ISESCO JOURNAL of Science and Technology
Volume 8 - Number 13 - May 2012 (25-29)

Determination of Strength and Energy Requirement for Onion Leaf Removing

[1]Mohsen Heidari Soltanabadi
[2]Shamsolah Abdolahpur
[3]Orang Taki
[1]Ph.D. Student of Agricultural Machinery Engineering Department, Agricultural college Tabriz University
[2]Assistant Professor of Agricultural Machinery Engineering Department, Agricultural Faculty of Tabriz University
[3]Assistant Professor of Agricultural Engineering Department, Esfahan center for Agricultural and natural resource research
Email: mheisol@gmail.com

Abstract

The Development of the onion harvesting machine is the important goal in the mechanization of this product. One of the major onion harvesting machines is the topper. To design a topper system, knowing of some physical and mechanical properties such as cutting strength and energy requirement are important. In this study the strength of onion leaf and specific rupture energy for onion leaf removing from its bulb in three loading rates (50,100 and 200 mm/min), three loading types (leaf cutting at the attached point to the bulb, leaf cutting at 5cm above the bulb and leaf tensile at 5cm above the bulb) and two moisture contents of leaf (65 and 85 percentage) were measured. Results showed that by increasing the loading rate, strength of the onion leaves was changed from 1.06 to 0.48 MPa and specific rupture energy was varied from 11.59 to 5.25 mJ/ mm^2. By reducing leaf moisture, strength of onion leaf and specific rupture energy were changed from 0.86 to 0.62 MPa and from 11.91 to 5.4 mm J/ mm^2 respectively. Cutting the leaves attached to the bulb had the maximum strength and specific rupture energy with values of 1.54 MPa and 11.52 mJ/ mm ^{2}.

Keywords: *Onion, Rupture Energy, Shear and Tensile Strength, Topping.*

1. Introduction

One of the most important machines in onion harvesting is the topper. Knowing of some physical and mechanical properties such as cutting strength and energy requirement for designing a topper system, are necessary. Much researches was carried out on the physical properties of many agricultural products (Maw *et al*, 1996; Mcrandal and Mcnulty, 1980; Tabil *et al* , 2002). During a research, the crushing and punching strength of the onion bulb was obtained 26.4 and 25 N, respectively (Maw *et al*, 1996). In other research the value of punching strength was obtained from 26.9 to 45.5 N (Bahnasawy *et al*, 2004). Tabatabaee Koloor and Borgheie (2006) achieved the static and dynamic shear strength of the rice stem for Khazar and Hashemi varieties, 1629 and 1429 kPa and 187.4 and 144 kPa respectively. Results of I˙nce, *et al*, (2005) showed that by increasing the moisture content of sunflower stalks, the modulus of elasticity and bending stress were decreased while shear strength values and cutting power were increased. Vursavus, *et al*, (2006) estimated some physical and mechanical properties of the cherry, including mass, density, shape, size, surface, spherical, stress and failure strain and the modulus of elasticity. The research of Chattopadhyay and Pandey (1999) showed that by increasing angle and speed of blade, the energy requirement in flail forage cutting was decreased.

Mc Randall and Mc Nulty (1980) built a machine that could record force changes in terms of the distance changes in the cutting of grass. The effect of factors such as cutting speed, blade angle, age hay, size hay and dry weight hay on shear energy was evaluated. The results showed that the mechanical properties depend on dry weight hay. Also blade angle was not of significant effect on shear energy. Research of Chattopadhyay and Pandey (2001) showed that increasing the linear speed of blade in fail cutting method caused a decrease in torque and specific cutting energy in both mathematical model and farming test. Mc Randall and Mc Nulty (1978) presented a mathematical cutting model for cantilever and beam model of forage. According to this model, the minimum speed of the cutting blade for a good cutting was 20 m/s. In addition, by increasing blade linear speed and blade angle, the cutting energy was decreased. Jang (2005) determined the mechanical properties of garlic stems for developing a garlic machine harvester. Results showed that the mean shear force of garlic stalks and modulus of elasticity were about 0.642 N and 2.4 x 10^7Pa respectively. He argued that by increasing the stem diameter, shear force was increased.

A study was carried out for the development of rice mechanization. Results showed that the ultimate tensile and shear strength was from 87 to 168 N and from 28 to 87 N respectively. Dynamic coefficient of friction was from 0.306 to 0.489 (Usrey *et al*, 1992). In other research, tensile and shear strength, modulus of elasticity and shear modulus of wheat stem were determined by an Instron apparatus. According to the results of this study, tensile and shear strength were 118 Pa and 8.47, Pa and modulus of elasticity and shear modulus were 13.1 and 0.64 GPa, respectively (Kronbergs, 2000).

