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CUTTING PROPERTIES OF OLIVE SUCKER

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The exact knowledge of olive suckers and branches cutting behaviour is one of the main parameters for optimizing the design of cutting elements in pruning machines. In this study, the cutting properties of five different varieties of the table olive, namely Halhali, Gullaki, Mavis, Belloti and Zoncuk respectively, were determined. The cutting properties were measured at three moisture content levels (17.05, 34.44, and 39.47 %) and four cross-sectional areas (12.56, 28.27, 50.26 and 78.54 mm²). The results showed that the cutting force and cutting energy requirement of olive suckers decreased with increasing moisture content in all of the olive varieties. However, these properties increased with increasing cross-sectional area. The maximum cutting force, cutting strength, cutting energy requirement and specific cutting energy of olive sucker were obtained at the Halhali variety as 869.15 N, 18.66 MPa, 4.29 J and 0.0875 J.mm⁻², respectively, while the minimum cutting values were obtained at the Zoncuk variety as 619.19 N, 14.75 MPa, 2.44 J and 0.0531 J.mm⁻², respectively. As a result, the data obtained from cutting tests of the olive sucker can be used in a new design and development of an experimental prototype of olive branch cutting and pruning machine.

Keywords: olive, pruning, cutting properties and energy, design

Olive (*Olea europaea*) is one of the oldest cultivated fruits and is growing in various microclimates and soil types throughout the world. The homeland of olive is Upper Mesopotamia, including Southeastern Anatolia Region of Turkey, and it has spread to other Mediterranean countries from this region (Ozkaya, 2004; Sessiz and Özcan, 2006). Nowadays, in Mediterranean countries, olive trees play a significant economic role. It has probably been grown in the Mediterranean region for the past four millennia and used either pickled or as a source of cooking oil. Olives have played an important role in the diet of people living in that region (Anonymous, 1995; Sessiz, 2005). Olives have been grown on a large scale in Turkey. While world production is 15,340,488 tones, the olive is cultivated on 597,000 hectares with an annual production of 1.8 million tonnes in Turkey. It is the fourth after Spain, Italia, and Greece in terms of olive production (FAO, 2004). However, nearly most of olive harvesting and pruning involves traditional methods, and it is largely pruned by hand, by workers in Turkey. In olive growing, pruning is a crucial practice to maintain olive productivity, and it is essential in order to limit the size of trees and to allow easy harvesting as well as to maintain a good reproductive and vegetative balance. Pruning, after olive harvesting, requires the largest utilization of farm labour in the whole crop cycle, and the progressive shortage of skilled labour and its increasing cost force farmers to carry out pruning less often than is necessary. In modern olive growing, the training system should permit an easy movement of machinery in orchard; little attention needs to be paid to specific tree shapes (Georget et al., 2001; Dias et al., 2012).

The mechanization of agriculture particularly after harvest has produced high demand on the knowledge of physical and mechanical properties of products. These properties depend on species, variety, diameter, maturity, moisture content and cellular structure (Persson, 1987; Nazari Galedar et al., 2008). The variation in physical properties of plant stalks and the resistance of cutting equipment have to

be known in order to understand the behaviour of material with respect to a different operation of conditions. Knowing those properties will be useful for both manufacturers and consumers of food processing equipment. Especially, information on plant properties and the power or energy requirement of equipment has been very valuable for selecting the design and operational parameters (Persson, 1987; Emadi et al., 2004; Voicu et al., 2011; Ghahraei et al., 2011; Hoseinzadeh and Shirneshan, 2012). Perhaps, the stem of plants cutting energy is one of the main parameters for optimizing the design of cutting elements in harvesting and pruning machines (Alizadeh et al., 2011). Therefore, a comparative performance of cutting elements applied in the harvester and pruning machine design can be justified by their cutting energy requirements, cutting force and stress applied. Hence, it is necessary to determine the cutting energy requirement for a suitable knife design and also operational parameters (Alizadeh et al., 2011).

The objective of this study was to determine the cutting properties such as cutting force, cutting strength and cutting energy requirement and the specific cutting energy of suckers of five olive varieties depending on moisture content and cross-sectional area.

