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Energy Requirement for Cutting Corn Stalks (Single Cross 704 Var.)

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Abstract**—**Corn is cultivated in most countries because of high consumption, quality, and food value. This study evaluated needed energy for cutting corn stems in different levels of cutting height and moisture content. For this reason, test device was fabricated and then calibrated. The device works on the principle of conservation of energy. The results were analyzed using split plot design and SAS software. The results showed that effect of height and moisture content and their interaction effect on cutting energy are significant (P<1%). The maximum cutting energy was 3.22 kJ in 63 (w.b.%) moisture content and the minimum cutting energy was 1.63 kJ in 83.25 (w.b.%) moisture content.

Keywords**—**Cutting energy, Corn stalk, Cutting height, Moisture content, Impact cutting.

I. Introduction

WITH scientific name of *Zea mays*, corn is monoecious, annual plant. After rice and wheat, corn is the third important crop in the world and its importance is due to high yields and cultivability in vast areas of world [1]. The food quality of forage in crop is very high. Corn is a very delicious food for cattle. Green soilage of corn is harvested after picking tassel up. If corn is harvested in phase of milky kernel state, it will have high protein level, dry matter and nutrients. This crop is very momentous for dairy sector and animal food processing due to short growing period and high performance. It is predicted that demand for forage corn will increase until 2020 about 45 percent. Forage corn plays key role in supplying bestial protein in world and country for producing white and red meat. Needed mechanical energy was measured for chopping three types of product including corn, wheat straw and grass by a knife cutter. Total net energy at (kW $m^{-1}g^{-1}$) was considered as needed energy for cutting by cutter. The results of their experiments showed that total net energy increases with increased speed of shear knifes for grass, wheat straw and corn and consequently the sum of total energy and effective energy increase with decreasing grain size [2]. Researcher reported that cutting plant productions in smaller piece is an energy consuming process and needed energy is variable based on initial length of grain, moisture content, their mechanical and physical properties and feeding rate of machine [3]. Reference [4] conducted a study to determine the effect of cut angle of sample based on cut quantities which it is possible to reduce cut energy in corn stem with moisture content of 15 to 20 (w.b.%). They concluded that the properties and features of earned shear force in corn stem vary with different directions. The maximum of failure force, stem cut and various nodes have significant relationship with cross-sectional area of stem. Total net energy amount from dry stem of corn is 23.5 to 11.3 kN/m. Shear energy is much less in parallel direction than perpendicular direction and shear energy and net energy is about one-tenth in parallel direction and about one-fifth for nodes.

Researchers reported that rotary harvester machines are used increasingly in terms of ease in construction, low cost for repair and maintenance and ability to cut all stems with large and small diameters [5]. One of the most important factors in designing the types of grain combine and harvesters is resistance to cut in agricultural crops during harvesting [6]. So it is important to determine resistance to cut rate in canola plant. Cutting a stem by one edge device has difference with cutting a two edge device. Next, cutting is done by two elements with opposite action. The stem is kept constant in the vicinity of cut blade and then the blade does its work. Cutting with a single element can be largely affected by blade speed, product inertia and the sharpness of cutting edge. Leaning stem crop against knife pressure and preventing penetration to interior materials occurs to some extent. Cutting process depends on stem inertia for overcoming opposite force [7].

According to many researches, needed energy for the cut unit of stem in cutter bar consists of as follows: overcome on air friction, chopping of crops, overcome on the friction of chopped products, friction in some parts of machine and cutting stem [8]-[13]. Cutting energy in the stem of agricultural crops shows that how much energy is needed for cutting stems in agricultural crops. Harvesting machines and harvesters should be redesigned for lowering energy consumption [14]. Expressions for determining cutting energy requirement and peripheral knife speed for other crops were given as stated by [15]-[17], [2]. Researchers reported that needed energy for cutting wheat stem is affected moisture content, type of wheat, blade angle and cutting speed [18]. With decreasing moisture content and blade angle and increasing cutting speed, cutting energy will decrease. The effect of variety on cutting energy is remarkable. In terms of product type and physical and mechanical properties of stem in crops, the estimation of harvesting energy in agricultural products can be completely different [17].

The aim of this study is to survey needed energy for cutting corn stalks in different levels of height and moisture content.

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The most appropriate moisture content and height for cutting corn plant based on obtained results will recommend.

