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Effects of blades types on shear force and energy requirement of paddy stem

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Abstract

This study was aimed to determine of the shearing force and shearing energy of paddy stem as a function of blade type, blade-edge angle and cutting speed. The Karacadag white paddy variety was used as plant materials. Shearing properties were measured by a universal testing machine. Depend on measured shear force and cross-section area of paddy stem, energy values were calculated by measuring the surface area under the cutting force-deformation curve for each test separately. The tests were conducted at five blade angles, five loading speed with various three different type blades. The tests results showed that the shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load were affected significant ($p<0.01$) by blade type, cutting angle and cutting speed. While the lowest values were determined at serrated 2 blade types, followed by the serrated 1 and flat-edge blade. The paddy stalk shearing force and energy values has increased with decrease in the blade edge angle from 90° to 50°. The highest force and energy values were measured at 90° cutting edge of blade as 25.47 N and 5.8 N cm. The effect of loading speed on the cutting forces, cutting strength, cutting energy and specific cutting energy were found significant ($p<0.01$). The shearing and energy has slightly decreased with an increase of blade cutting speed. While the highest values were found at 2 m s^{-1} loading speeds, the lowest values were found at 6 mm s^{-1} cutting speed.

Keywords: Cotton, Cutting properties, Design, Shearing force, Stalk

Introduction

Paddy (Oryza sativa L.) is one of the oldest cereals and important staple food and the main source of income for about half of the world's population and it is growing in more than half of the countries in the world and it will continue to be the mainstay of life for future generations as well (Correa at al., 2007; Badawi, 2001; Esgici et al., 2016). 90% of world paddy production takes place in Asian continent. One of the paddy producer countries in terms of climate, soil and environmental conditions is Turkey. Southeastern part of Turkey is also an important paddy producer. In this region, the paddy variety known as Karacadag white widely is grown.

Harvesting and threshing operations of paddy are known as one of crucial part and influential processes on quantity, quality, grain losses and production cost. Paddy harvesting is mostly performed by worker using sickles. So, in paddy harvest stage, use of labor is intensity and also harvest cost is very high. In the recent years, paddy producers in this region have been using conventional grain harvesters that are not suitable for paddy. As a result, combine harvesters have negative impacts on quantity and quality of paddy grains which seriously affect the profitability of the crop since majority of the losses are due to improper adjustment of the machines according to paddy varieties and crop conditions. Losses in paddy production is an

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estimated ratio ranging between 25 % to 30 % (Esgici et al., 2016) in this region. This value of losses is quite high and we have to reduce a reasonable level. Because, the objective of good harvesting is to maximize grain yield while minimizing grain losses and quality deterioration. Therefore, it is very important to choose proper shearing parameters of paddy stem and kernel during harvesting processes to minimize the level of grain damage and to increase grain quality (Correa et al., 2007; Yore et al., 2002). Paddy harvesting machines and combine-harvesters are commonly equipped with reciprocating cutting mechanism. In this case, a cutting bar has some blades and counter edges which move against each other. If plants stem stands between them, it is cut due to reciprocating movement of blade or both blade and counter edge. The performance of cutting elements on harvesting mechanisms can be judged by cutting energy requirement, shearing force, shearing strength and applied force. Various parameters such as physical and mechanical properties of the stem, paddy cultivar, blade velocity and blade components are effective on the cutting force energy and the specific cutting energy (Allameh and Alizadeh, 2016). Cutting energy of a plant stem can be estimated from the relationships between the force of cutting the stem and the displacement of the blade (Chen et al., 2003).

