictional force, N
F_N : Normal force, N

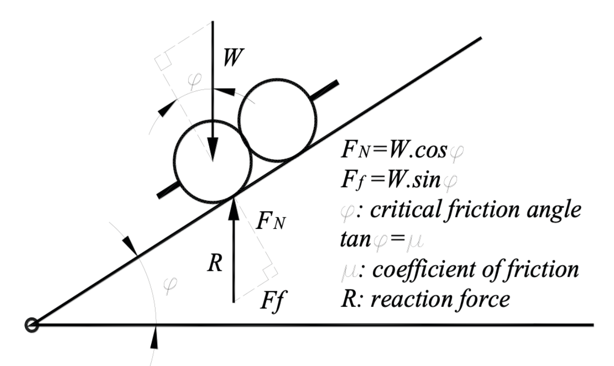

Fig. 1. Determination of friction angle by inclined surface method.

The weighed samples were kept in a drying oven (Nuve brand NV 500, England) at 105°C for 24 h. Then, an electronic scale (Sartorius brand GP 3202, Germany) was used to determine the wet mass and dry mass required for moisture determination of the plant material. The masses were measured again and moisture content was calculated (wet basis) using Eq. 2 (Mohsenin 1971).

$$WC_{WB} = \frac{(MM-DM)}{MM} * 100 \quad (2)$$

Here;
WC_{WB} : Moisture Content, %
MM : Moist Mass, g
DM : Dry Mass, g

The design and manufacture of the disc knife cutting test setup consists of two stages. First, a cutting device suitable for the physical characteristics of the sesame plant was designed using computer-aided drawing and design programs. Afterwards, the necessary materials and quantities were determined for the production of this device, which was manufactured by a company in Hatay, Turkey.

In their study, Uğurluay and Özcan (2001) used reapers in harvesting sesame. Such machines use shear cutters to remove plants from the field. The shear cutting system, which causes vibration, can cause the seeds in the capsule to fall out when harvesting overripe sesame plants. These issues are not observed in systems that rotate and cut freely. However, free-cutting devices are more suitable for plants with small stems and herbaceous features (e.g., forage crops, grass, meadow, etc.). Plant stem density and moisture content are the factors that have the most influence on the cutting process (Bright and Kleis 1964). Sesame plant stems, especially near the root, have a woody structure and are not very suitable for free-cutting systems. Therefore, this study aimed to develop and use a cutting system with rotating disc blades.

The process of feeding the plant stems to the blades was done manually, as it was studied in a laboratory environment. It is expected that the plant stems coming between the blades will be caught and cut with the effect of the friction forces that will occur between the blade and the stem. (Fig. 2).

In the capture process with disc blades rotating at different speeds and in opposite directions, the angular velocities are ω1 and ω2; disc diameters D_1 and D_2; vertical forces N_1 and N_2 acting on a handle of thickness h; if the friction forces acting tangentially to the discs are assumed to be F_1 and F_2; in the direction of the stem axis, when all these elements are added, the equation that gives the necessary condition for the rotating discs to catch the plants can be calculated using the following formula (Klenin et al. 1985):

$$F_1 cos\alpha_1 + F_2 cos\alpha_2 \geq N_1 sin\alpha_1 + N_2 sin\alpha_2 \quad (3)$$

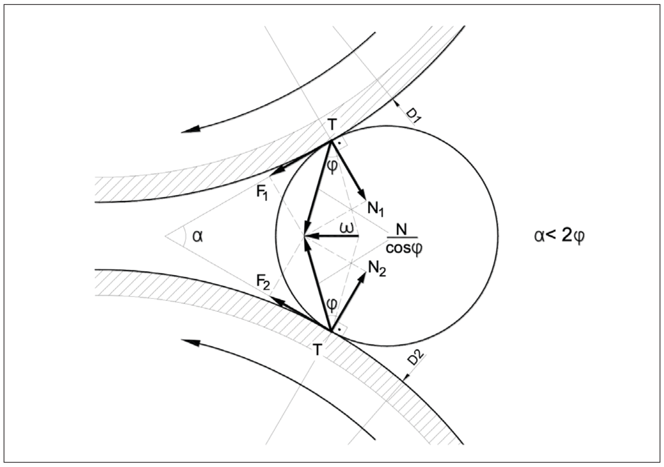

Fig. 2. The condition of the discs to catch the plant stem (Uğurluay et al. 2009).

