Advances in Research

21(2): 25-30, 2020; Article no.AIR.55332
ISSN: 2348-0394, NLM ID: 101666096

Cassava Stem Crop Parameters Effect on Cutting Energy

K. Prasanthkumar[1*] and M. Saravanakumar[1]

[1]Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, Trichy, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author KP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MS managed the analyses of the study. Authors KP and MS managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2020/v21i230186
Editor(s):
(1) Dr. Elly Josephat Ligate, Solomon Mahlangu College of Science and Education, Tanzania and Fujian Agriculture and Forestry University, China.
Reviewers:
(1) James Burke, University of Arkansas, USA.
(2) Jackson Akpojaro, University of Africa, Bayelsa State, Nigeria.
(3) Usman Jimoh Michael, Federal College of Forestry, Ibadan, Nigeria.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55332

Original Research Article

Received 20 January 2020
Accepted 24 March 2020
Published 02 April 2020

ABSTRACT

The study was conducted to understand the energy involves in cassava stem cutting in order to optimize design of cutting elements in cassava stem cutting. The cutting energy is measured using pendulum type test rig and it works under the principle of law of conservation of energy. The tests were conducted at 3 levels of average moisture content [43.75, 56.50 and 64% (wb)] and stem diameter (25.22, 28.71 and 33.29 mm) with 3 replications. The results revealed that the cutting energy was increased with increase in moisture content and stem diameter. The cutting energy of cassava stem increased by 23.26% when the average moisture content was increased from 43.75 to 64% and reduced by 17.31% when the stem diameter was increased from 25.22 to 33.29 mm.

Keywords: Cassava; cutting energy; crop parameters; stem diameter; moisture content.

**Corresponding author: E-mail: prasanthkumar027@gmail.com;*

ABBREVIATIONS

wb : Wet Basis
mm : Millimeter
J : Joule
MPa : Megapascal
mJ : Millijoule

1. INTRODUCTION

The variation in the physical properties of plant stalks and the resistance of cutting equipment should be studied to understand the behavior of material with respect to different operating conditions. Information on the physico-mechanical properties of cassava stem is important for the design of cutting elements. Many researchers have reported on the cutting energy of the plant stem and effective parameters on cutting energy for wheat [1,2], barely [3], sesame [4], sorghum [5] and alfalfa [6].

Energy requirement at 65% moisture content (wb) stalk was 100% more than that at 8% moisture content (wb) stalk [7]. The shear strength of wheat straw with different blade bevel angles and moisture content and a maximum (25.09 MPa) and minimum (15.80 MPa) shear strength at 17.8 and 17% moisture content (wb), respectively [8]. The shearing stress of 3.25 MPa at 15% (wb) moisture content and 3.86 MPa at 45% (wb) moisture levels for wheat stalk [2].

Jekendra [9] studied the physical and rheological properties of maize and sorghum with reference to cutting using the direct shear test apparatus and found that shear strength increased at the rate of 3.89 and 3.63% for sorghum and maize respectively, when the moisture content decreased from 80 to 20%. The cutting energy of sorghum stalk measured in laboratory using pendulum like oscillating arm and they concluded that the cutting energy had negative linear correlation with stalk moisture content [10].

In sunflower stalk the highest shearing stress of 1.07 MPa was recorded at moisture content of 80%, while the lowest of 0.187 MPa at 20% moisture content [11]. The highest shear strength of 28.16 MPa at 80% (wb) moisture content and lower shear strength of 5.98 MPa at 10% (wb) moisture content observed for alfalfa [6]. A higher cutting energy for khodasht variety of alfalfa stem observed as 0.86 MJ-mm^{-2} because of its larger diameter compared with other varieties [1]. The effect of moisture content, internodes position evaluated on the shearing characteristics of barley straw and result showed that increase in moisture content of barley straw increased the shearing energy [3]. Increase in moisture content and diameter of stalk increased the maximum energy for cutting sesame stalk [4].

An increased shearing energy with increase in stalk diameter observed for miscanthus [12]. Increase in moisture content increased the shearing energy for sugarcane [13]. A highest shearing energy of 10.96 mJ at 36% moisture content (wb) and lowest shearing energy of 9.77 mJ at 57% moisture content (wb) for canola stems [14]. The highest cutting energy of 12.2 J and lowest cutting energy of 6.9 J for cross sectional area of 175 and 125 mm^2, respectively observed for cutting cane stems [15].

The cutting energy was affected by crop parameters like moisture content and stem diameter in most of the studies. Hence the stem diameter and average moisture content was selected as independent variables. The diameter of the specimen measured using the Vernier caliper. The specimen was weighed, oven-dried at 103°C for 24 h to measure moisture content of the cassava stem [16]. The aim of this study is to measure the energy required for cutting cassava stems in different levels of stem diameter and average moisture content with a pendulum type test rig.