Material and methods

Sample preparation and measuring apparatus

To determine the cutting properties of the olive sucker, five olive varieties, namely Halhali, Gullaki, Mavi, Belloti and Zoncuk, were selected in the experiment. A sample of olive suckers was obtained in a commercial grove in Derik town (Fig. 1) in Mardin province, southeastern Turkey. Experimental tests were performed during the olive pruning season in year 2012.

Specimens were kept in a refrigerator at temperature 4–5 °C in the laboratory of Agricultural Machinery

Figure 1 Experimental olive orchard

Department. In order to determine the initial moisture content, five samples of 30 g were weighed and dried in an oven at 105 °C for 24 h (ASABE, 2006) and then reweighed to measure the moisture content using a gravimetric method.

Determination of cutting properties

To determine the cutting force, cutting energy and displacement, the blade was held and fixed to the crosshead of Lloyd LRX plus, an Instron universal testing machine (Fig. 2). The olive sucker was positioned on the counter shear support and cut with a constant blade speed of 100 mm·min⁻¹. Prior to experiment, the specimen diameter was measured with a digital calliper, and then, the olive sucker samples were divided into four different diameter groups, from a 4 mm to 10 mm hole (4, 6, 8, 10 mm).

The maximum cutting strength of olive suckers was determined by the following equation (Mohsenin, 1980; Beyhan, 1998; Sessiz, 2005; Amer Eissa et al., 2008; Tavakoli et al., 2009; Zareiforoush et al., 2010)

$$\sigma_s = \frac{F_{\max}}{A} \quad (1)$$

where:

σ_s – the maximum cutting strength in (MPa)

$F_{\max}$ – the maximum cutting force in (N)

A – the cross-sectional area of sucker in (mm²)

Cutting energy was calculated by measuring the surface area under the cutting force-deformation curve (Kocabiyik and Kayisoglu, 2004; Ekinci et al., 2010; Heidar and Chegini, 2011; Chen et al., 2004; Nazari Galedar et al., 2008; Zareiforoush et al., 2010). The cutting energy and displacement was calculated, by the Instron universal testing instrument, of the area under the curve, with the help of force and displacement data by using a NEXYGEN computer program. A typical force-deformation curve is given in Fig. 3.

Figure 3 Typical force-deformation curve for cutting of olive sucker (branch)

From cutting energy data, specific cutting energy was determined by the following equation (Heidar and Chegini, 2011).

$$E_{sc} = \frac{E_c}{A} \quad (2)$$

where:

E_{sc} – specific cutting energy, J·mm⁻²

E_c – cutting energy, J

A – cross-sectional area, mm²

Figure 2 Universal testing machine and cutting blade

Experimental design and statistical analysis

Experimental results were tested using a standard variance analysis (ANOVA) for a randomized complete block design. Cutting properties were determined with three repetitions in each treatment of suckers. Mean separations were made for significant effects with LSD and means were compared at the 1 % and 5 % levels of significance using the Tukey's multiple range tests in the JAMP software.

Results and discussion

Effects of moisture content on mechanical cutting properties

The results of the cutting properties are shown in Table 1. As shown in the table, the moisture content has a significant effect on the cutting properties of olive sucker ($P < 0.01$). It is seen from Table 1 that increasing moisture content led to a decrease in cutting force, cutting strength, energy requirement and specific cutting energy. The decrease in cutting force and energy with increasing moisture content may be due to the behaviour of plant material.

It was observed that the maximum values of cutting force, cutting strength, energy requirement and specific cutting energy were obtained at a moisture content of 17.05 % as 846.02 N, 19.28 MPa, 4.07 J and 0.082 J.mm⁻², respectively, while the minimum values of cutting force, cutting strength, energy requirement and specific cutting energy were obtained at a moisture content of 39.47 % as 652.20 N, 15.28 MPa, 2.95 J and 0.065 J.mm⁻², respectively.