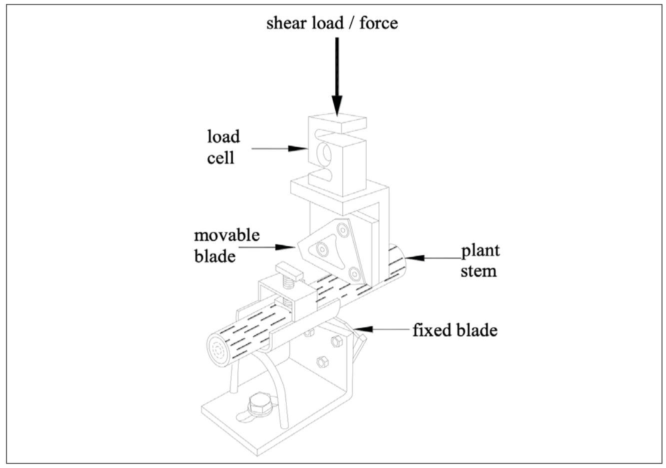

Fig. 3. The setup used in sesame stems shearing tests.

The values of the "α" angles formed when the sesame plant stems first come into contact with the disc blades were obtained by placing the actual dimensions of the disc diameters and plant body into a drawing program (AutoCAD 2007). Here, the theoretical capture conditions were reached.

There are three methods of positioning the cutting edge relative to the opposite edge in shear cutting: vertical, oblique, and oblique variant. In this study, the vertical cutting method, which is widely used in determining the cutting forces of biological materials, was used (Kanafojiski and Karwowski 1976; Sitkei 1986; Persson 1987; Chen et al. 2004; İnce et al. 2005; Sessiz et al. 2018). Özcan and İlbuga (1998) used an experimental device (Fig. 3) to determine the shear force of citrus thin branches, and Vursavu and Özgüven (2004) to examine the mechanical behavior of apricot pits under pressure loading. The stem samples were cut by straight blades with a 40°-wedge angle. Shearing tests were carried out at a blade speed of 1.2 mm s^{-1}.

Shearing forces were recorded at all stages where the blade moved along the stem section. Shear stress was calculated using Eq. 4 (Mohsenin 1971):

$$\tau = \frac{F_{smax}}{A} \quad (4)$$

Here;
τ : Shear stress, MPa
F_{smax} : Maximum shearing force, N
A : Stem cross section, mm2

Blade displacement was calculated using cutting speed and time. Displacement-force curves were plotted for each stem diameter. Shear energy was calculated using the area under these curves (Chattopadhyay and Pandey 1999; Chen et al. 2004). The area under the curve was calculated by integrating the polynomial equation that characterizes the displacement-force curve. Finally, the specific shear energy was obtained by proportioning this value to the section area of the plant stem (Eq. 5).

$$E_{SC} = \frac{E_S}{A} \quad (5)$$

Here;
E_{SC} : Specific shear energy, mJ mm^{-2}
E_S : Total shear energy, mJ
A : Section area, mm^2

Cutting experiments were carried out under laboratory conditions, approximately 10 cm above the root zone. Cutting was done with five repetitions at plant diameters of 10 ± 1, 15 ± 1, and 20 ± 1 mm.