Information on plant properties and the power or energy requirement of equipment has been very valuable for selecting design and operational parameters of the equipment (Persson, 1987; Chen et al., 2003; Jicheng et al., 2017). Such information is needed for the design of paddy harvesters and combine harvesters, assuring appropriate machine functions and an efficient use of energy. Although there is considerable interest in mechanical processing of paddy, there is little information on shearing properties depend on blade type, shearing angle and loading speed of paddy stems. This information is important to know behavior of cutting of paddy stem. We have to be made paddy harvest at high moisture contents by Combine harvesters. Because during the harvesting season, the moisture content of paddy stalk is higher than the other cereals and the strength of paddy is more. Also, the behavior is different from paddy variety to variety during cutting stage. So, both suitable blade type and edge angle are important parameters for reducing shearing force, cutting energy and increase effective cutting performance of cutter bar of machine (Koloor and Borgheie, 2006).

The main aim of this study was to determine the shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load speed depend on blade type, blade cutting- angle and blade-loading speed in a laboratory condition with paddy stems.

Materials and Methods

The Karacadag white paddy variety (Figure 1) was used for tests. Paddy stems were collected at harvesting season from a commercial farm in Diyarbakır province in 2018, Turkey. The whole paddy plants average 0.82 m in height and were cut manually prior to the cutting testes at height of 25 cm above the soil level. After the paddy stem was harvested, it was covered and transported to University of Dicle, Department of Agricultural Machinery and Technologies Engineering Research Laboratory for tests. The tests samples stored at a temperature of 4 ºC for one month until start to shearing tests. Selected some properties of paddy are seen in Table 1.

Figure 1. Paddy stalk with panicles

Table 1. Some physical properties of paddy.

Physical properties	
Plant height, m	0.82
Panicle length, cm	18
Panicle weight, g	2.08
Moisture content of stalk, %	68.00
Moisture content of kernel, %	29.00
The weight of 1000 kernel, g	33.90
Stem diameter, mm	4.40

Moisture content of paddy stems samples were measured according to ASABE standards (ASABE, 2008). Before tests, four samples of 25 g paddy stalks were weighed and dried in an oven of 103ºC for 24 h which were then reweighed in order to determine the average moisture content of paddy stem. The average moisture content of paddy stems (stalk) was obtained as 68.00 % w.b during tests. The diameter varied greatly within the field, ranging from 4 to 4.8 mm and averaged 4.4 mm. Diameters of stalks were measured with a digital caliper. So, stem diameter was considered as 4.40 mm for the cutting experiments. The stalks diameter (mm) was converted to cross-section area in mm^2.

An Universal Materials Testing Machine, Lloyd LRX Plus, were used to measure of shearing properties of paddy stalks (Figure 2). The shear force was recorded as a function of displacement depend on selected parameters. The tests were carried out with three different types of blades (Figure 2), two of them are serrated type (serrated 1 (blade-edge thick), serrated 2 (blade-edge thin) and flat (blade-edge flat). Five blade angles (50º, 60º, 70º, 80º and 90º) and five cutting speed (2, 3, 4, 5, and 6 mm s^{-1}) were selected independent parameters. The shearing energy of paddy stalk was calculated by measuring the surface area under the force-deformation curve by an instron universal material testing machine (Chattopadhyay and Pandey, 1999; Yore et al., 2002; Chen et al., 2003; Kocabiyik and Kayisoglu, 2004; Ekinci et al., 2010; Zareiforoush et al., 2010; Ghahraei et al., 2011; Voicu et al., 2011; Ozdemir et al., 2015; Nowakowski, 2016; Pekitkan et al., 2018). A computer data acquisition system recorded all force-displacement curves during the cutting process by using a NEXYGEN computer program for each parameter.

