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DETERMINATION OF STRENGTH PROPERTIES FOR MECHANICAL HARVEST OF ROCKET (*ERUCA VESICARIA*)

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Abstract

Rocket (Eruca vesicaria) is a vegetable from the family Turpentaria (Brassicaceae) that eats leaves as a salad. Although rocket vegetable to produce small areas our country, it has started to make production in large and larger areas in recent years. This study aimed to determine the strength of Rocket (Eruca vesicaria) specifications for mechanical harvesting. For this purpose, properties as the maximum force, stress in the maximum force point, work at maximum force point, shearing force, deformation at maximum force, bioyield force, and shearing stress of rocket (Eruca vesicaria) stalk, leaf and root have determined. Average values for maximum force, stress, work to maximum force and deformation in maximum force were determined as 4.820 N, 0.474 MPa, 0.015 J and 22.149 mm, respectively. The shearing force and shearing stress were found to be as 2.150 N and 0.219 MPa, respectively. Average values for bioyield force were determined to be 3.856 N. These features can be used in determining the design and operating conditions for the mechanical harvester cutting blade.

Key words*: Rocket (Eruca vesicaria), strenght properties, mechanical harvesting.*

INTRODUCTION

'Rocket' is a common name used for some species in the family Brassicaceae that have a pungent aroma and a sharp taste (Figure 1). They are native to the Mediterranean and Near East, and they possibly acquired their original common name from the Lat-in-speaking Roman citizens who in-habited this area. The common name and many of its derivatives, including rughetta, rucola, roquette and others, most likely descended from the Latin word roc meaning harsh or rough (Pignone, 1997). Common names currently used to describe these species include roquette, rucola, arugula and rocket. As with all common names, the choice of common name varies with ethnicity, location and language group.

Rocket is traditionally grown in Italy, Portugal, Egypt, and Turkey (Bianco et al., 1997; Mohamedien, 1995; Pimpini et al., 1997; Silva Dias, 1997; Tuzel, 1995), it has also been successfully investigated as a new crop for Indiana and US Midwest (Morales et al., 2002), where it can be cultivated in open field and protected areas. In the past years, rocket has increasingly become popular also in the Central Europe.

Figure 1. Rocket (*Eruca vesicaria*) plant

It has 23,000 (1000 ha) of farmland in Turkey. 3.4 percent of this area (809,000 ha) used for vegetable production. Vegetable production has been increasing in recent years. According to 2015 data; the rocket production is 9110 tons, while tomato takes place on top with 12,615,000 tons in production volume of about 30 million tons.

The vegetable mechanization is conducted by hand in Turkey. Mechanization is needed due to the increase in production area.

The recent studies focused on chemical, herb and oil properties of rocket (*Eruca vesicaria*)

(Doležalová et al., 2013; Nurzyńska-Wierdak R., 2006). However, studies on strength properties of rocket are limited. This study covers determination of maximum force, stress in the maximum force point, work at maximum force point, shearing force, deformation at rupture force, bioyield force, shearing stress of rocket (*Eruca vesicaria*) stalk, leaf and root.

MATERIALS AND METHODS

For this study, rocket (*Eruca vesicaria*) plants were harvested by hand from the experimental field in Suleyman Demirel University, Isparta, Turkey.
Diameter and cross-sectional area of the experimental samples were measured before the shearing tests. Moisture content of the plants was determined at harvest time. Specimens were weighed and dried in an oven at 102°C for 24 h and then reweighed (ASABE, 2006). It was provided concise but complete information about the materials and the analytical and statistical procedures used.
A universal testing machine (LF Plus, UK) with a 500 N load cell and a computer-aided cutting and picking apparatus (Figures 2, 3) was used to measure the strength properties of the rocket plant. Knife material was hardened iron. All the tests were carried out at a speed 0.8 mm s^{-1}, and data were recorded at 10 Hz. All data were analysed by nexygen software program.