II. Materials and Method

A. Preparation of Samples

Corn variety of Single Cross 704 harvested from the experimental farm in Gorgan, Iran was used in the study. Product management was done completely from planting time to maturity period and harvest time. During harvest time, built device was placed in farm and the tests were done into farm. Cutting height was measured by a ruler with an accuracy of 0.1cm. The height levels of cutting were selected under 20cm e.g. 5, 10 and 15cm. Moisture content was determined using the standard oven drying procedure ASAE Standard S.352 [19]. The corn stalk sample for the determination of the moisture content was collected immediately upon the completion of test-run. At least 15 corn stalk samples were collected. The mass of the collected corn stalk samples was determined using a scale balance with an accuracy of 0.01g, and placed in a constant temperature oven for drying at a temperature of about 105°C for a minimum drying period of 24 hours as described in [17]. In order to obtain different levels of moisture, the tests were done in three different times and one time for per 10 days. Different levels of 63%, 74.3% and 83.25 (w.b.%) were obtained for corn stem.

B. Making Device

For cutting test, pendulum system was designed and constructed based on [20], [17] (Fig. 1).

Fig. 1 Pendulum impact system

The device consists of the beams, pivot axle, pendulum arm, frame, blade and finger. The pendulum is consists of a rod which is attached from bottom to a blade and from top to a pivot axle. It has a swinging movement around it. The second edge of cutting is a finger. The pendulum is placed into the device as the blade can pass through it (Fig. 2).

Fig. 2 Blade and finger statue during impact cutting

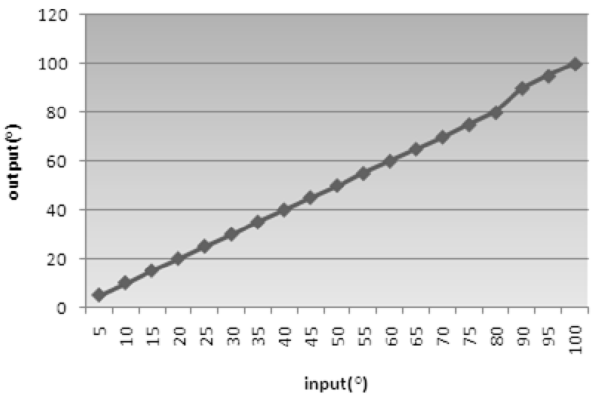

Fig. 3 Relation the initial releasing angle and the final angle of pendulum

C. Test Device Calibration

As can be seen in Fig. 3, there is a linear relation between the releasing angle and final angle of pendulum with a proper estimate ratio. Using the least squares method, regression equation will determine the maximum deviation angle showing in (1). This equation has many similarities with earned equation by [17].

$$\theta_{\circ}^{\circ} = 1.02\theta_{i}^{\circ} - 2.9 \quad (1)$$

where, $\theta_o{}^o$ = maximum angular upswing deflection without cutting (^{o}) and α_1 = initial angular deflection of swinging arm (^{o}).

D. Principle of Operation

The device works on the principle of conservation of energy that was employed by some researcher [17], [20] (Fig. 4).

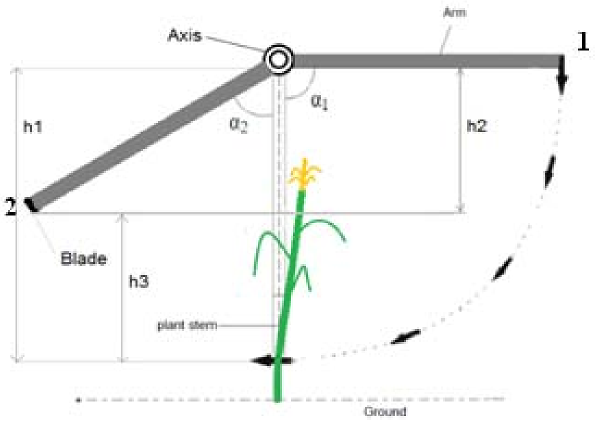

Fig. 4 Impact and after impact angle

According to Fig. 4 and principal of work and energy, the amount of work between place 1 and 2 is equal to sum of changes of kinesthetic and potential energy [21].

$$\Delta_{1-2} = \Delta(T + V_g) \quad (2)$$

After impact, the situation of blade will be in place 2. Kinesthetic energy in place 1 and 2 is zero, so the amount of work after impact is:

$$E = \Delta_{1-2} = \Delta v_g = Mg[h_1 - h_3] = Mg[h_1 - (h_1 - h_2)] = Mgh_2 \quad (3)$$

$$h_2 = R\cos\alpha_2 \quad (4)$$

where, E = Stalk cutting energy requirement(J), h_1 = Situation of blade before cutting, h_3 = Situation of blade after cutting, h_2 = The difference between h1 and h3, α_1 = Maximum angular displacement before cutting (^{o}), α_2 = Maximum angular displacement after cutting (^{o}).