The data obtained after the cutting trials were evaluated using one-way ANOVA in the SPSS (Statistical Package for the Social Sciences) program. Experiments were applied in a total of 36 groups in the form of 4 x 3 x 3 according to the factorial experiment plan with five repetitions. The independent variables were the cutting edge type, disc diameter, and stem diameter. Additionally, an independent-samples t-test was performed to determine whether there was a significant difference between the two methods in terms of energy consumption for each stem thickness group (10, 15, and 20 mm). Disc-shaped knives with three different blade structures were used in the study. The aim was to try to determine the type of blade that can do the most ideal cutting work with the lowest energy consumption. These knives were manufactured because they were not available in the market. Profile views of blade pairs are given in Fig. 4.

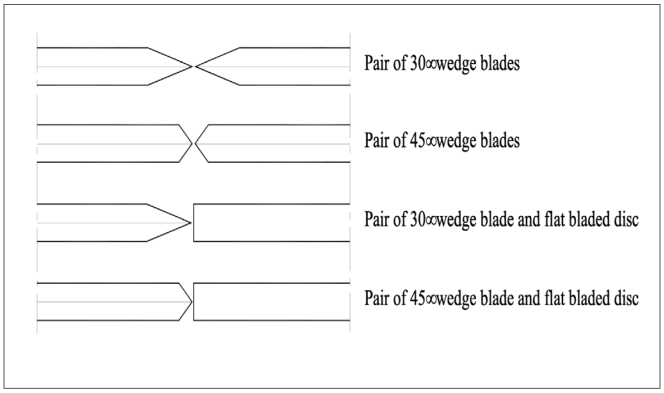

Fig. 4. Oppositely arranged disc blades types.

Disc-shaped knives with three different diameters were used in the study to determine the smallest-diameter disc blade that can cut sesame plant stems smoothly and with the lowest energy requirement. Thus, the cost will be reduced and the physical dimensions suitable for the harvest conditions will be provided. The selection of the flat-bladed disc was made to determine the possibility of cutting with a single blade and the amount of energy to be spent.

As for the dependent variables, the amount of energy consumed was examined. In the trials of cutting the stems using the disc knife cutting device, five plant stems were passed through the cutting device each time.

RESULTS AND DISCUSSION

The friction coefficient (μ) between the sesame plant stems and the steel blade material was found to be 0.46 ± 0.02. The average moisture values of the plant samples used in the experiments were 65 ± 2% according to the wet base.

The experimental setup consisted of two disc blades placed opposite each other to cut the plant stems (Fig. 5). The disc blades should rotate in the opposite direction to each other and should be designed to be easily detachable in order to create different conditions (diameters, blade types, etc.). Also, when disc blades of different diameters are used, one of the blade bearings must be capable of sliding in the horizontal direction. It should be able to be fixed after being slid enough.

The results of the theoretical catching conditions for different disc diameters and plant stem diameters are shown in Table 1.

When the results were examined, it was observed that some sizes designed for the experimental setup were not suitable, especially for 20-mm diameter plant stems; that is, theoretically, plant stems could not be caught by the disc blades. For this reason, an auxiliary apparatus (stem feeding device) was added to the experimental setup that would feed/push the plant stems between the blades to ensure that they were cut precisely. An isometric view of the experimental setup is shown in Fig. 6.

Table 1. Theoretical catching conditions for different disc diameters and plant stem diameters.

	α angle (°)	Coefficient of friction (μ)	Friction angle (°)	Catching conditions $\tan \varphi_1 + \tan \varphi_2 \geq 2.\tan \alpha$
		For **10-mm** diameter plant stem		
Disc, Ø150	20.4			0.92 > 0.74
Disc, Ø180	18.7	0.46	24.7	0.92 > 0.67
Disc, Ø210	17.3			0.92 > 0.62
		For **15-mm** diameter plant stem		
Disc, Ø150	24.6			**0.92 ≥ 0.92**
Disc, Ø180	22.6	0.46	24.7	0.92 > 0.83
Disc, Ø210	21			0.92 > 0.76
		For **20-mm** diameter plant stem		
Disc, Ø150	28.1			**0.92 < 1.06**
Disc, Ø180	25.8	0.46	24.7	**0.92 < 0.97**
Disc, Ø210	24.1			0.92 > 0.89

