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DETERMINATION OF STRENGTH PROPERTIES FOR MECHANICAL HARVEST OF DILL (Anethum graveolens l.) PLANTS

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Dill (Anethum graveolens l.), is a green color and vascular plant species. Although parsley plant to produce small areas our country, it has started to make production in large and larger areas in recent years. Due to the increased dill production, application of the requirements of mechanization increased. In developed countries, mechanized harvesting practices are carried out. The plant's strength are required to know the specifications for the design of a dill harvesters. This study aimed to determine the strength of dill plant specifications for mechanical harvesting.

For this purpose, properties as the maximum force, stress in the maximum force point, work at maximum force point, rupture force, deformation at rupture force, bioyield force, rupture stress of dill stalk and flower have determined the effects of four moisture contents such as 80%, 55% and 35% d.b. (Stalk1, Stalk2, Stalk3) on the properties were investigated. The highest maximum force (6.235 N) was observed at Stalk1. The maximum bioyield force of 4.988 N was observed at Stalk3. The maximum rupture force was observed at Stalk3 ($p<0.05$). The rupture stress values decreased at moisture level. The maximum rupture stress value (0.223 MPa) was observed at Stalk1. The maximum picking force was observed at Flower1

Keywords: Dill, rupture properties, mechanical harvesting

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INTRODUCTION

Dill (Anethum graveolens l.) has a long and ancient history in many countries as a culinary and medicinal herb. The earliest known record of dill as a medicinal herb was found in Egypt 5,000 years ago, when the plant was referred to as a “soothing medicine” [Le Strange, 1977]. Around 3,000 B.C.E. the Babylonians were known to have grown dill in their gardens [Hemphill, 200]. It is cultivated in Mediterranean, Aegean and Marmara regions of Turkey. Fresh and dried dill used in pickles, salads, soups, sauces and savory meals [Esturk and Soysal, 2010].

During prolonged periods of drought, dill will require supplemental watering. Dill grows best in full sun. However, hot weather can be a determining factor in causing the plant to flower early, which brings a halt to leaf production [Small, 2006]. Dill grows well in a light to medium- textured soil that is kept moist and has adequate drainage [Tucker and DeBaggio, 2000]. The optimum time for harvesting dill is in the early morning. The higher moisture content of the plants when harvested at this time results in better flavor and the possibility of seed shattering is minimized (Figure 1).

Figure 1. Dill plant (Baydar, 2009)

The quality of the imported dill varies depending upon the country because of differences in harvesting and drying. For example, dill grown in India is harvested by hand and left out in the sun to dry, leaving it more open to insect infestation, while dill in Canada and the United States is usually harvested and dried more quickly with machines [Tainter and Grenis, 2001].

The recent studies focused on chemical, herb and oil properties of Dill (Anethum graveolens l.) [Faber et al., 1995; Bailer et al., 2001; Callan et al., 2007]. However, studies on strength properties of Dill *(Anethum graveolens l.)* are limited. This study covers determination of maximum force, stress in the maximum force point, work at maximum force point, rupture force, deformation at rupture force, bioyield force, rupture stress of dill stalk and Flower.

MATERIALS AND METHODS

For this study, dill (Anethum graveolens l.) 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 (Fig. 2, Fig. 3) was used to measure the strength properties of the Dill (*Anethum graveolens l.)* stalks. 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 Nexgen software program.

Figure 2. Computer-aided systems for measuring the cutting of dill (Anethum graveolens l.) plant

The shearing forces on the load cell with respect to knife penetration were recorded by computer [Ozbek, 2009].

The shearing stress in $N.mm^2$ was calculated using the equation of Shahbazi [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 shearing tests were conducted with 0.8 $mm.s^{-1}$ knife speed progress [Simonton, 1992]. 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. The energy of shearing was determined as the area under these curves [Chen et al., 2004; Srivastava, 2006]. A randomized complete block design experiment was used in all experiment.

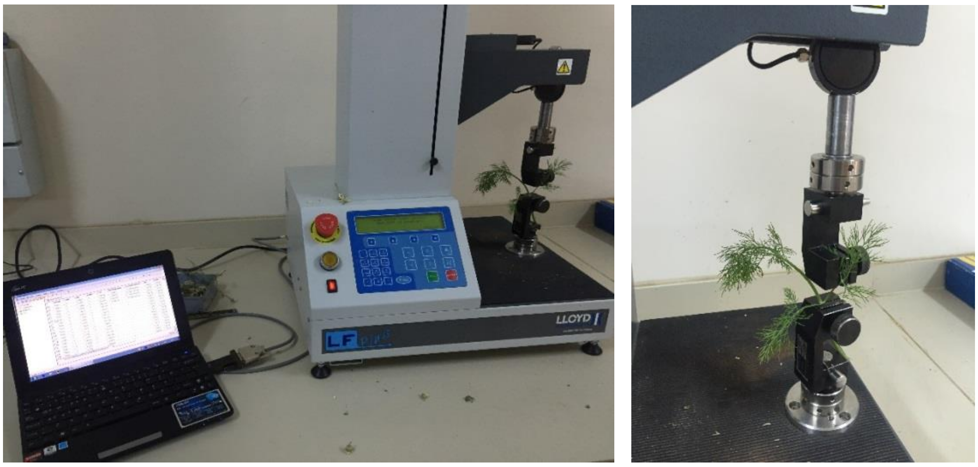

Figure 3. Measuring the picking force of dill (Anethum graveolens l.) plant

Picking force can be defined as force required to separate flower from ovary point (picking force of flowers). The load cell of the machine was then pulled upward to determine the picking force of the dill flowers (Figure 3).