The results have also indicated that there were found large differences between the highest and lowest values depending on moisture contents in terms of cutting force, cutting strength and cutting energy. However, the difference between values of both cutting energy and specific cutting energy at 34.44 % and 39.47 % were not significant at the probability level. These results are in agreement with Ghahraei et al. (2011) for kenaf stem. According to Liu et al. (2009), cutting force increased with decreasing moisture content, which is due to fibre tensile strength being related to moisture content; cutting strength was high when moisture content was low. However, we can recommend high moisture content to minimise the cutting strength and cutting energy requirements. According to Igathinathane et al. (2010), cutting energy is related to the maximum cutting force, stem shear strength, stem diameter, dry matter density, and moisture content. A similar research conducted by Tabatabaee Kolor and Borgheie (2006) on a rice harvester showed that higher moisture content reduced the cutting force needed for rice stems.

Table 2 Regression equations of cutting properties as a function of moisture content

Parameters	Regression equation	R ²
Cutting force in N	$Y = -96.91MC + 946.22$	0.998
Cutting strength in MPa	$Y = -1.975 MC + 21$	0.997
Cutting energy in J	$Y = -0.56 MC + 4.58$	0.976
Specific cutting energy in J.mm ⁻²	$Y = -0.0085 MC + 0.0893$	0.946

*MC – moisture content in %

The best relationship between moisture content and cutting force, cutting strength, energy requirement and specific cutting energy can be represented by the regression equation shown in Table 2. Equations can be used to predict the mechanical cutting properties of olive sucker as a function of moisture content. These calculations can be considered in designing the prototype of olive pruning machine.

Effects of cross-sectional area on mechanical cutting parameters

The results of the cutting properties depending on cross-sectional area are shown in Table 3. The results shown in Table 3 indicate that the cutting force, cutting strength, cutting energy and specific cutting energy requirement increased with increasing cross-sectional area. There were found significant differences between cutting force, cutting strength, cutting energy and specific cutting energy in all of cross-sectional areas at a 1 % probability level.

The maximum values of cutting force, cutting strength, energy requirement and specific cutting energy were obtained at 78.54 mm² cross-sectional area as 1,379.60 N, 18.46 MPa, 7.130 J and 0.0908 J.mm⁻², respectively, while the minimum values of cutting force, cutting strength, energy requirement and specific cutting energy were obtained at 12.56 mm² cross-sectional area as 208.15 N, 15.47 MPa, 0.634 J and 0.0505 J.mm⁻², respectively. Especially, the cross-sectional area has a significant influence on cutting energy, and cutting energy requirement increased linearly with increasing cross-sectional area. The cutting energy values varied from 0.634 J to 7.130 J (0.0505–0.0908 J.mm⁻²). The effect of cross-sectional area was also reported by Chen et al. (2004), by Kronbergs et al. (2011) for hemp stalk. The specific cutting energy for hemp stalk was observed within 0.02–0.04 J.mm⁻² by Kronsberg et al. (2011). The results have shown that the cutting strength and cutting energy related to plant physical and mechanical properties (Igathinathane et al., 2010). Similar results were reported by Kronsberg et al. (2011) for hemp stalk, by Alizadeh et al. (2011) for rice stem, and by Ghahraei et al. (2011).

Table 1 The relationship between average cutting properties and moisture content

Moisture content in % w.b	Cutting force in N	Cutting strength in MPa	Cutting energy in J	SCE in J.mm ⁻²
17.05	846.02 ^a *	19.28 ^a	4.07 ^a	0.082 ^a
34.44	758.97 ^b	17.20 ^b	3.36 ^b	0.070 ^b
39.47	652.20 ^c	15.28 ^c	2.95 ^b	0.065 ^b
Mean	752.20	17.25	3.46	0.072
LSD values	57.83	1.27	0.519	0.0044

* means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level

Table 3 The relationship between average cutting properties and cross-sectional area

Cross-sectional area in mm ²	Cutting force in N	Cutting strength in MPa	Cutting energy in J	Specific cutting energy in J.mm ⁻²
12.56	208.15 ^d	15.47 ^b	0.634 ^d	0.0505 ^d
28.27	493.70 ^c	17.46 ^a	1.929 ^c	0.0682 ^c
50.26	928.12 ^b	17.57 ^a	4.152 ^b	0.0826 ^b
78.54	1379.60 ^a	18.46 ^a	7.130 ^a	0.0908 ^a
Mean	752.39	14.24	3.461	0.0730
LSD	73.24	1.756	0.659	0.0061