The purpose of this study was to determine tensile and shear strength of onion leaf and measure the energy requirement for leaf cutting. These mechanical properties are important parameters for the design of onion topper machines. Dimensions and power requirement in these machines depend on leaf strength and rupture energy for onion leaf removing.

2. Material and method

A factorial test method based on randomized block design with four replications was carried out for determining the effect of loading rate, loading type and leaf moisture content on leaf strength and specific rupture energy. In this study, the loading rate was changed in three value, 50, 100 and 200 mm/min. loading types were included; leaf cutting at the attached point to the bulb (S0), leaf cutting at 5cm above the bulb (S5) and leaf tensile at 5cm above the bulb (T5). Leaf moisture contents were 85 and 65 percentage (%w.b.). In order to measure the leaves shear (cutting) strength (σs) and tensile strength (σt), an Instron universal testing machine (model: 1140) was used. This device was able to record the tensile force (Ft) or shear force (Fs) versus time through, connection to a personal computer (Texture analyzer acquiesce soft ware). Shear (cutting) and tensile strength values and displacement (x) are expressed by:

$$\sigma c = F_c / A$$

$$\sigma t = F_t / A$$

$$x = R_L . t$$

In the equations A is the cross-sectional area of the leaves at rupture point, t was the time of the loading, and RL was loading rate. In the records, the maximum shear and tensile strength value was considered as the shear strength or tensile strength. In the tensile test, in order to maintain the bulb and connect the leaf to the load cell, a metal perforated plate and a clamp was designed and used (***Figure 1***). In cutting tests the shear probe of Warner-Bratzler (***Figure 2***) was used. For each test, a diagram of displacement-force was obtained. Specific rupture energy in the case of cutting (Esc) and tensile (Est) is found by dividing the under curve area of the displacement-force diagram to the cross section area of leaf. These are obtained by:

$$E_{sc}= \frac{1}{A}\int F_c . dx$$

$$E_{st}= \frac{1}{A}\int F_t . dx$$

Data obtained from experiments was analyzed using SAS software and averages were grouped by MSTATC software.

Figure 1: *Maintaining method of onion in tensile test.*

Figure 2: Varner-Bratzler shear probe.

3. Results and Discussion

The Main effects of loading rate, loading type and leaf moisture content on tensile and shear strength of leaf were shown in *Table 1*. Based on these results, by increasing the moisture content of leaves, the strength and specific rupture energy were significantly increased. This behavior may be explained on the basis of the fact that the plant stalk has viscoelastic behavior and therefore, the viscous resistance against cutting or tension is changed by increasing the moisture. In the onion leaf by increasing the moisture, resistance material was increased. Similar results were observed by another researcher for sunflower stems (I˙nce *et al*, 2005).

By increasing the loading rate, the strength and specific energy was decreased (*Table 1*). Comparing three types of loading showed that S0 has the greatest strength and specific energy. It can be described that in the point of contact bulb and leaf, the leaf has the largest diameter and in this region, tissue is denser. Comparing S5 with T5 in the same height of leaf (5cm) showed that the leaf cutting required less force and energy. The interaction effect of moisture content and type loading (*Figure 3*) showed a leaf moisture content of 85%.

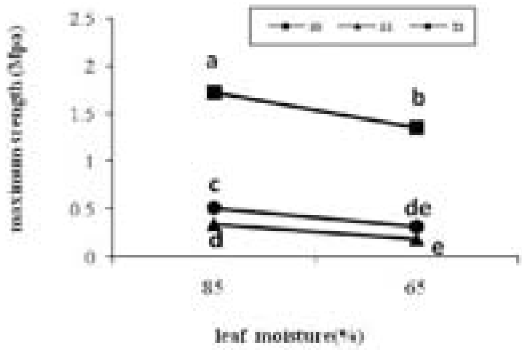

Figure 3: interaction effect of leaf moisture content and loading type on maximum onion leaf strength.

S0 and S5 had maximum and minimum strength respectively. In leaf moisture content of 65% the most leaf strength was observed in S0. Other types loading (T5 and S5) didn't have significant difference in the amount of strength. The trend of specific energy was similar to the strength (*Figure 4*).

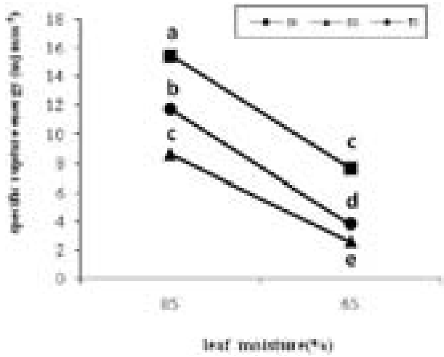

Figure 4: interaction effect of leaf moisture content and loading type on specific rupture energy.