2. MATERIALS AND METHODS

A pendulum type test apparatus Fig. 1 was used to measure the cutting energy which works under the principle of law of conservation of energy. Pointers were provided on the axis of rotation of the pendulum arm, to indicate the angular displacement on a disc graduated in degrees [17].

2.1 Materials Used

The experiments were conducted on kumkum rose varieties of cassava brought from nearby fields of Namakkal district. The diameter of the samples ranged from 22 to 35 mm. The range of average moisture content of the stem during the experiment ranged from 43.75 to 64% (wb). All the experiments were replicated thrice and the averages of the calculated cutting energy are presented.

2.2 Calculation of Cutting Energy

When the pendulum arm is in the equilibrium position, i.e., the angular displacement made by the axis of pendulum arm with respect to vertical is zero, the potential energy stored on the pendulum was considered as zero. When it is raised to an angle (θ), from the equilibrium position, the potential energy stored or available at the pendulum arm (E_s) is given by

$$E_s = Mgh = MgR\left(1 - \cos\theta\right) \quad (1)$$

When the pendulum arm is released from an angle 'θ' (angle of release) from an equilibrium position without any obstacles or placing the cassava stem on the stalk holder, the pendulum arm moves through oscillation and making an angle θ_o' (angle of reach without stem) on the other side of the equilibrium position. This procedure was repeated by releasing the pendulum arm from different angles of θ_o. For all the cases the θ_o was observed to be lesser than that of θ. This effect may be due to the energy lost to friction and air resistance during the travel of pendulum. The pendulum arm has overcome the air and frictional resistance (E_f) reached the angle θ_o due to the energy developed by lifting the pendulum arm to the initial position of 'θ'. The angular displacement θ_o depends on the energy availability at θ and energy expedite on air and frictional resistance. The energy available on the pendulum arm overcoming the loss is used to move the arm to other side to an angle θ_o. The energy loss (E_f) was calculated as

$$E_f = MgR\left[(1-\cos\theta)-(1-\cos\theta_0)\right] \quad (2)$$

$$E_f = MgR\left(\cos\theta_0 - \cos\theta\right) \quad (3)$$

After placing the cassava stem on the stalk holder, the pendulum arm was released from 'θ' to cut the stem. After cutting the stem the pendulum arm moves to an angle 'θ_c' (angle of reach). This value of θ_c was observed to be lesser than that of 'θ_0' for all experiments. The energy utilized to cut the stem (E_u), is the difference between the potential energy stored (E_s) and the sum of potential energy available in the swing arm after cutting (E_c) and the energy lost due to friction (E_f). It is expressed as:

$$E_s = E_u + E_f + E_c$$
$$E_u = E_s - (E_f + E_c) \quad (4)$$

$$E_u = MgR\left(\cos\theta_c - \cos\theta_0\right) \quad (5)$$

Where,

Es = Energy stored in the pendulum arm at θ (J)

E_u = Energy utilized for cutting the cassava stem (J)

E_f = Energy utilized to overcome the friction and air resistance by the swing arm (J)

E_c = Energy utilized to move the swing arm to other end to make θ_c (J)

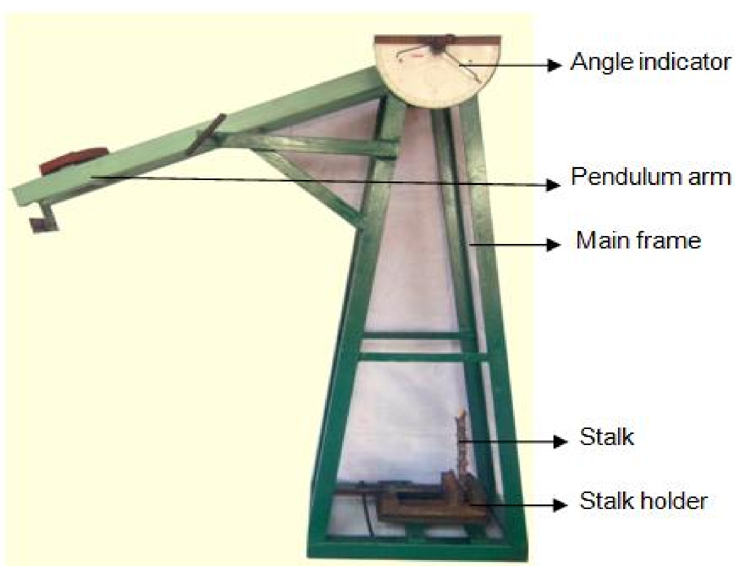

Fig. 1. Pendulum type test rig

3. RESULTS AND DISCUSSION

The analysis of variance for the effect of moisture content on cutting energy is presented in Table 1. The effect of moisture content on cutting energy had 1% significance.