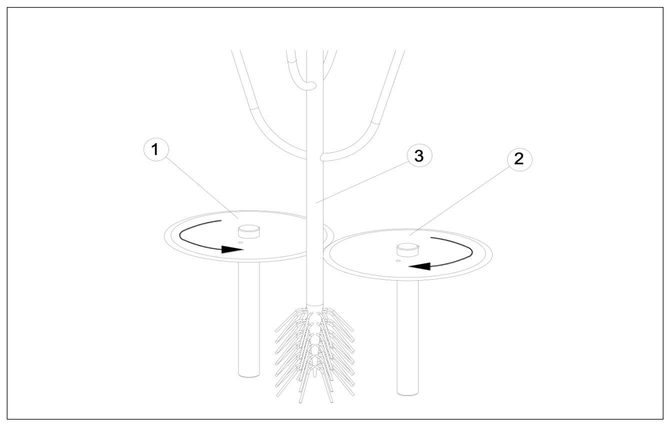

Fig. 5. The position of the discs and the plant in the stem cutting experiment setup. 1 Disc blade, 2 Opposite disc blade, 3 Plant stem.

The first of the disc blades (3) is mounted to a geared electric motor (2). The electric motor has a power of 0.75 kW, a speed of 1440 min-1, and an R:12 reducers. In addition, there is an electronic speed control unit to change the speed of the electric motor. The second disc blade (4) is bedded in such a way that it can rotate freely. To use discs of different sizes, the counter blade bearing (5) on the assembly is designed to be slidable.

It is assumed that the cutting energy is equal to the electrical energy consumed by the motor at the time of cutting.

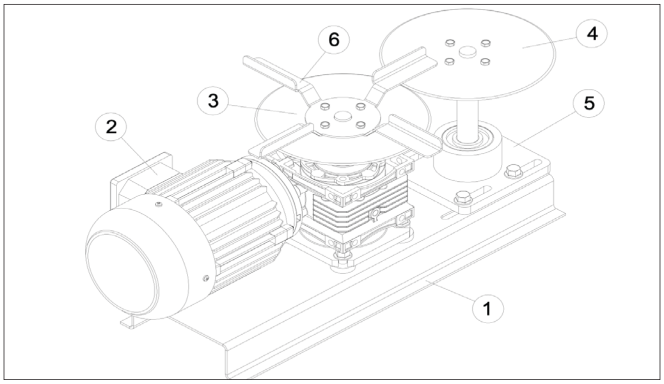

Fig. 6. Isometric view of the experimental setup.

Fig. 7. Cutting energy measurement with electricity consumption measuring device.

An electricity consumption measuring device (Fig. 7) was used to measure the electrical energy at the time of cutting.

This device measures power consumption in W (Watts), which is a unit of power and shows the amount of work done per unit time. It can be obtained by the ratio of energy (Joule) to time (second). If the cutting time of the stem is set to last 1 s, the energy consumption is (J/s)*1 s = J. Thus, the amount of energy spent for cutting is directly obtained. The value read at the time of cut-off is subtracted from the value read during idling. There are four wings in the stem feeding apparatus on the cutting disc. The spindle speed is adjusted according to the number of wings; that is, the disc blade completes one revolution in 4 s. As a result, it is necessary to adjust the number of revolutions of the disc blades to be 15 min^{-1}. In this case, the peripheral speeds (linear velocity) of the 150, 180, and 210-mm diameter disc blades are 0.11, 0.14, and 0.16 m s^{-1}, respectively. Statistical results of energy consumption values during cutting of stems of different thicknesses by disc blade pairs are shown in Table 2.

Table 2. Statistical results of cutting energy values according to stem diameter.