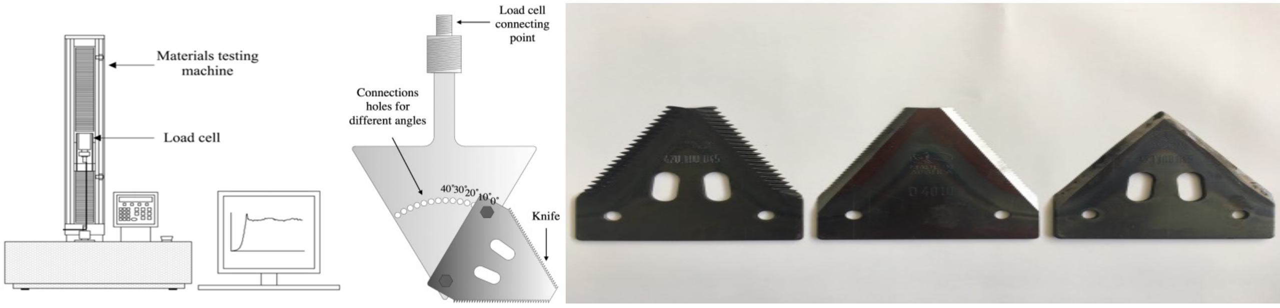

Figure 2. View of testing machine and blades

A force-deformation curve is given in Figure 3. As you seen in Figure 3, the first peak value was considered as the yield point (lower yield) at which stalk damage was initiated. The second peak value (upper yield) corresponds to maximum force (Figure 3).

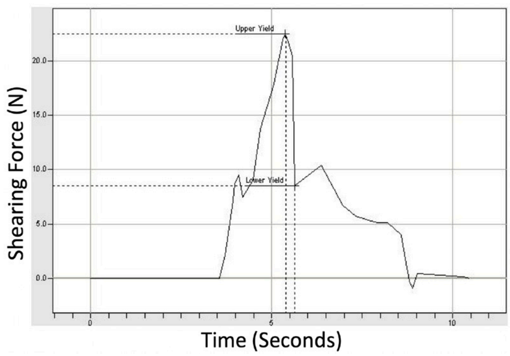

Figure 3. The time –shearing curve for cutting of paddy stalks.

The maximum shearing strength, obtained from the force values, was determined by the following equation (Mohsenin, 1986; O'Dogherty et al., 1995; Zareiforoush et al., 2010; Ekinci et al., 2010; Chandio et al., 2013; Sessiz et al., 2013; Sessiz et al., 2018):

$$\sigma_s = \frac{F_{max}}{A}$$

Where: σ_s is the maximum shearing strength in (MPa), F_{max} is the maximum shearing force in (N) and A is the cross-sectional area in (mm^2).

Specific shearing energy, Esc was calculated by:

$$E_{sc} = \frac{E_s}{A}$$

Where: E_{sc} is the specific cutting energy (J mm^{-2}) and E_s is the shearing energy (J).

Test results were subjected to variance analysis. Mean comparisons were made according to Duncan's multiple range tests .

Results and Discussion

The effect of Blade type

The shearing properties depend on blades types are given in Table 2. The analysis of variance and Duncan's test results showed that the effect of blade type was found significant ($p<0.01$) on shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load. There were found significant differences among the three blade types ($p<0.01$) according to measured properties. The lowest values were determined at serrated 2 blade types, followed by the serrated 1 and flat type blade (Table 2). The highest shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load values were obtained at flat blade type as 22.66 N, 1.490 N mm^{-2}, 0.045 Nm, 0.004 J mm^{-2} and 8.35 mm, respectively. A serrated blade edge gives a lower cutting force and requires lower cutting energy than a flat- edge type. So, we can argue that serrated blade types are better than the flat type blades for paddy harvesting. According to results, flat-edge blade type is not suitable for shearing paddy stem. It is concluded that the edge of serrated blades has a good grasp of the paddy stems than flat-edge type blade. This means that the energy requirement of flat edge blade for cutting of paddy stem is more than serrated blades. In contrast, Koloor and Borgheie (2006) argued that blade bevel angle and blade type had no significant effect on the shearing strength of paddy stem.

Table 2. Analysis of variance of the cutting force and cutting energy with respect to blade type.