* means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level

Table 4 Regression equations of cutting properties as a function of cross-sectional area

Parameters	Regression equation	R ²
Cutting force in N	$Y = 394.88CS^* - 234.8$	0.990
Cutting strength in MPa	$Y = 0.908CS + 14.97$	0.862
Cutting energy in J	$Y = 2.173CS - 1.97$	0.970
Specific cutting energy in J.mm ⁻²	$Y = 0.0135CS + 0.0392$	0.975

*CS – cross-sectional area in mm²

The best relationship between ultimate cutting strength and cross-sectional area is presented by the regression equation in Table 4. As shown in the table, cutting strength decreased with increasing cross-sectional area. In other words, there is a positive relationship between independent parameters and cross-sectional area. Regression analysis indicated that cross-sectional area had a strong effect on cutting force and energy. To predict the cutting force and energy of olive branches with regard to cross-sectional area, this regression equation can be applied to the design of the harvester and pruning machine.

This effect is in agreement with a previous study on maize stalks, in which both the cutting energy and maximum cutting force were directly proportional to cross-sectional area (Prasad and Gupta, 1975). It can be expressed that cross-sectional area played more effect on cutting energy than the stem wall thickness and diameter (Alizadeh et al., 2011). Esehaghbeygi et al. (2009) reported that taller plants have lower stem diameter, and shearing energy will be decreased. The effect of stem diameter on the maximum cutting force and cutting energy is consistent with Chen et al. (2004), who reported that both the cutting energy and maximum cutting force are directly proportional to the cross-sectional area of hemp stalk.

Effects of olive varieties on mechanical cutting parameters

Table 5 shows the results of comparing the cutting properties among the varieties. The results indicated that the highest cutting force, cutting strength, cutting energy and specific cutting energy were obtained at the Halhali variety as 869.15 N, 18.66 MPa, 4.29 J and 0.0875 J.mm⁻², respectively, and followed by the varieties Gullaki, Maviş, Belloti and Zoncuk. The minimum cutting force, cutting strength, cutting energy and specific shearing energy were obtained at the Zoncuk variety as 619.19 N, 14.75 MPa, 2.44 J and 0.0531 J.mm⁻², respectively. This effect could be related to a higher stem wall thickness of Halhali compared to the other examined varieties. Similar results were obtained for the Gullaki variety. The highest cutting force and energy was obtained at the Halhali variety, but there was no significant difference among the means for Gullaki and Maviş. Cutting force and cutting energy varied between 619.19 and 869.15 N and between 2.44 and 4.29 J, respectively.

This difference may be due to different physical, mechanical and physiological properties of stem varieties (Hediari and Chegini, 2011; Hoseinzadeh and Shirneshan, 2012). This information is very valuable for selecting a suitable equipment design. The selection of suitable cutting apparatuses and equipment plays an important role in economizing on cutting force requirement. So, we must consider the olive variety, variety branch diameter, and physical and mechanical properties.

According to Skubisz (2001), mechanical properties are correlated with the structure of plant stems. Similar trends were reported by Nazari Galedar et al. (2008) for alfalfa stem, Tavakoli et al. (2009) for barely stem, Ince et al. (2005) for sunflower stalk, Esehaghbeygi et al. (2009) for wheat, Yilmaz et al. (2009) for sesame stalk, Ekinici et al. (2001) for carob pod and Zareiforush et al. (2010) for rice straw.

Table 5 The relationship between the average cutting properties and olive varieties

Grape varieties	Cutting force in N	Cutting strength in MPa	Cutting energy in J	Specific cutting energy in J.mm ⁻²
Halhali	869.15 ^{d*}	18.66 ^a	4.29 ^a	0.0875 ^a
Gullaki	787.84 ^d	17.99 ^a	3.86 ^a	0.0867 ^a
Maviş	754.15 ^{cd}	17.96 ^a	3.78 ^a	0.0776 ^a
Belluti	731.65 ^{bc}	16.83 ^{ab}	2.91 ^b	0.0604 ^b
Zoncuk	619.19 ^b	14.75 ^b	2.44 ^b	0.0531 ^b
Mean	940.49	17.24	3.45	0.0730
LSD	87.39	2.08	0.472	0.0159