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

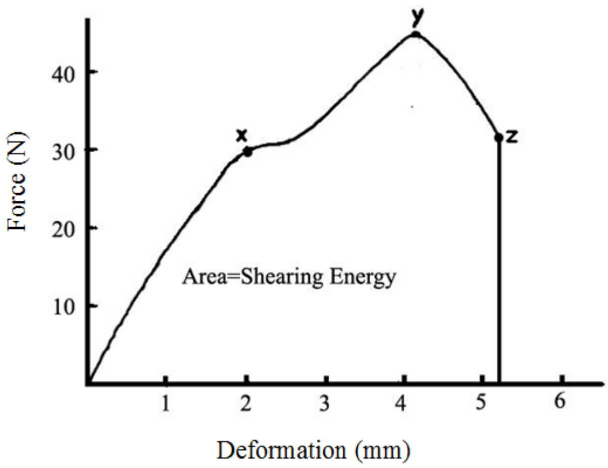

Figure 4. Typical force-deformation curve of dill stalk during shearing loading

Note. Labels on the graph indicate the following points: x – bioyield force, y – maximum force, z – shearing force (Liu, 2012).

RESULTS AND DISCUSSION

The strength measurements of dill stalk (Anethum graveolens l.) are given at different moisture levels were given in Table 1.

Maximum force was evaluated as a function of moisture contents. Maximum force decreased with increasing moisture contents. The effect of moisture content on the maximum force applied to the dill stalks (Anethum graveolens l.) was statistically significant ($P < 0.05$). The highest maximum force (6.235 N) was observed at Stalk3. The bioyield force increased at successive moisture content ($p<0.05$).

Table 1. Average strength properties of dill stalks (Anethum graveolens l.)

	Maximum force	Bioyield force	Rupture force	Stress in maximum force (MPa)	Work at rupture force	Rupture stress (MPa)	Deformation at rupture force(mm)
	(N)	(N)	(N)		(J)		
Stalk1 (80 % d.b)	4.936[c]	3.949[c]	2.042[c]	0.600[a]	0.018[a]	0.223[a]	24.458[a]
Stalk2 (55 % d.b)	5.632[b]	4.505[b]	2.620[b]	0.510[b]	0.017[b]	0.198[b]	22.632[b]
Stalk3 (30 % d.b)	6.235[a]	4.988[a]	3.012[a]	0.492[c]	0.015[c]	0.168[c]	21.589[c]

All data represent the mean of three replications; a;b;c letters indicate the significant levels at 5

This may be attributable to decreased moisture level in the stalk with decreased moisture content. The maximum bioyield force of 4.988 N was observed at Stalk3. Rupture 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 rupture force was observed at Stalk3 ($p<0.05$). The rupture stress values decreased at moisture level. The maximum rupture stress value (0.223 MPa) was observed at Stalk1. The work at rupture force varied between 0.018 and 0.015 J. Deformation has an important place among the strength characteristics of the plant. The maximum rupture deformation (24.458 mm) was observed at Stalk1.

The strength measurements of dill flower (Anethum graveolens l.) are given at different moisture levels were given in Table 2.

Table 2. Average strength properties of dill flower (Anethum graveolens l.)

	Maximum force	Bioyield force	Picking force	Stress in maximum force (MPa)	Work at picking force	Picking stress (MPa)	Deformation at picking force(mm)
	(N)	(N)	(N)		(J)		
Flower1 (80%)	2.044[a]	1.635[a]	1.057[a]	0.326[c]	0.008[a]	0.030[a]	8.933[a]
Flower2 (55%)	1.995[b]	1.327[b]	1.010[a]	0.354[b]	0.007[b]	0.024[b]	7.123[b]
Flower3 (30%)	1.852[c]	1.022[c]	0.954[b]	0.378[a]	0.007[b]	0.022[c]	6.154[c]

All data represent the mean of three replications; a;b;c letters indicate the significant levels at 5

The effect of moisture content on the maximum force applied to the dill flowers (Anethum graveolens l.) was statistically significant ($P < 0.05$). The highest maximum force (62.044 N) was observed at Flower1. The bioyield force increased at successive moisture content ($p<0.05$). The maximum bioyield force of 1.635 N was observed at Flower1. The maximum picking force was observed at Flower1 ($p<0.05$). The picking stress values decreased at moisture level. The maximum picking stress value (0.030 MPa) was observed at Flower1. The work at picking force varied between 0.008 and 0.007 J. The maximum picking deformation (8.933 mm) was observed at Flower1.

CONCLUSIONS

In this study, properties as the maximum force, stress in the maximum force point, work at maximum force point, rupture force, deformation at rupture force, bioyield force, rupture stress of dill stalk and flower have determined the effects of three moisture contents such as 35%, 55% and 80% d.b. on the properties were investigated.

Maximum force decreased with increasing moisture contents. The effect of moisture content on the maximum force applied to the dill stalks (Anethum graveolens l.) was statistically significant.

The rupture stress values decreased at moisture level. The maximum rupture stress value (0.223 MPa) was observed at Stalk1.

The maximum picking force was observed at Flower1. The picking stress values decreased at moisture level. The best moisture content was 30%.

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