Blade type	Shearing force (N)	Energy strength (N mm^{-2})	Energy (Nm)	SCE (J mm^{-2})	Extension at maximum load (mm)
Serrated type 1 (blade-edge thick)	18.54b*	1.220 b	0.047 a	0.003 a	18.74 a
Serrated type 2 (blade-edge thin)	13.84c	0.910 c	0.030 b	0.002 b	11.11 b
Flat type (blade-edge flat)	22.66a	1.490 a	0.045 a	0.004 a	8.35 c
Mean	18.35	1.214	0.041	0.003	12.73

*means followed by the same letter in each column are not significantly different by Duncan's multiple range test at the 1 % level.

The Effect of Blade Edge Angle

Table 3 shows the mean values of the shearing force, strength, energy, specific shearing energy and extension under maximum load at different blade- edge angle. The effect of blade cutting angle on shearing properties were found significant as statistically ($p<0.01$). The study showed that the mean shearing values gradually decreased with decrease in the blade-edge angle from 90° to 50°. The highest shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load values were obtained at 90° angle as 25.476 N, 1.677 N mm^{-2}, 0.058 Nm, 0.004 J mm^{-2} and 11.31 mm, respectively, followed by 80°, 70°, 60° and 50° blade-edge angles. The lowest results were determined at serrated 2 blade types as 11.86 N, 0.780 N mm^{-2}, 0.0026 Nm, 0.003 J mm^{-2} and 12.05 mm, respectively (Table 3). By decreasing vertical shearing angle, the paddy stem will be bent alongside the applied force. Therefore, more energy is taken in order to complete shear operation. The similar results were observed by Kronbergs et al. (2011). They argued that shearing force and energy depends on some parameters such as the material deformation process, blades edge- angle and friction forces. These parameters cause significant increase of cutting energy. According to the results, the suitable blades edge angle is change between 25º and 45º. The decrease of shearing force and energy depend on blade- edge angle allows proper design of the cutting unit and cutting machine for paddy stem and predicting the power requirements. Hoseinzadeh et al. (2009) investigated the effect of moisture content, bevel angle and cutting speed on shearing energy for three wheat varieties. According to theirs results, the blade edge angle has significant effect on the cutting force and energy. Dowgiallo (2005) also reported that besides the cutting edge, blade edge sharpness and blade speed are effect parameters on cutting properties. The cutting force and energy required for the pigeon pea crops were investigated by Dange et al. (2011). The study investigated that the cutting energy and cutting force were directly proportional to cross-sectional area and moisture content at the time of harvesting of pigeon pea crop. 30º and 45º bevel angle were selected for the cutting experiment. According their result, the blade 45º bevel angle required 23.74 % more cutting energy than the blade with 30º bevel angle for 30 mm diameter stem. Whereas the blade with 45º bevel angle required 16.05 % more cutting force than the blade with 30 º bevel angle. Optimum blade-edge angle, shear angle, oblique angle, and rake angle were measured 25º, 40º, 40º, and 40º, respectively, for Kenaf stems (Ghahraei et al., 2011). Koloor and Borgheie (2006) studied that the effect of blade parameters on the cutting energy of paddy stem by an impact type shears tests apparatus. According their results, specific cutting energy decreased with increasing in oblique angle and it is a minimum at 30º. Yore et al. (2002) investigated the cutting properties of paddy straw to aid development of novel header system for combines. Tavakoli et al. (2010) compared mechanical properties of two Iranian varieties of paddy straw, namely Hashemi and Alikazemi. The results showed that the energy requirement for cutting of Hashemi straw is more than Alikazemi variety. Mathanker et al. (2015) investigated the effect of cutting speed and blade oblique angle on cutting energy. The results showed that the specific cutting energy increases with cutting speed. The specific cutting energy showed a close correlation with stem diameter and stem cross-sectional area. Our results indicated that shear force and energy were significantly larger for the 90º angle than the other four cutting edge angles. The mean of this situation that using 50º blade edge angle and serrated 2 blade types can minimize the shearing force and shearing energy requirements.

