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The Effects of Loading Conditions on Strength and Energy Requirement for Onion Leaf Removing

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Abstract

Development of onion harvesting machine is the important goals in the mechanization of this product. One of the major onion harvesting machines is 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 of 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, Topping, Shear and Tensile Strength, Rupture Energy.

INTRODUCTION

One of the most important machine in onion harvesting is topper. Knowing of some physical and mechanical properties such as cutting strength and energy requirement for design a topper system, are necessary. Many researches were carried out on the physical properties of many agricultural products [8,10,12]. In a research, the crushing and punching strength of onion bulb was obtained 26.4 and 25 N, respectively [8]. In other research the value of punching strength was obtained from 26.9 to 45.5 N [1]. Tabatabaee Koloor and Borgheie achieved the static and dynamic shear strength of rice stem for Khazar and Hashemi varieties, 1629 and 1429 kPa and 187.4 and 144 kPa respectively [11]. Results of I˙nce, urluay, Gu¨zel, and O¨zcan showed that by increasing moisture content of sunflower stalks, modulus of elasticity and bending stress were decreased while shear strength values and cutting power were increased [5]. Vursavus, Kelebek, and Selli estimated some physical and mechanical properties of cherry, including mass, density, shape, size, surface, spherical, stress and failure strain and modulus of elasticity [14]. The research of Chattopadhyay and Pandey showed that by increasing of angle and speed of blade, the energy requirement in flail forage cutting was decreased [2].

Mc Randall and Mc Nulty built a machine that could record force changes in terms of the distance changes in 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 significant effect on shear energy [10]. Research of Chattopadhyay and Pandey showed that increasing the linear speed of blade in fail cutting method cause to decrease of torque and specific cutting energy in both of mathematical model and farming test [3,4]. Mc Randall and Mc Nulty 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 of blade linear speed and blade angle, the cutting energy was decreased [9]. Jang 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 2.4×10^7Pa respectively. He argued by increasing the stem diameter, shear force was increased [6].

A study was carried out for 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 [13]. In other research, tensile and shear strength, modulus of elasticity and shear modulus of wheat stem were determined by an Instron apparatus. According to 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 [7].

The purpose of this study was to determine of tensile and shear strength of onion leaf and measure of 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 leaves strength and rupture energy for onion leaf removing.

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 leaves strength and specific rupture energy. In this study, loading rate was changed in three values 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 equations A is cross-sectional area of the leaves in rupture point, t was time of loading, and R_L was loading rate. In the records, the maximum shear and tensile strength values 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, diagram of displacement-force was obtained. Specific rupture energy in case of cutting (Esc) and tensile (Est) is founded by dividing the under curve area of displacement-force diagram to 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.

Fig.1. Maintaining method of onion in tensile test

Fig.2. Varner-Bratzler shear probe

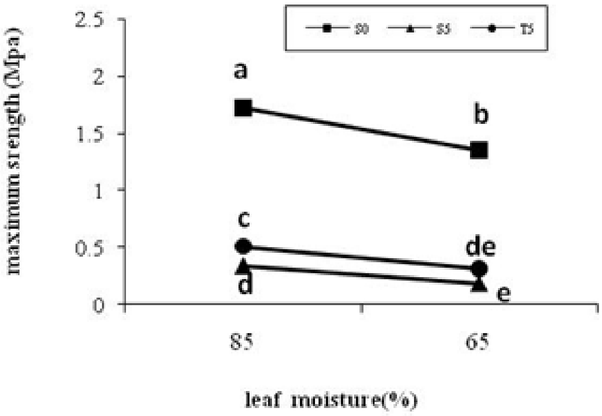

Fig.3. Interaction effect of leaf moisture content and loading type on maximum onion leaf strength

RESULTS AND DISCUSSION

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 the viscoelastic behavior and therefore, the viscous resistance against cutting or tension is changed with increasing the moisture. In onion leaf by increasing the moisture, resistance material was increased. Similar results were observed by another researcher for sunflower stems [5].

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

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.

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

Trend of specific energy was similar to the strength (Figure 4).

Interaction effect of rate loading and type loading on leaf strength (Figure 5) showed that the increase of the rate loading in S0, caused to decrease the force to leaf cutting. 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 and Chattopadhyay and Pandey also had a similar observation [9,4]. In loading rate 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 loading rate of 200 mm/min, the amount of specific energy in S5 and T5 didn't have difference. At this loading rate, the average specific energy in S0 was highest significantly.