Table 2 shows the comparison of cutting energy with different average moisture content. The maximum cutting energy of 31.95 J recorded at average moisture content of 64%, also the minimum cutting energy of 24.32 J at 43.75% average moisture content (wb). The cutting energy increased by 23.26% when the average moisture content increased from 43.75 to 64%.

Fig. 2 shows the exponentially increasing relationship between the cutting energy and average moisture content. When average moisture content of stalk is low, it becomes dry and brittle so the impact force of knife causes breaking of stalk. This failure makes the cutting easier, while the stalk with high average moisture content resists the failure. High average moisture content would also cause coalition of the stalk tissue and consequently, increase the cutting energy. This conclusion was in consistent with the findings of [1,2,6,8,9,10,11] who studied the effect of average moisture content on physico-mechanical properties of different crops.

The analysis of variance for the effect of stem diameter on cutting energy is presented in Table 3. The effect of stem diameter on cutting energy had 1% significance.

Table 4 shows the comparison of cutting energy with different stem diameter. The maximum cutting energy of 34.84 J observed at 33.29 mm stem diameter and the minimum cutting energy was 28.81 J at lower stem diameter. The cutting energy increased by 17.31% when the stem diameter increased from 25.22 to 33.29 mm.

Relation of stem diameter and cutting energy is shown in Fig. 3. The cutting energy increased by increasing stem diameter. Therefore the energy requirement for cutting of small diameter stalks could be lower than large diameter. The researchers [1,2,3,4,12,15] have stated that as the stem diameter decreases thus, the cutting energy will reduce. The present study for cassava stem shows similar results with the other researchers.

It was understood that the increase in moisture content and stem diameter increased the cutting energy in all the treatments. Hence the designing of cutting element for cassava stem was more energy efficient in less moisture content.