Table 3. Analysis of variance of the cutting force and cutting energy with respect to blade edge angle

Blade cutting angle (°)	Cutting force (N)	Energy strength (N mm^{-2})	Energy (Nm)	SEC (J mm^{-2})	Extension at Max. load (mm)
90	25.48 a*	1.677 a	0.058 a	0.004 a	11.31 d
80	23.13 b	1.521 b	0.050 a	0.003 a	13.28 b
70	17.63 c	1.159 c	0.040 ab	0.003 a	14.19 a
60	14.09 d	0.931 d	0.028 b	0.002 b	12.86 b
50	11.86 e	0.780 e	0.026 b	0.003 a	12.05 c
Mean	18.35	1.214	0.041	0.003	12.73

*means followed by the same letter in each column are not significantly different by Duncan's multiple range tests at the 1 % level.

The effect of loading speed on shearing properties of paddy stem is summarized in Table 4. The Table 4 shows that the effect of blade loading speed has been significant ($p<0.01$) on the shearing forces, shearing strength, shearing energy, specific shearing energy and extension at maximum load. There has been an inverse relationship occurred between stem loading speed and independent shearing properties such as shearing force, strength and energy. The cutting force and energy values decreased with increase loading speed from 2 mm s^{-1} to 6 mm s^{-1}. The highest shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load were obtained at 2 mm s^{-1} as 19.48 N, 1.281 N mm^{-2}, 0.043 Nm, 0.003 J mm^{-2} and 12.49 mm, respectively. The minimum values were occurred at 4, 5 and 6 mm s^{-1}. While the significant differences were found between 2 mm s^{-1} and the other loading speed values, there were not found significant differences among 4, 5 and 6 mm s^{-1} cutting speed. The resistance of plant to lodging is closely related to the physical and mechanical properties of their stems (Alizadeh et al., 2011). According to O'Dogherty et al. (1995) the physical properties of plant materials depend on rate of loading. Similar results were reported by Yore et al. (2002) for paddy straw, by Alizadeh et al. (2011) for paddy stem. These results are in agreement with Chandio et al. (2013) who concluded that the average shear force and strength was obtained from 13 N to 15 N at 5, 10 and 15 mm min^{-1} for paddy stalk. Similar results were found by Yiljep and Mohammed (2005). They investigated that the effect of blade velocity on shearing energy and efficiency during impact of sorghum stalk. According to their results, the cutting energy requirement decreased with increase in blade velocity. The cutting energy required to cut sorghum stems showed a minimum at 2.9 m s^{-1} cutting speed and it increased as the cutting speed increased above 2.9 m s^{-1}. However, contrary to these results, our results did not in agreement with Yiljep and Mohammed (2005) results. The cutting force, strength and cutting energy increased with an increase in loading speed from 5 to 15 mm min^{-1}. Allameh and Alizadeh (2016) conducted a study on cutting properties of paddy. The results revealed that paddy cultivar and blade velocity had significant effects ($P<0.01$) on the specific cutting energy. There were significant differences among cultivars in the view of specific cutting energy so that the highest and lowest values belonged to Hashemi variety (29.29 kJ m^{-2}) and Khazar variety (16.81 kJ m^{-2}), respectively. When blade velocity increased from 1.5 m s^{-1} to 2.5 m s^{-1}, specific cutting energy raised about 77 %.

Also, to calculate and estimate the cutting force and energy values as the theoretical, a regression equation was derived from the average values for five blade-edge angle levels and five loading speeds. The linear regression equations and coefficients values are shown in Table 5 and Table 6. This derived linear relationship can be used to estimate the shearing properties to cut paddy stem.

Table 4. The relationship between cutting properties and cross-sectional area of paddy stem

Cutting speed (mm s^{-1})	Cutting force (N)	Energy strength (N mm^{-2})	Energy (Nm)	SEC (J mm^{-2})	Extension at Max. load (mm)
2	19.48 a*	1.281 a	0.043 a	0.003 a	12.49 b
3	18.94 ab	1.245 ab	0.042 a	0.004 a	13.43 a
4	18.01 b	1.185 b	0.041 a	0.003 a	12.34 b
5	17.64 b	1.160 b	0.037 b	0.003 a	12.83 b
6	17.58 b	1.157 b	0.039 b	0.002 b	12.59 b
Mean	18.35	1.214	0.041	0.003	12.73

*means followed by the same letter in each column are not significantly different by Duncan's multiple range test at the 1 % level.