		Stem Diameter (SD), mm		
		10	15	20
Blade Type (BT)	30°-30°	5.20 ± 1.93^{a}	7.70 ± 2.17^{a}	25.0 ± 12.24^{a}
	45°-45°	5.70 ± 1.25^{ab}	8.40 ± 2.14^{a}	29.5 ± 11.26^{ab}
	30°-Flat	6.70 ± 1.70^{b}	19.0 ± 16.83^{b}	295.6 ± 189.60^{c}
	45°-Flat	6.10 ± 1.15^{ab}	9.0 ± 5.02^{a}	37.0 ± 39.49^{b}
	P	*	***	***
Disc Diameter (DD), mm	150	5.90 ± 0.60^{a}	9.70 ± 2.36^{a}	127.90 ± 177.64^{b}
	180	5.70 ± 1.59^{a}	7.80 ± 2.01^{a}	25.80 ± 11.03^{a}
	210	6.20 ± 1.25^{a}	15.6 ± 15.27^{b}	136.60 ± 213.44^{b}
	P	*NS*	***	***
	BTxDD	***	***	***

Note: Different lettering characterizes statistical differences within the same column. $P < 0.05$ *, $P < 0.01$**, $P < 0.001$ ***

The effect of the blade wedge angle on the energy consumption values for cutting 10-mm diameter stems was statistically significant; as the blade wedge angle narrows, the energy spent on cutting decreases. The effect of disc diameter on the energy consumed for cutting plants with a stem thickness of 10 mm was not statistically significant ($P > 0.05$). The interaction of blade angle and disc diameter had a statistically significant effect on the energy consumed for cutting plants with a diameter of 10 mm ($P < 0.001$). If the blade angle is reduced and the disc diameter is increased, less energy will be required.

The blade wedge angle had a statistically significant effect on the energy consumed for cutting plants with a diameter of 15 mm ($P < 0.001$). The cutting energy decreases as the wedge angle decreases. It was also observed that the effect of disc diameter on the energy consumed for cutting plants with a diameter of 15 mm was statistically significant ($P < 0.001$). The effect of blade angle and disc diameter interaction on the energy consumed for cutting plants with a diameter of 15 mm was found to be statistically significant ($P < 0.001$). If the blade angle is reduced and the disc diameter is increased, less energy will be required.

The effect of the blade angle on the energy consumed for cutting plants with a diameter of 20 mm was statistically significant ($P < 0.001$). As with the other results, cutting energy decreases as the wedge angle decreases. The effect of disc diameter on the energy consumed for cutting 20-mm diameter plants was statistically significant ($P < 0.001$). As the blade diameter increases, the cutting energy decreases. The effect of blade angle and disc diameter interaction on the energy consumed for cutting 20-mm diameter plants was found to be statistically significant ($P < 0.001$). If the blade angle is reduced and the disc diameter is increased, less energy will be needed.

In the disc knife cutting experimental setup, the energy consumption values of the plant stem cutting as a result of different knife arrangements were also verified. Statistical results examining the effects of plant stem diameter and disc diameter on energy consumption are shown in Table 3.

Table 3. Statistical results of cutting energy values according to blade edge.

		Blade Edges (BE)			
		30°-30°	30°-Flat	45°-45°	45°-Flat
Stem Diameter (SD), mm	10	5.26 ± 1.93[a]	6.74 ± 1.70[a]	5.74 ± 1.25[a]	6.11 ± 1.15[a]
	15	9.09 ± 5.02[a]	8.44 ± 2.14[a]	7.73 ± 2.17[a]	19.0 ± 16.83[b]
	20	25.05 ± 12.24[b]	29.5 ± 11.26[b]	37.08 ± 39.49[b]	295.66 ± 189.60[c]
	P	***	***	***	***
Disc Diameter (DD), mm	150	16.54 ± 16.03[b]	19.24 ± 17.10[b]	9.19 ± 2.78[a]	158.16 ± 218.40[c]
	180	9.56 ± 7.04[a]	11.66 ± 7.80[a]	33.19 ± 41.99[b]	134.18 ± 187.75[b]
	210	13.30 ± 9.06[ab]	13.77 ± 9.60[a]	8.16 ± 5.02[a]	28.43 ± 20.30[a]
	P	***	***	***	***
	SDxDD	***	***	***	***