Table 1. Analysis of variance for moisture content

S. no.	Source	df	SS	MS	F	Prob.
1.	Tot	8	90.985	11.373		
3.	Trt	2	89.550	44.775	187.300	**
7.	Err	6	1.434	0.239		

Table 2. Effect of moisture content on cutting energy

S. no.	Moisture content (%) (wb)	Mean cutting energy (J)
1.	43.75	24.32
2.	56.50	28.69
3.	64.00	31.95

Table 3. Analysis of variance for stem diameter

S. no.	Source	df	SS	MS	F	Prob.
1.	Tot	8	64.410	8.051		
3.	Trt	2	59.315	29.658	34.925	**
7.	Err	6	5.095	0.849		

Table 4. Effect of stem diameter on cutting energy

S. no.	Stem diameter (mm)	Mean cutting energy (J)
1.	25.22	28.81
2.	28.71	30.28
3.	33.29	34.84

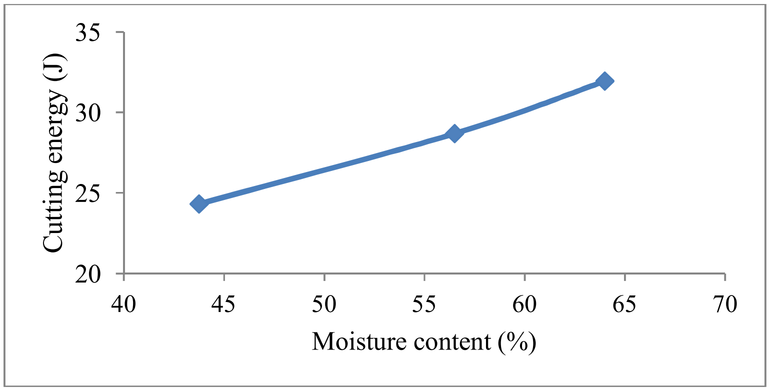

Fig. 2. Effect of moisture content on cutting energy

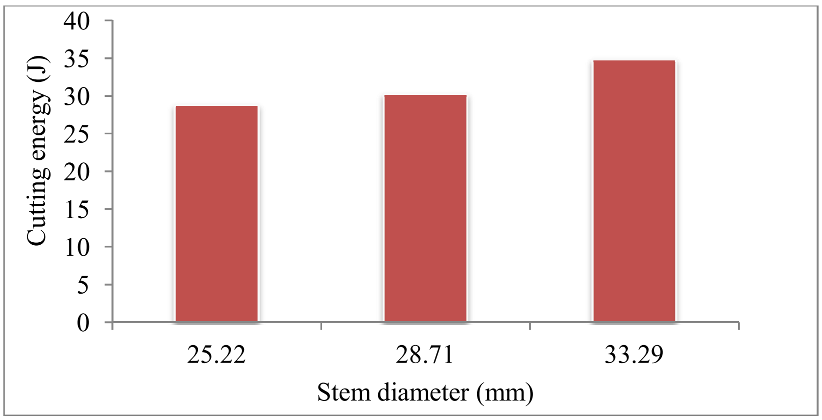

Fig. 3. Effect of cassava stem diameter on cutting energy

4. CONCLUSION

In this study effect of cassava stem crop parameters on cutting energy was observed to design a cutting element for cassava stem for planting of cassava. The pendulum type test rig was used to measure the cutting energy of cassava stem. The minimum cutting energy obtained at 25.22 mm stem diameter and 43.75% average moisture content for cassava stem. Maximum cutting energy was resulted at 64% average moisture content and 33.29 mm stem diameter. It was concluded that the cutting energy increased with increasing average moisture content and increased with increasing stem diameter.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hoseinzadeh B, Esehagghbeygi A, Raghami N. Effect of moisture content, bevel angle and cutting speed on shearing energy of three wheat varieties. World Appl. Sci. J. 2009;7(9):1120-1123.
2. Esehaghbeygi A, Hoseinzadeh B, Khazaei M, Masoumi A. Bending and shearing properties of wheat straw of alvand variety. World Appl. Sci. J. 2009;6(8):1028-1032.
3. Tavakoli H, Mohtasebi SS, Jafar A. Effect of moisture content and loading rate on the shearing characteristics of barley straw. CIGR Ejournal. 2009;11:1-11.
4. Yilmaz D, Kabas O, Akinci I, Ozmerzi A, Cagirgan MI. Effect of moisture content and stalk section on some engineering parameters of closed capsule sesame stalks (*Sesamum indicum* L.). J. of Food, Agriculture and Environment. 2009;7(3&4): 306-311.

5. Chattopadhyay PS, Pandey KP. Mechanical properties of sorghum stalk in relation to Quasi-static deformation. J. of Agrl. Engg. Res. 1999;73:199-206.
6. Galedar MN, Jafari A, Mohtasebi SS, Tabatabaeefar A, Sharifi A, O'Dogherty MJ, Rafiee S, Richard G. Effect of moisture content and level in the crop on the engineering properties of alfalfa stems. Biosystems Engineering. 2008;101(2):199-208.
7. Chen Y, Gratton JL, Liu J. Power requirement of hemp cutting and conditioning. Biosystems Engineering. 2004;87(4):417-424.
8. Kushwaha RL, Vaishnav AS, Zerob GC. Shear strength of wheat straw. Canadian Agrl. Engg. 1983;25:163-166.
9. Jekendra Y. Physical and rheological properties of forage crops with reference to cutting. Arch. Zootec. 1999;48:75-78.
10. Yilgep Y, Mohammad U. Effect of knife velocity on cutting energy and efficiency during impact cutting of sorghum stalk. CIGR EJournal. 2005;7(1):1-10.
11. Ince A, Ugurluay S, Guzel E, Ozcan MT. Bending and shearing characteristics of sunflower stalk residue. Biosystems Engineering. 2005;92(2):175-181.
12. Voicu G, Moiceanu E, Sandu M, Poenaru IC, Voicu P. Experiments regarding mechanical behavior of energetic plant miscanthus to crushing and shear stress. Jelgava. 2011;26:490-495.
13. Hemmatian R, Najari G, Hosseinzadeh B, Hashjin TT, Khoshtaghaza MH. Experimental and theoretical investigation of the effects of moisture content and internodes position on shearing characteristics of sugarcane stems. J. Agri. Sci. Tech. 2012;14:963-974.
14. Mahdavian A, Banakar A, Mohammadi A, Beigi M, Hosseinzadeh B. Modeling of shearing energy of canola stem in quasi-static compressive loading using artificial neural network (ANN). Middle-east J. Sci. Res. 2012;11(3):374-381.
15. Mathankar SK, Grift TE, Hansen AC. Effect of blade oblique angle and cutting speed on cutting energy for energy cane stems. Biosystems Engineering. 2015;133:64-70.
16. Anonymous. Moisture measurement–forages. ASABE Standards, St. Joseph, MI. 2006;608.
17. Prasanthkumar K, Saravanakumar M. Development and calibration of pendulum type test rig. Int. J. Curr. Microbiol. App. Sci. 2017;6(9):1498-1503.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55332