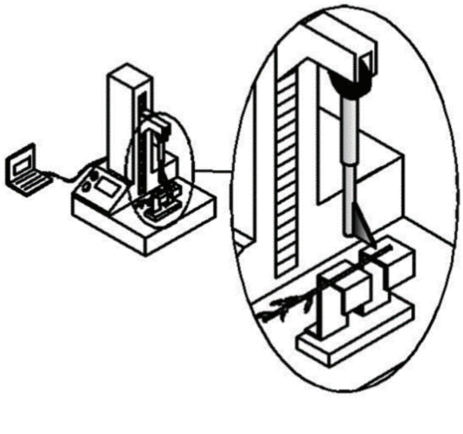


Figure 2. Cutting system

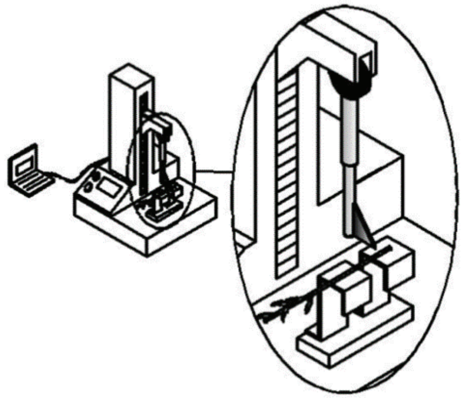


Figure 3. Picking system

The shearing forces on the load cell with respect to knife penetration were recorded by computer (Ozbek et al., 2009).
The shearing stress in N/mm^2 was calculated using the equation of Shahbazi et al., 2012:

$$\tau = \frac{F_{s\max}}{A}$$

Where F_{smax} is the maximum shearing force of the curve in N, and A is the area of the stalk at the deformation cross-section in mm^2.

The rocket plants were attached to the apparatus from its stalks (Figure 4). The shearing tests were conducted with 0.8 mm.s^{-1} knife speed progress (Simonton, 1992).

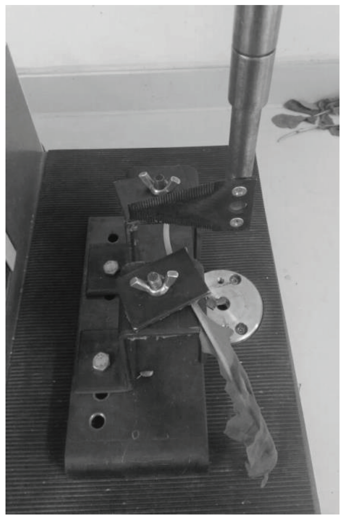


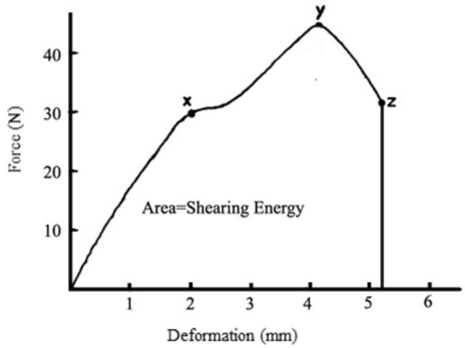
Figure 4. Measuring the cutting of rocket (*Eruca vesicaria*) plant

Picking force can be defined as the force required to separate leaf from ovary point (picking force of leafs). The load cell of the machine was then pulled upward to determine the picking force of the rocket leafs (Figure 5).

Figure 5. Measuring the picking force of rocket leaf

Bioyield force, shearing force, bending stress, shearing stress, and shearing deformation were calculated from the force-deformation curves at the inflection point as defined by ASAE Standard (1985). S368.1 (ASAE Standards, 1985) was obtained from all curves (Figure 6).

The energy of shearing was determined as the area under these curves (Chen et al., 2004; Srivastava, 2006).



Note. Labels on the graph indicate the following points:

x – bioyield force, y – maximum force, z – shearing force (Liu, 2012).