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

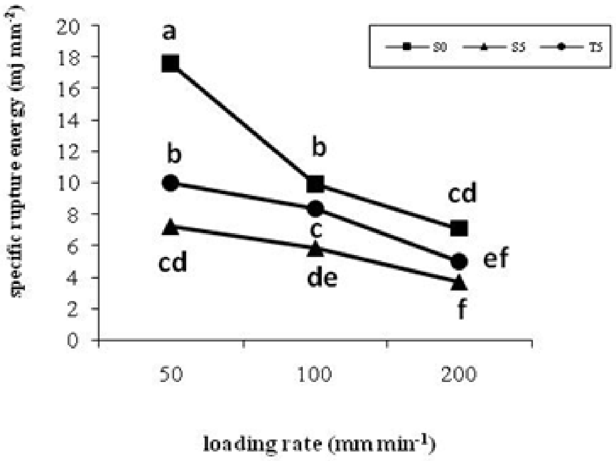

Fig.6. Interaction effect of loading rate and loading type on specific rupture energy

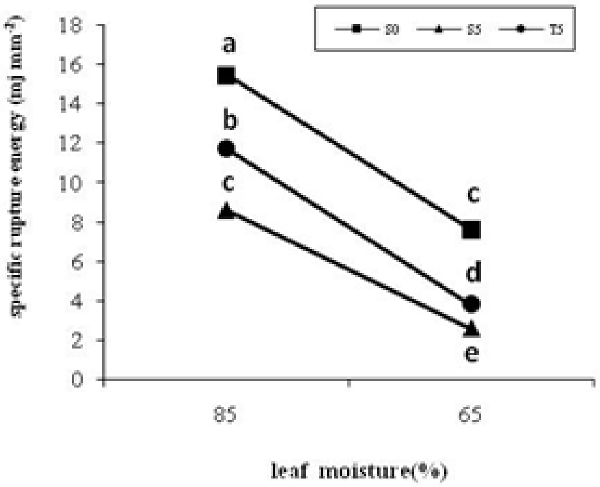

Fig.4. Interaction effect of leaf moisture content and loading type on specific rupture energy

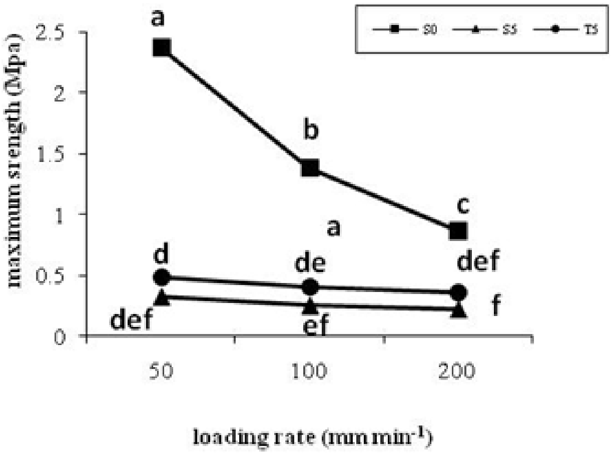

Fig.5. Interaction effect of loading rate and loading type on maximum onion leaf strength

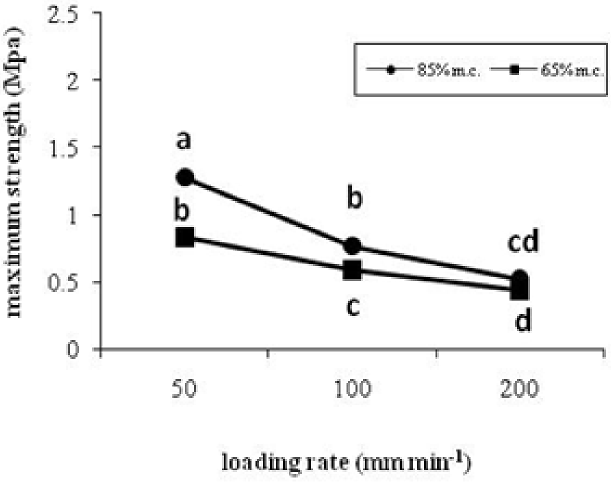

Fig.7. Interaction effect of moisture content and loading rate on maximum onion leaf strength

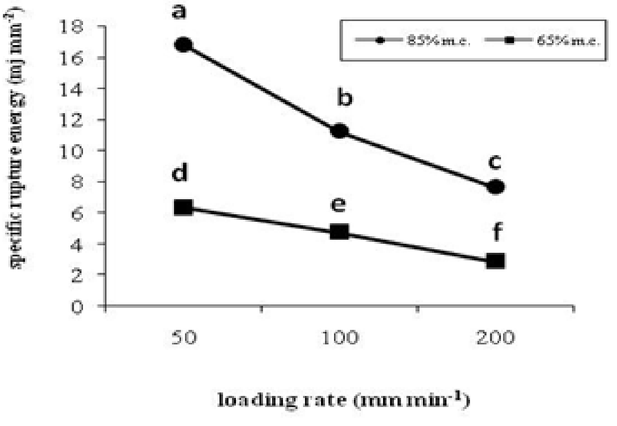

Fig.8. Interaction effect of moisture content and loading rate on specific rupture energy

CONCLUSION

This study was curry out to determination of strength and energy requirement for removing of onion leaf in three types loading, three rates loading and two leaf moisture contents. Based on results, 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/mm^2. The amount of energy to remove onion leaves in the cutting mechanisms was lower than tensile mechanisms. By decreasing of leaf moisture content and increasing the height of remaining leaf on the onion bulb, energy was reduced.

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