The effect of the stem diameter on the energy consumed for cutting with discs with a 30º -blade angle was statistically significant ($P < 0.001$). Less energy is required for cutting stems with diameters of 10 and 15 mm than for cutting stems with a diameter of 20 mm. The effect of disc diameter on the energy consumed for cutting the stem with discs with a 30º -edge angle was statistically significant ($P < 0.001$). Discs with a diameter of 180 mm had the lowest energy consumption. The interaction of stem thickness and disc diameter had a statistically significant effect on the energy consumed for cutting stems with discs with a 30º -edge angle ($P < 0.001$). As the stem thickness increases, the required cutting energy increases. If the disc blade cutting system is to be used in a harvesting head, the double-blade application with a blade with a wedge angle of 30º or less has been observed as the most suitable arrangement. The disc diameter should also be as large as physically possible in the harvesting head.

The effect of stem thickness on the energy consumed for cutting the plants was statistically significant in the 30º -flat edge disc pair ($P < 0.001$). Cutting stems with diameters of 10 and 15 mm requires considerably less energy than the other. The effect of disc diameter on the energy consumed for cutting the handles in the 30º -flat rim disc pair was statistically significant ($P < 0.001$). As disc diameters increase, cutting energy also decreases. Discs with diameters of 180 and 210 mm have the lowest energy consumption. The interaction of stem thickness and disc diameter had a statistically significant effect on the energy consumed for cutting the stems with 30º -flat paired discs ($P < 0.001$). As the stem thickness increases and the disc diameter decreases, the cutting energy also increases.

The effect of stem diameter on the energy consumed in cutting with 45º -angled discs was statistically significant ($P < 0.001$). Cutting plants with a diameter of 10 and 15 mm requires much less energy than the other. It was observed that the effect of disc diameter on the energy consumed for cutting the stems with 45º -angled discs was statistically significant ($P < 0.001$). Discs with diameters of 210 and 150 mm have the lowest energy consumption. Moreover, the interaction of stem thickness and disc diameter had a statistically significant effect on the energy consumed for cutting the stems with 45º -edge-angled discs ($P < 0.001$). As the stem diameter increases and the disc diameter decreases, the energy required for cutting also increases.

The effect of the stem thickness on the energy consumed for cutting the stems in the 45º -flat-edge disc pair was statistically significant ($P < 0.001$). There was a huge difference between the cutting energies of the first two stems and the 3[rd]. Results verified that the effect of the disc diameter on the energy consumed for cutting the stems with 45º -flat-pair discs was statistically significant ($P < 0.001$). Discs with a diameter of 210 mm have the lowest energy consumption. The interaction of stem thickness and disc diameter had a statistically significant effect on the energy consumed for cutting the stems with 45º -flat-pair discs ($P < 0.001$). As the stem diameter increases and the disc diameter decreases, the energy required for cutting also increases. Pairs of sharp-edged and straight-edged disc blades were used to observe the energy consumption and to understand whether single-sided cutting was possible. The results were not satisfactory and it is not recommended for use in practice.

Shearing experiments were also carried out, and the amount of cutting energy consumed per unit area exposed to shear was calculated. The average values of the data obtained from the shear-cutting trials are given in Table 4.

Table 4. Energy consumption values per unit area of sesame stems of different diameters in shear cutting.