Figure 6. Typical force-deformation curve of rocket (*Eruca vesicaria*) stalk during shearing loading

RESULTS AND DISCUSSIONS

Moisture content of the plants was determined as 89% at harvest time and all tests were conducted at harvest moisture. The strength measurements of rocket stalks are given in Table 1.

Table 1. Average strength properties of rocket stalk

	Maximum force (N)	Bioyield force (N)	Shearing force (N)	Stress in maximum force (MPa)	Energy in maximum force (J)	Shearing stress (MPa)	Shearing deformation (mm)	Area (mm^2)
Stalk	4.820	3.856	2.510	0.474	0.015	0.219	22.149	10.534
Standard deviation	2.940	1.256	2.544	0.154	0.012	0.133	2.509	6.124

The maximum force was observed as 4.820 N at rocket stalk. The bioyield force of 3.856 N was observed at Stalk. Shearing force is one of the most important plant characteristics affecting plant harvesting. If the weight of the plant is known, the shearing force and the shearing height can be used to determine the speed of the blade to be used in harvesting (Igathinathane et al., 2010; Taghijarah et al., 2011). The maximum shearing force was observed as 2.510 N at Stalk. The maximum stress value (0.474 MPa) was observed at Stalk. The energy at maximum force was found to be as 0.015 J. Deformation has an important place among the strength characteristics of the plant. The maximum shearing deformation (22.149 mm) was observed at Stalk. The average cross-sectional area of rocket was determined as 10.534 mm^2 at harvest moisture (89.9 %). The strength measurements of rocket leaf are given in Table 2.

Table 2. Average strength properties of rocket leaf

	Maximum force (N)	Bioyield force (N)	Shearing force (N)	Stress in maximum force (MPa)	Energy in maximum force (J)	Shearing stress (MPa)	Shearing deformation (mm)
Leaf	6.233	4.986	3.659	0.235	0.024	0.114	7.477
Standard deviation	3.044	1.563	2.088	0.102	0.017	0.085	2.623

The maximum force required to separate leafs from stalk was determined as 6.233 N. As a function of the maximum force the bioyield force was found to be 4.986 N. Lower shearing forces required for mechanical harvesting leads to savings in power and energy usage. Leaf shearing force of rocket observed 3.659 N is higher than stalk shearing force. The maximum stress in maximum force value (0.235 MPa) was observed at leaf. The energy at maximum force was found to be as 0.024 J.

Average shearing deformation value for rocket leaf was determined as 7.447 mm. The strength measurements of rocket root are given in Table 3.

Table 3. Average strength properties of rocket root

	Maximum force (N)	Bioyield force (N)	Shearing force (N)	Stress in maximum force (MPa)	Energy in maximum force (J)	Shearing stress (MPa)	Shearing deformation (mm)	Diameter (mm)
Root	21.798	17.439	18.912	1.097	0.084	1.017	19.785	3.924
Standard deviation	8.207	6.566	11.642	0.652	0.047	0.713	3.708	0.845

The maximum force and shearing force are important design parameters for harvesters and they should be known for power requirement. Therefore, the maximum force and shearing force were determined as 21.798 and 18.912 N, respectively. The bioyield force of (17.438 N) was observed at root. The stress value in maximum force was found to be as 1.097 MPa. The energy at maximum force (0.084 MPa) was observed at root. Average shearing deformation value of rocket root was observed as 19.785 N. The average root diameter of rocket *Eruca vesicaria* was determined as 3.924 mm at harvest moisture (89.9 %)

CONCLUSIONS

This study was carried out to determine the strength properties of rocket plant (*Eruca vesicaria*) at leaf, stalk and root sections in the harvest moisture. Properties as the maximum force, bioyield force, shearing force, stress in maximum force, energy in maximum force, shearing stress, shearing deformation of rocket leaf, stalk and root have determined at moisture content of 89.9%.

The strength parameters measured at root section higher than that of the stalk and leaf sections.