During the test, it has been tried to the device be a proper model from common cutting devices. Because of this, the device is designed as it can take the stem between its arms in farm and the stem is cut via passing blade through finger lips. Pendulous arm is released from initial angle α_1 and it continues its path until it reaches the maximum speed and passes from between finger lips and consequently after cutting the stem, it comes up in the other side at an angle α_2. The tests were repeated 15 times for any level of moisture and height and they were analyzed using split plot design and SAS software.

III. Results and Discussion

Table I shows results of a variance analysis of corn stalk cutting under different height and primary moisture content. Effect of height and moisture content on cutting energy in probability level of 1% (P<1%) is significant.

Table I also shows that interaction effect of height and moisture content on cutting energy in probability level of 1 % (P<1%) is significant. In order to study two-way effect of different factors on cutting energy, compare of mean was done by LSD method, hereby, compare of mean moisture content in each level of height and compare of mean different height level in each level of moisture content was done separately and results presented in Table II.

TABLE I
VARIANCE ANALYSIS OF CUTTING CORN STALK UNDER DIFFERENT CUTTING HEIGHT AND PRIMARY MOISTURE CONTENTS

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value
Moisture (mc)	2	9.36	4.68	822.08 **
Height(cm)	2	0.16	0.08	14.41 **
cm ×mc	4	0.15	0.03	6.59 **
Error	12	0.06	0.005	

** Significant in statistic level of 1 % (P<1%).

TABLE II
CUTTING CORN STALK AND MOISTURE COMPARISON OF MEAN ON CUTTING ENERGY

Moisture (w.b.%)			Height(cm)
63	74.3	83.25	
3.22 Aa	2.85 Ab	2.05Ac	5
3.21 Aa	2.74 Ab	1.73Bc	10
3.20 Aa	2.73 Ab	1.63Bc	15

* Same capital letters in each column and same small letters in each raw show not significant different (LSD1%).

It was observed that the maximum cutting energy was 3.22 kJ in 63% moisture content. Also the minimum cutting energy was 1.63 kJ in 83.25% moisture content. According to Table II in moisture 83.25%, there was significant difference between cutting energy and different heights. In this moisture levels cutting energy will increase by decreasing in height levels. Also, there was no significant difference between 63 and 74.3% moistures levels in different height levels. There was significant difference between height levels in all of the moistures content levels. By decreasing moisture, cutting energy will increase. The reason is that in the low moisture and dry conditions thickness of corn stalk have wooden state and are greater than other crops like wheat and canola, so more energy is needed for cutting. These findings are similar to research results of reference [22] that reported a decrease in cutting energy of pigeon pea stalks by increasing of moisture content.

According to Fig. 5 by decreasing height and moisture, cutting energy increased in all three moisture content levels. Considering that stalk diameter decreases with increasing height, Therefore the energy requirement for cutting of small diameter stalks will be lower than large diameter. These findings are similar to research results of [23], [17] that announced a decrease in cutting energy of rice and sorghum stem by decreasing of stalk diameter.

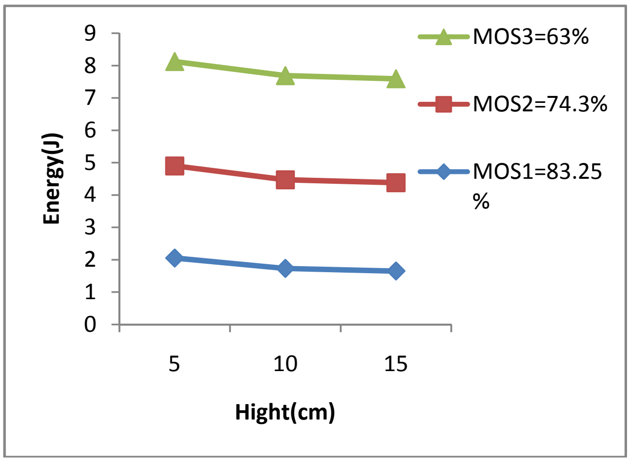

Fig. 5 The effects of different height on cutting energy at different primary moisture content

IV. Conclusions

- Effect of cutting height and moisture content on cutting energy was statistically significant.
- Interaction of cutting height and moisture content on cutting energy was not significant.
- The cutting energy was increased by increasing in moisture content.
- The cutting energy was decreased by increasing in cutting height.

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