TABLE 1. Means comparison of the effect of leaf moisture content, loading type and loading rate on tensile and cutting strength and Specific rupture energy.

	Loading rate (mm/min)			Loading type			Leaf moisture	
	200	100	50	T5	S5	S0	65%	85%
Strength	0.48c	0.68b	1.06a	0.41b	0.26c	1.54a	0.62b	0.86 a
Specific rupture energy	5.25c	8.01b	11.59a	7.75b	5.58c	11.52a	4.5b	11.91a

The means with common litter don't have significant difference in 5% level (Duncan test).
S0: leaf cutting at the attached point to the bulb
S5: leaf cutting at 5cm above the bulb
T5: leaf tensile at 5cm above the bulb

Interaction effect of rate loading and type loading on leaf strength (*Figure 5*) showed that the increase of the rate loading in S0, caused the force to leaf cutting to decrease. The interaction effect of rate loading and type loading on specific rupture energy (*Figure 6*) showed that by increasing the rate loading, energy requirement to leaf rupture was decreased. Mac Randall and Mac Nulty (1978) and Chattopadhyay and Pandey (2001) also had a similar observation. In loading rates of 50 and 100 mm/min, the amount of specific energy had significant difference in three types of loading including S0, S5 and T5 respectively. In a loading rate of 200 mm/min, the amount of specific energy in S5 and T5 showed no difference. At this loading rate, the average specific energy in S0 was the highest significantly.

Figure 7 shows the interaction effect of leaf moisture content and loading rate on the leaf strength. It showed that by increasing the rate of loading in both 85% and 65% moisture content, the leaf strength was decreased significantly. In loading rates of 50 and 100 mm/min, leaf strength in 85% moisture content was higher than 65%. In loading rates of 200 mm/min, the leaf strength didn't show significant difference by varying moisture contents. For all loading rates, decreasing leaf moisture content causes a decrease in specific rupture energy (*Figure 8*). Maximum Energy for removing onion leaf was in 50 mm/min loading rates and 80% moisture content, while minimum energy was achieved in 200 mm/min loading rates and 65% moisture content.

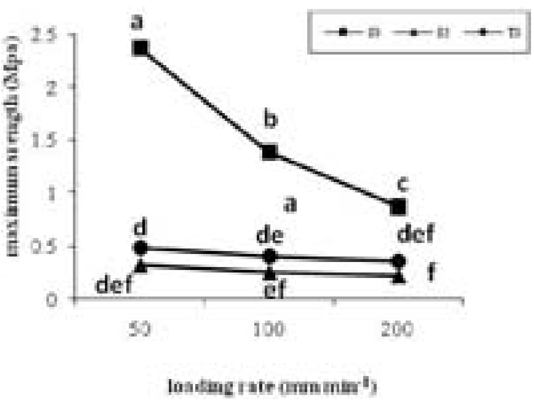

Figure 5: *interaction effect of loading rate and loading type on maximum onion leaf strength.*

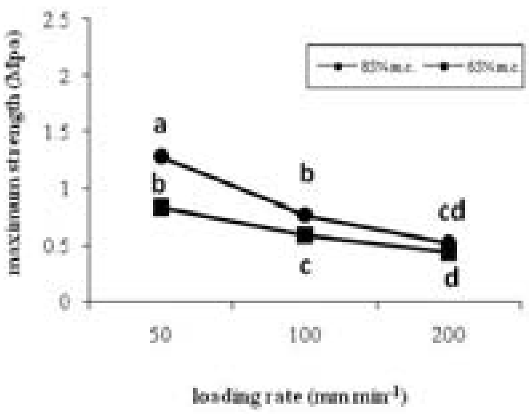

Figure 7: *interaction effect of moisture content and loading rate on maximum onion leaf strength.*

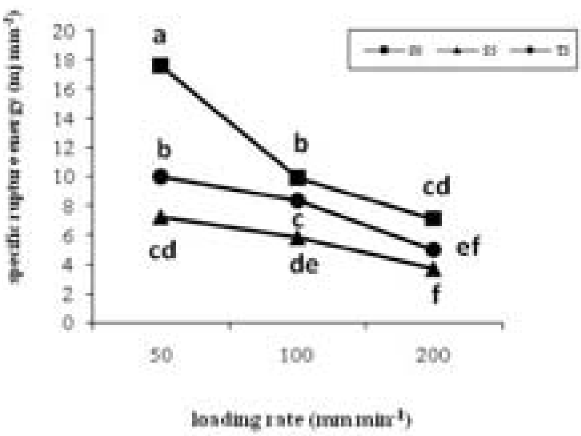

Figure 6: *interaction effect of loading rate and loading type on specific rupture energy.*