Table 5. The regression equations depend on blade edge-angle.

Parameter	Regression equation	R^2
Shearing force (N)	$Y=29.322 – (3.628) X_1$	0.979
Shearing strength (N mm^{-2})	$Y=1.9284 – (0.238) X_1$	0.979
Shearing energy (Nm)	$Y=0.00662 – (0.0086) X_1$	0.969
Specific shearing energy (J mm^{-2})	$Y=0.0042 – (0.004) X_1$	0.80

X_1 is the angle of blade edge.

Table 6. The regression equations depend on blade loading speed.

Parameter	Regression equation	R^2
Shearing Force (N)	$Y=19.847 – (0.5026) X_1$	0.911
Shearing strength (N mm^{-2})	$Y=1.3055 – (0.0333) X_1$	0.910
Shearing energy (Nm)	$Y=0.0449– (0.0015) X_1$	0.969
Specific shearing energy (J mm^{-2})	$Y=0.0042 – (0.004) X_1$	0.80

X_1 is the blade loading speed.

Conclusion

The results of the analysis of variance and Duncan's test also showed that the main effect of blade type, blade angle and cutting speed and their interactions were found significant on shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load ($p<0.01$). The lowest and best results were determined at serrated 2 blade types; 90° shearing angle and 6 mm s^{-1} loading speed, followed by the serrated 1 and flat-edge type blade. The highest values were observed at flat blade type. The cutting force and cutting energy increased with an increase in the blade edge angle from 50° to 90° edge angle. When we evaluated all measurement of interactions of Duncan test results, the peak values of shearing force, shearing strength, shearing energy, specific shearing energy and extension at maximum load were observed at flat-edge blade, 90° shearing angle and 2 mm s^{-1} cutting speed as 43.47 N, 2.86 nmm^{-2} and 0.106 Nm, 0.007 Jmm^{-2} and 24.5 mm.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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References

Alizadeh, M.R., Ajdadi, F.R., Dabbaghi, A. (2011). Cutting energy of paddy stem as influenced by internode position and dimensional characteristics of different varieties. Australian Journal of Crop Science 5(6):681-687. Doi: http://www.cropj.com/alizadeh_5_6_2011_681_687.pdf

Allameh, A., Alizadeh, M.R. (2016). Specific cutting energy variations under different paddy stem cultivars and blade parameters. IDESIA (Chile), Volumen 34, Nº 5. Páginas 11-17. Doi: http://dx.doi.org/10.4067/S0718-34292016005000024

ASABE Standards, (2008). S358.2. Moisture measurement – Forages. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

Badawi, A.A. (2001). A proposal on the assessment of paddy post-harvest losses. CIHEAM- Cahiers Options Méditerranéennes. 58. Doi: https://om.ciheam.org/om/pdf/c58/03400069.pdf

Chandio, F.A., Changying J., Tagar, A.A., Mari, I.A., Guangzhao, T., Cuong, D.M. (2013). Comparison of mechanical properties of wheat and paddy straw influenced by loading rates. African Journal of Biotechnology Vol. 12(10), pp. 1068-1077. Doi: https://www.ajol.info/index.php/ajb/article/view/128164/117714

Chattopadhyay, P.S, Pandey, K.P. (1999). Mechanical properties of sorghum stalk in relation to quasi-static deformation. J. Agric. Eng. Res. 73:199-206. Doi: https://doi.org/10.1006/jaer.1999.0406

Chen, Y., Gratton, J.L., Liu, J. (2003). Power requirements of hemp cutting and conditioning. Biosystems Engineering, 87(4), 417–424. Doi: https://doi.org/10.1016/j.biosystemseng.2003.12.012