The lowest values were found at rocket stalk. The strength parameters of stalk section should be considered for mechanical harvesting of rocket plant to provide data for the design machines for mechanized applications.

REFERENCES

ASABE Standards., 2006. Moisture measurement e Forages. St. Joseph, MI: American Society of Agricultural and Biological Engineers (ASABE). S358.2

Asae Standards, 1985. Compression test of food materials of convex shape. St. Joseph, Mich.: American Society of Agriculture Engineering, S368.1

Bianco V.V., Boari F., 1997. Up-to-date developments on wild rocket cultivation, In: Padulosi S, Pignone D (Eds.). Rocket: A Mediterranean crop for the world. Report of a workshop 13-14 December 1996, Legnaro (Padova), Italy, 41-49.

Chen Y., Gratton J. L., Liu J., 2004. Power requirements of hemp cutting and conditioning. Biosystems Engineering, 87(4), 417-424.

Dolezalova I., Duchoslav M., Dusek, K., 2013. Biology and Yield of Rocket. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41(2), 530.

Igathinathane C., Womac A. R., Sokhansanj S., 2010. Corn stalk orientation effect on mechanical cutting. Biosystems engineering, 107(2), 97-106.

Mohamedien S., 1995. Conservation and utilization of rocket in Mediterranean countries. Rocket cultivation in Egypt, p. 61-62. In: Padulosi S (Ed.). Rocket Genetic Resources Network. Report of the First Meeting, 13-15 November 1994, Lisbon, Portugal.

Morales M., Janick J., 2002. Arugula: A promising specialty leaf vegetable, In: Janick J, Whipkey A (Eds.). Trends in new crops and new uses. ASHS Press, Alexandria, VA, p. 418-423.

Nurzyńska-Wierdak R., 2006. The effect of nitrogen fertilization on yield and chemical composition of garden rocket (*Eruca sativa* Mill.) in autumn cultivation. Acta Sci PolHortoru 5:53-63.

Ozbek O., Seflek A.Y., Carman K., 2009. Some Mechanical Properties of Safflower Stalk. Appl. Eng. Agric., 25: 619–625.

Pignone D. 1997. Present status of rocket genetic resources and conservation activities, In: Padulosi S. & Pignone D. (ed.). Rocket: a Mediterranean crop for the world. Report of a workshop, 13-14 December 1996, Legnaro (Padova), Italy. International Plant Genetic Resource Instute, Rome, Italy, 2-12.

Pimpini, F., Enzo M., 1997. La coltura della rucola negli ambienti veneti. Colture protette 4:21-32.

Shahbazi F., Nazari Galedar M., 2012. Bending and shearing properties of safflower stalk. Journal of Agricultural Science and Technology, 14(4), 743-754.

Silva Dias J.C., 1997. Rocket in Portugal: botany, cultivation, uses and potential, In: Padulosi S, Pignone D (Eds.). Rocket: A Mediterranean crop for the world. Report of a workshop 13–14 December 1996, Legnaro (Padova), Italy, 81-85.

Simonton W., 1992. Physical properties of zonal geranium cuttings. Trans. ASAE, 35(6): 1899-1904.

Srivastava A.K., Goering C.E., Rohrbach R.P., Buckmaster D.R., 2006. Engineering principles of agricultural machines (2nd ed.). American Society of Agricultural and Biological Engineers, St. Joseph, USA, 185.

Taghijarah H., Ahmadi H., Ghahderijani M., Tavakoli M., 2011. Shearing characteristics of sugar cane (*Saccharum officinarum* L.) stalks as a function of the rate of the applied force. Australian Journal of Crop Science, 5(6), 630.

Tuzel Y., 1995. Conservation and utilization of rocket in Mediterranean countries. Rocket growing in Turkey, In: Padulosi S (Ed.). Rocket Genetic Resources Network. Report of the First Meeting, 13-15 November 1994, Lisbon, Portugal, 58-60.

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