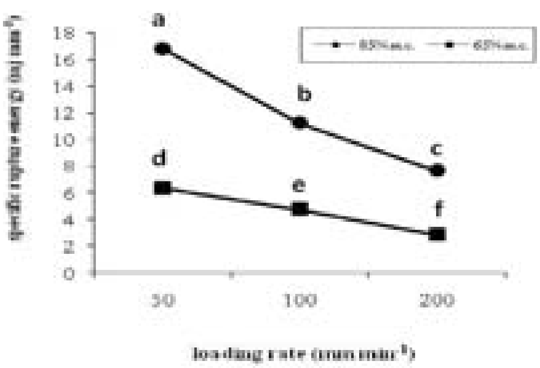

Figure 8: *interaction effect of moisture content and loading rate on specific rupture energy.*

Conclusion

This study was a curried out to determinate strength and energy requirement for removing onion leaf in three types of loading, three rates of loading and two leaf moisture contents. Based on results:

1- The onion leaf strength was measured from 0.19 to 1.72 MPa and specific rupture energy was obtained from 2.58 to 16.84 mj/mm2.

2- The amount of energy to remove onion leaves in the cutting mechanisms was lower than tensile mechanisms.

3- By decreasing leaf moisture content and increasing the height of the remaining leaf on the onion bulb, energy was reduced.

References

[1] A.H. Bahnasawy, Z.A. El-Haddad, M.Y. El-Ansary, et al. Physical and mechanical properties of some Egyptian onion cultivars. Journal of Food Engineering 62. 2004. 255-261.

[2] P.S. Chattopadhyay, K.P. Pandey. Effect of knife and operational parameters on energy requirement in flail forage harvesting. J. Agric. Engng Res. 73 (3), 12. 1999.

[3] P.S. Chattopadhyay, K.P. Pandey. Influence of knife configuration and tip speed on conveyance in flail forage harvesting. J. agric. Engng Res.78 (3), 2001. 245-252.

[4] P.S. Chattopadhyay, K.P. Pandey. Impact cutting behavior of sorghum stalk using a flail-cutter-a mathematical model and its experimental verification. J. agric. Engng Res. 78 (4), 2001. 369-376.

[5] A. I˙nce, S. Ugˇ urluay, E. Gu¨zel, et al. Bending and Shearing Characteristics of Sunflower Stalk Residue. Biosystems Engineering 92 (2). 2005. 175-181.

[6] D. So. Jung. Mechanical characteristics of garlic scapes for developing mechanical Garlic bulbils harvester. ASAE Annual International Meeting Sponsored by ASAE Tampa Convention Center Tampa, Florida. 2005.

[7] E. Kronbergs. Mechanical strength testing of stalk materials and compacting energy evaluation. Industrial Crops and Products 11. 2000. 211-216.

[8] B.W. Maw, Y.C. Hung, E.W. Tollner, et al. Physical and mechanical properties of fresh and stored sweet onions. American Society of Agricultural Engineers. Vol. 39(2): 1996. 633-637.

[9] D.M. Mcrandal, P.B. Mcnulty. Impact cutting behavior of forage crops. Mathematical Models and Laboratory Tests. J. agrk. Eilgng Res23, 1978. 313-328.

[10] D.M. Mcrandal, P.B. Mcnulty. Mechanical and physical property of grass. Transaction of the ASAE. 1980.

[11] R. Tabatabaee Koloor, A. Borgheie. Measuring the static and dynamic cutting force of stems for Iranian rice varieties. J. Agric. Sci. Techol. Vol. 8: 2006. 193-198.

[12] L.G. Tabil, Jr.S. Sokhansanj, W.J. Crerar, et al. Physical characterization of alfalfa cubes: I. Hardness. Canadian Andian Biosystems Engineering. Vol. 44. 2002.

[13] L.J. Usrey, J.T. Walker, O.J. Loewer. Physical characteristics of straw for harvesting simulation. American Society of Agricultural Engineers. Vol. 35(3). 1992.

[14] K. Vursavus, H. Kelebek, S. Selli. A study on some chemical and physicomechanic properties of three sweet cherry varieties (Prunus avium L.) in Turkey. Journal of Food Engineering 74. 2006. 568-575.