Correa, P.C., Silva, F.S., Jaren, C., Junior, P.C.A., Arana, I. (2007). Physical and mechanical properties in paddy processing. Journal of Food Engineering Vol:79, pp: 137–142. Doi: https://doi.org/10.1016/j.jfoodeng.2006.01.037

Dange, A.R., Thakare, S.K., Rao, I.B. (2011). Cutting energy and force as required for Pigeon pea stems. Journal of Agricultural Technology 2011 Vol. 7(6), pp. 1485-1493. Retrieved from https://www.cabdirect.org/cabdirect/FullTextPDF/2011/20113397919.pdf

Dowgiallo, A. (2005). Cutting force of fibrous materials. Journal of Food Engineering 66(1):57-61. Doi: https://doi.org/10.1016/j.jfoodeng.2004.02.034

Ekinci, K., Yilmaz, D., Ertekin, C. (2010). Effects of moisture content and compression positions on mechanical properties of carob pod (Ceratonia siliqua L.). African Journal of Agricultural Research, 5(10), pp 1015–1021. Retrieved from https://academicjournals.org/journal/AJAR/article-full-text-pdf/404EAD329811

Esgici, R., Sessiz, A., Bayhan, Y. (2016). The relationship between the age of combine harvester and grain losses for paddy. International Scientific Journal. Mechanization in Agriculture. Issue: 1/2016, 18-21, ISSN 0861-9638, Sofia, Bulgaria. Retrieved from https://stumejournals.com/journals/am/2016/1/18.full.pdf

Ghahraei, O., Ahmad, D., Khalina, A., Suryanto, H., Othman, J. (2011). Cutting tests of kenaf stems. Transactions of the ASABE, 54(1), pp 51-56. https://pubag.nal.usda.gov/catalog/2342727

Hoseinzadeh, B., Esehaghbeygi, A., Raghami, N. (2009). Effect of moisture content, bevel angle and cutting speed on shearing energy of three wheat varieties. World Applied Sciences Journal 7 (9), 1120–1123. Retrieved from http://www.idosi.org/wasj/wasj7(9)/7.pdf

Jicheng, H., Cheng S., Xianwang, L., Kunpeng, T., Qiaomin, C., Bin, Z. (2017). Design and tests of hemp harvester. International Agricultural Engineering Journal Vol. 26(2), 117-127. Retrieved from http://www.iaej.cn/EN/volumn/volumn_1172.shtml#

Kocabiyik, H., Kayisoglu, B. (2004). Determination of shearing features of sunflower stalk. Journal of Agricultural Sciences, Vol.10(3), 263–267. Retrieved from https://dspace.ankara.edu.tr/xmlui/bitstream/handle/20.500.12575/56230/15268.pdf?sequence=1&isAllowed=y

Koloor, R.T., Borgheie, A. (2006). Measuring the static and dynamic cutting force of stems for Iranian Paddy Varieties. Journal of Agricultural Science and Technology Vol. 8: 193-198. Retrieved from https://jast.modares.ac.ir/article-23-5-en.pdf

Kronbergs, A., Širaks, E., Kronbergs, A.E. (2011). Mechanical properties of hemp (cannabis sativa) biomass. Environment. Technology. Resources. Proceedings of the 8th International Scientific and Practical Conference. Vol 1. Retrieved from http://zdb.ru.lv/conferences/4/VTR8_I_184.pdf

Mathanker, S.K., Grift, T.E., Hansen, A.C. (2015). Effect of blade oblique angle and cutting speed on cutting energy for energycane stems. Biosystems Engineering, Vol.133, pp. 64-70. Retrieved from https://doi.org/10.1016/j.biosystemseng.2015.03.003

Mohsenin, N.N. (1986). Physical properties of plant and animals materials. 2nd edition. New York, NY: Gordon and Breach Science Publishers.