* means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level

Conclusion

The results showed that the mechanical cutting properties changed depending on moisture, cross-sectional area and varieties. The olive variety Halhali is approved as the strongest, but the Zoncuk variety the weakest material in cutting. The maximum cutting force, cutting strength, cutting energy and specific cutting energy were obtained at the Halhali variety as 869.15 N, 18.66 MPa, 4.29 J and 0.0875 J.mm⁻², respectively, followed by the varieties Gullaki, Maviş, Belloti and Zoncuk. The minimum cutting force, cutting strength, cutting energy and specific shearing energy were obtained at the Zoncuk variety as 619.19 N, 14.75 MPa, 2.44 J and 0.0531 J.mm⁻², respectively. As a result, the data obtained from the cutting tests of olive sucker can be used in the new design and development of an experimental prototype of olive branch cutting and pruning machine.

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References

- ALIZADEH, M. R. – AJDADI, F. R. – DABBAGHI, A. 2011. Cutting energy of rice stem as influenced by internode position and dimensional characteristics of different varieties. In *AJCS*, vol. 5, 2011, no. 6, pp. 681–687.
- AMER EISSA, A. H. – GOMAA, A. H. – BAIOMAY, M. H. – IBRAHIM, A. A. 2008. Physical and mechanical characteristics for some agricultural residues. In *Misr J Ag Eng*, vol. 25, 2008, no. 1, pp. 121–146.
- ANONYMUS. 1995. The Australian new crops newsletter. Issue no. 3, January. <http://www.uq.az/-gagregio/newslett/ncnl3-91.htm>
- ASABE STANDARDS. 2006. S358.2: 1:1 Measurement – Forages. 52nd ed. American Society of Agricultural and Biological Engineers, St Joseph MI.
- BEYHAN, M. A. 1996. Determination of shear strength of hazelnut sucker. In *J. Agric. Fac.*, vol. 11, 1996, no. 3, pp. 167–181.
- CHEN, Y. – GRATTON, J. L. – LIU, J. 2004. Power requirements of hemp cutting and conditioning. In *Biosystems Engineering*, 2004, no. 87, pp. 417–424.
- DIAS, A. B. – PEÇA, J. O. – PINHEIRO, A. 2012. Long-term evaluation of the influence of mechanical pruning on olive growing. In *Agronomy Journal*, vol. 104, 2012, iss. 1. Crop
- EKINCI, K. – YILMAZAND, D. – ERTEKIN, C. 2010. Effects of moisture content and compression positions on mechanical properties of carob pod (*Ceratonia siliqua* L.). In *African Journal of Agricultural Research*, vol. 5, 2010, no. 10, pp. 1015–1021.
- EMADI, B. – KOSSE, V. – YARLAGADDA, P. 2004. Relationship between mechanical properties of pumpkin and skin thickness. In *International Journal of Food Properties*, vol. 8, 2004, no. 2, pp. 277–287.
- ESEHAGHBAY, G.I. – HOSEINZADEH, B. – KHAZAEI, M. – MASOUMI, M. 2009. Bending and shearing properties of wheat stem of Alvand variety. In *World Appl Sci J*, 2009, no. 6, pp. 1028–1032.
- FAO. 2004. Production Yearbook.
- GEORGET, D.M.R. – SMITH, A.C. – WALDRON, K.W. 2001. Effect of ripening on the mechanical properties of Portuguese and Spanish varieties of olive (*Olea europaea* L.). In *Journal of the Science of Food and Agriculture*, 2001, no. 81, pp. 448–454.
- GHAHRAEI, O.D. – AHMAD, A. – KHALINA, H. – OTHMAN, J. 2011. Cutting tests of kenaf stems. In *Transactions of the ASABE*, vol. 54, 2011, no. 1, pp. 51–56.
- HEIDARI, A. – CHEGINI, G.R. 2011. Determining the shear strength and picking force of rose flower. In *Agricultural Engineering*, vol. 14, 2011, no. 2, p. 13. Available online: <http://www.ejpau.media.pl/volume14/issue2/art-13.html>.