	10 mm	15 mm	20 mm
Stem diameters, mm	10.04 ± 0.09	14.86 ± 0.54	20.50 ± 0.60
Shear Energy, J	1.29 ± 0.08	3.78 ± 0.84	7.84 ± 0.34
Area, mm^2	79.17 ± 1.42	173.61 ± 12.64	330.27 ± 18.92
Shear Energy, mJ	1296.06 ± 81.30	3 780.89 ± 844.26	7841.64 ± 335.52
Energy consumed per unit area, mJ mm^{-2}	16.36 ± 0.85	21.61 ± 3.59	23.82 ± 2.02

In shear cutting, the effect of stems of different diameters on energy consumption per unit area was found to be significant. As the stem diameter of the plant grows (15 and 20 mm), the amount of energy required per unit area for cutting additionally increases.

Some previously conducted studies were only for determining the branch cutting resistances (Özcan and İlbuğa 1998; Polat 2002).

In the studies conducted by Kocabıyık and Kayişoğlu (2004) and İnce et al. (2005), the cutting forces and maximum shear stress values required for cutting sunflower stalks were verified. Cutting experiments were conducted at different moisture contents or different parts of the plant stem, and similar results were obtained. They found that shear stress and specific shear energy increased as the plant moisture content increased. Both shear stress and specific shear energy were found to be higher in the lower region of the stem.

A similar study was conducted by Amirian et al. (2017) to determine the effects of moisture content and different stalk parts on some physical and cutting properties of chickpea stalks. These values increased with increasing moisture content and also increased towards the lower part of the stem. Another study was conducted by Kamandar and Massah (2017) at four different loading rates to measure shear strength, shear force, and shear energy requirement at different nodes of boxwood stem. Statistical differences were found between results, both in loading rates and between nodes.

In this study, a disc cutting system was designed, manufactured, and tested in various parameters (disc blade diameter, disc blade angle, etc.) for a harvesting head likely to be used in harvesting sesame plants and similar products. No previous study was found for cutting sesame stalk. In previous literature on cutting and pruning, shear forces, stresses, etc. were obtained by using the shearing method. For this reason, cutting sesame stalks using the shearing method is also included in the study.

Using the shearing method, direct shear forces can be obtained due to the load cell located on one of the blades. However, since there is no load cell on the disc cutting device developed in this study, direct shear force could not be obtained. Instead, measurements were made on the electrical energy consumed by the electric motor that rotates the disc blades at the time of loading.

If the mean values of the cutting energy values obtained by using the two methods in this study are compared, an energy of 6.9 J (30º -30º blade pair) is required to cut a plant stem with a diameter of 10 mm in the disc blade cutting system. In the shearing system, 1.3 J of energy is required. It was found that there was a significant difference between the energy consumption of these two methods ($P < 0.001$).

In disc cutting, the energy consumption for a 15-mm diameter stem was 10.0 J (30º -30º blade pair), while it was 21.6 J in shear cutting. There was no significant difference between the energy consumption of these two methods ($P > 0.05$).

When cutting with discs, the energy consumed for a 20-mm diameter stem was 23.0 J (30º -30º blade pair), while it was 23.8 J when cutting with shears. No significant difference was observed between the energy consumption of these two methods ($P > 0.05$).

It can be observed that the values obtained in shearing are closer to each other compared with the other method; this is because three different diameter disc blades are used. The cutting energy obtained may actually be slightly lower due to electrical losses in the engine and small friction losses due to mechanical transmission in the gearbox. In terms of energy consumption, the results are quite reasonable and promising.

CONCLUSION

This study evaluated the suitability of the disc blade cutting system, a rotary cutting system, for sesame harvesting. An experimental setup that can be operated under different cutting conditions (blade angle, type of blade, disc diameter, etc.) was designed and tested both in terms of energy consumption and in comparison with the shearing method. The disc blade cutting system was confirmed to be suitable for use in the header of a harvesting machine that would be used to pick sesame and similar plants. Future studies may involve the evaluation of a prototype's performance in field conditions and its comparison with shearing systems.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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