Nowakowski, T. (2016). Empirical model of unit energy requirements for cutting giant miscanthus stalks depending on grinding process parameters. Annals of Warsaw University of Life Sciences – SGGW, Agriculture (Agricultural and Forest Engineering) 67: 63–70. Retrieved from https://www.cabdirect.org/cabdirect/FullTextPDF/2016/20163299165.pdf

O'Dogherty, M.J., Huber, J.A., Dyson, J., Marshall, C.J. (1995). A study of the physical and mechanical properties of wheat straw. Journal of agricultural Engineering Research,62(2): 133-142. Doi: https://doi.org/10.1006/jaer.1995.1072

Ozdemir, G., Sessiz, A., Esgici, R., Elicin, A.K. (2015). Cutting properties of wine grape cultivars. Scientific Papers. Series B, Horticulture. Vol. LIX. Retrieved from http://horticulturejournal.usamv.ro/pdf/2015/art23.pdf

Pekitkan, F.G., Esgici, R., Elicin, A.K., Sessiz, A. (2018). The change of shear force and energy of cotton stalk depend on blade type and shear angle. Scientific Papers. Series A. Agronomy, Vol. LXI, No. 1, pp. 360-366. Retrieved from http://agronomyjournal.usamv.ro/pdf/2018/issue_1/Art56.pdf

Persson, S. (1987). Mechanics of cutting plant material. ASAE Publications, St Joseph, MI, USA.

Sessiz, A., Elicin, A.K., Esgici, R., Ozdemir, G., Nozdrovicky, L. (2013). Cutting properties of olive sucker. Acta Technologica Agriculturae. The Scientific Journal for Agricultural Engineering, The Journal of Slovak University of Agriculture in Nitra. 16 (3): 80–84. Doi: https://doi.org/10.2478/ata-2013-0021

Sessiz, A., Guzel, E., Bayhan, Y. (2018). Determination of cutting force and energy in grape cane in some domestic and foreign grape varieties. Turkish Journal of Agricultural and Natural Sciences. 5(4): 414–423. Doi: https://doi.org/10.30910/turkjans.471203

Tavakoli, M., Tavakoli, H., Azizi, M.H., Haghayegh, G.H. (2010). Comparison of mechanical properties between two varieties of paddy straw. Advance Journal of Food Science and Technology 2(1): 50-54. Doi: http://maxwellsci.com/print/ajfst/v2-50-54.pdf

Voicu, G., Moiceanu, E., Sandu, M., Poenaru, I.C., Voicu, P. (2011). Experiments regarding mechanical behaviour of energetic plant Miscanthus to crushing and shear stress. In Engineering for Rural Development Jelgava, 26. Doi: http://tf.llu.lv/conference/proceedings2011/Papers/091_Voicu.pdf

Yiljep, Y.D., Mohammed, U.S. (2005). Effect of blade velocity on cutting energy and efficiency during impact cutting of sorghum stalk. Agricultural Engineering International: CIGR Journal VII,004–05 (Manu. PM). Retrieved from https://cigrjournal.org/index.php/Ejounral/article/view/604/598

Yore, M.W., Jenkins, B.M., Summers, M.D. (2002). Cutting properties of paddy straw. Paper Number: 026154.ASAE Annual International Meeting / CIGR XVth World Congress. Doi: https://doi.org/10.13031/2013.9785

Zareiforoush, H., Mohtasebi, S.S., Tavakoli, H., Alizadeh, M.R. (2010). Effect of loading rate on mechanical properties of paddy (Oryza sativa L.) straw. In Aust J Crop Sci, 4(3): 190-195. Retrieved from http://www.cropj.com/tavakoli_4_3_2010_190_195.pdf

Zhou, Y., Shen, C., Li, X., Zhang, B., Huang, J., Tian, K. (2016). Design and Test of 4LMD-160 Hemp Harvester. Applied Mechanics and Materials Submitted: ISSN: 1662-7482, Vol. 851, pp 389-395. Doi: https://doi.org/10.4028/www.scientific.net/AMM.851.389