- HOSEINZADEH, B. – SHIRNESHAN, A. 2012. Bending and shearing characteristics of canola stem. In *American-Eurasian J. Agric. & Environ Sci*, vol. 12, 2012, no. 3, pp. 275–281.
- IGATHINATHANE, C. – WOMAC, A.R. – SOKHANSANJ, S. 2010. Corn stalk orientation effect on mechanical cutting. In *Biosystem Engineering*, 2010, no. 107, pp. 97–106.
- İNCE, A. – UĞURLUAY, S. – GÜZEL, E. – ÖZCAN, M.T. 2005. Bending and shearing characteristics of sunflower stalk residue. In *Biosystem Engineering*, vol. 92, 2005, no. 2.
- KOCABIYIK, H. – KAYISOGLU, B. 2004. Determination of shearing features of sunflower stalk. In *J Agric Sci*, vol. 10, 2004, no. 3, pp. 263–267.
- KRONBERGS, A. – KRONBERGS, E. – SIRAKS, E. – ADAMOVIĆ, A. 2011. Cutting properties of different hemp varieties in dependence on the cutter mechanism. In *Engineering for Rural Development Jelgava*, 26.–27. 5. 2011.
- LIU, L. – YANG, Z.B. – YANG, W.R. – JIANG, S.Z. – ZHANG, G.G. 2009. Correlations among shearing force, morphological characteristic, chemical composition, and in situ digestibility of alfalfa (*Medicago sativa* L) stem. In *Asian-Aust J Anim Sci*, vol. 22, 2009, no. 4, pp. 520–527.
- MOHSENIN, N.N. 1980. Physical properties of plant and animal materials. New York : Gordon and Breach Publishers.
- NAZARI, G.M. – TABATABAEFAR, A. – JAFARI, A. – SHARIFI, A. – RAFIEE, S. 2008. Bending and shearing characteristics of alfalfa stems. In *Agricultural Engineering International: the CIGR Ejournal*, Manuscript FP 08 001, vol. 10, 2008, May.
- ÖZKAYA, M.T. 2004. Zeytin ve Zeytin yağı (Olive and olive oil). Retrieved from: <http://www.tariszeytin.com.tr>
- PERSSON, S. 1987. Mechanics of cutting plant material. ASAE Publications, Michigan.
- PRASAD, J. – GUPTA, C. B. 1975. Mechanical properties of maize stalks as related to harvesting. In *J Agric Eng Res*, vol. 20, 1975, no. 1, pp. 79–87.
- SESSİZ, A. 2005. Physical and mechanical properties of soybean crops and their relationship. In *Indian Journal of Agricultural Engineering*, vol. 40, 2005, no. 2, pp. 30–38.
- SESSİZ, A. 2005. Physical properties of some green olive cultivars. In 9th International Congress on Mechanization and Energy in Agriculture. 27–29 Eylül, İzmir.
- SESSİZ, A. – ÖZCAN, M.T. 2006. Olive removal with pneumatic branch shaker and abscission chemical. In *Journal of Food Engineering*, 2006, no. 76, pp. 148–153.
- SKUBISZ, G. 2001. Development of studies on the mechanical properties of winter rape stems. In *Agrophysics*, 2001, no. 15, pp. 197–200.
- TABATABAEE, K.R. – BORGHEIE, A. 2006. Measuring the static and dynamic cutting force of stems for Iranian rice varieties. In *J Agric Sci Technol*, 2006, no. 8, pp. 193–198.
- TAVAKOLI, H. – MOHTASEBI, S.S. – JAFARI, A. – GALEDAR, M.N. 2009b. Some engineering properties of barley straw. In *Appl Eng Agric*, vol. 25, 2009, no. 4, pp. 627–633.
- 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.–27. 5. 2011.
- YILMAZ, D. – KABAS, O. – AKINCI, I. – CAGIRGAN, M.I. 2009. Strength and deformation parameters of sesame stalk in relation to harvest. In *Philipp Agric. Sci.*, 2009, no. 92, pp. 85–91.
- ZAREIFOROUSH, H. – MOHTASEBI, S.S. – TAVAKOLI, H. – ALIZADEH, M.R. 2010. Effect of loading rate on mechanical properties of rice (*Oryza sativa* L.) straw. In *Aust J Crop Sci*, vol. 4, 2010, no. 3, pp. 190–195.

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