Effects of Moisture Content and Knife Bevel Angle on Shearing Properties of Cassava Stems

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Abstract. The effects of the moisture content and the knife bevel angles on the shearing properties of cassava stem were examined. In order to determine their effects on the shearing stress and shearing energy of cassava stems, the stems were classified into three regions: the lower, middle, and the upper regions. The results showed that the shearing stress and the specific shearing energy had increased as the knife bevel angle was increased from 20 to 40 degrees and that the moisture content had decreased from 64.27% w.b. to 17.67% w.b. The maximum shearing force, shearing stress, and the specific shearing energy were found to be 2.16 kN, 4.62 Mpa, and 55.58 mJ/mm², respectively. Due to structural heterogeneity, the shearing stress and specific shearing energy were found to be higher in the lower regions of the stems.

1. Introduction
Cassava is an important product around the world, and production from all countries amounts to approximately 200 million tons per year [1]. As an agricultural country, Thailand produces tens of thousands of tons of cassava annually and has a cultivation area of approximately 1.4 million ha. [2]. After the annual harvest, there are tons of leftover cassava stems, which are produced from this plant. Afterwards, the remaining cassava is used as animal feed and for other purposes. The amounts are 2.43 million tons of cassava stems and 1.83 million tons of cassava rhizomes with an energy equivalent of 44.76 million GJ. The farmers will burn cassava stem residues for replanting. Cassava stems have a heating value of 18.42 MJ/kg [3] and can be used as the raw material for producing biomass pellets. In order to reach these objectives, the cassava stem trash, which is to be used for biomass fuel, must be finely chopped into small bits by using chopping machines. However, if inappropriate parameters are used when these machines are being operated, critical problems can arise during the chopping and threshing processes.

The important shearing properties of the material, which are related to cutting, are shear stress and shearing energy. This study has been carried out in order to determine the exact effects that the moisture content of the cassava stalks and the positions where the cuts are made actually have on the cutting
process. In examining the decreasing moisture contents, all parameter values could be reduced with the exception of the shearing stress [4]. However, it was found that shearing stress had increased when the cutting line was lowered. Maximum and minimum shearing stress occurred at the top and bottom parts of the stems, respectively. The findings regarding the mechanical properties of Kenaf stems revealed a shearing energy of 8.75 J. and a maximum cutting force of 1584.55 N. at a moisture content of 35%, as well as an increased shearing energy of 3.50 J. with a maximum cutting force of 694.86 N. at the moisture content of 72%. A greater shearing energy was obtained from the lower regions of the stems [5]. The results from the shearing and bending characteristics of sunflower stem residues showed that the specific shearing energy and the shearing stress had increased as the moisture content (db) had increased. Moreover, the specific shearing energy and shearing stress were found to be higher in the lower parts of the stems [6]. The mechanical properties of cassava stalks (with five different moisture contents at three different regions) differed from the factors considered in this study given the results from where the cuttings had been obtained. It was found that the range of the failure load had been between 241.22 to 1150.32 N. at a range of strength of between 1.55 to 7.51 MPa. With regard to cutting, the range of failure load had been between 261.80 to 1235.60 N. at a range of strength between 1.12 to 5.00 MPa. [7]. The results of the cutting properties in olive orchards showed that the cutting force and cutting energy requirement for olive suckers had decreased with increases in moisture content. However, these properties were found to increase with an increase in cross-sectional area [8].

Thus, the objective of the research was to meet the need for information on the variations of the mechanical properties of cassava stems in order to determine the best chopping position. In this study, the effects of the angle of the knife bevel and the moisture content on the shearing properties of cassava stem trash was shear stress and shearing energy.

2. Material and methods

2.1. Sample preparation

The study was conducted in order to determine the shearing properties of cassava stem trash as a function of the angle of the knife bevel and moisture content. The cassava stem (Variety - Rayong 11), which was used in this study, was manually obtained from a farm in Khon Kaen Province in Northeastern Thailand. Twelve-month-old cassava stems were selected as samples. All samples were separated into five groups and each of the groups consisted of 10 samples. Then, each of the samples from each of the groups was divided into three parts (the upper, the middle and the lower). Moreover, each part was cut into small pieces and sample lengths of 15-20 cm of were created. The first group consisted of fresh cassava. After drying in the sun for an additional 15 days, the second group was obtained, while the third group was obtained after drying in the sun for 30 days. After drying in the sun for 45 days, the fourth group was obtained, while the fifth group was obtained after drying in the sun for 60 days.

Therefore, in order to determine the average moisture content, the stems were placed in an oven at 104 °C for 24 h [9]. Ten samples from each group were weighed and then dried. After drying, the moisture contents were determined by using the ASAE method [10], and were found to be as follows: 64.27, 48.20, 24.06, 17.67, and 8.93% (w.b.) for the first, second, third, fourth and fifth groups, respectively. In addition, the knife bevel angles of 20, 25, 30, 35, and 40 degrees of were selected for this study. These factors comprised the examined aspects. Next, the controlled factor was the shearing speed of 300 mm/min [11]. The UTM was used to record the shearing force (Figure 1), whereas the maximum shearing force was recorded by using the NEXYGEN program.
2.2. The mechanical properties
The diameters of all samples from Section 2.2 were measured using a Mitutoyo absolute digimatic vernier caliper (precision = 0.010), and the shearing force was recorded by the UTM. The experimental design is shown below in Figure 2.

2.3. The shearing tests
In order to determine the shearing stress and the specific shearing energy for the cassava stems, the tests were carried out at five levels of moisture content (64.27, 48.20, 24.06, 17.67, and 8.93% (w.b.) and five knife bevel angles (20, 25, 30, 35, and 40 degrees, respectively). The knife bevel cuts were made at 300 mm/min of velocity. Using Equation (1) and (2), the shearing stress and specific shearing energy were determined by utilizing a force-displacement curve and the different angles of the knife bevels. The shearing energy was calculated by integrating the curves of the shear force and the displacement [12].
\[ \tau = \frac{F_{\text{max}}}{A} \]  

in which \( \tau \) = maximum shearing stress \( (\text{N/mm}^2) \)  
\( F_{\text{max}} \) = maximum shear force \( (\text{N}) \)  
\( A \) = cross-sectional area of the cassava stem \( (\text{mm}^2) \)

The calculated shearing energy was determined using the area under these curves. The area under the curve was shared into the basic geometric shapes, and using computer program, the calculations of the area under the curve represented the force and displacement data. The specific shearing energy was found by

\[ E_{sc} = \frac{E_s}{A} \]  

in which \( E_s \) = total shearing energy in \( (\text{mJ}) \)

3. Results and discussion
3.1. The shearing stresses

The lower portions of the cassava stems have a more fibrous structure. Therefore, the shearing stress was found to be higher when compared to the upper parts of the stems. In this lower region, the shearing stress varied from between 2.50 to 4.62 MPa at 17.67 % w.b. moisture content when the angle of the knife bevel varied from between 20 to 40 degrees. Figure 3 shows the effects of the escalation of knife bevel angle in relation to an increase in shearing stress. The maximum value was found in the lower parts at a moisture content of 17.67 % w.b., 4.62 MPa. Conversely, the maximum value in the upper part of the stem was found at a moisture content of 8.93 %, while the lowest shearing stress was determined to be 1.22 MPa. Moreover, as the angle of the knife bevel was increased from 20 to 40 degrees, the shearing stress increased from the lower to upper regions of the stems. As the moisture content decreased, the shearing stress in the intermediate stem regions was also reduced.

![Figure 3: The shearing stress against the bevel angle](image_url)
3.2. The specific shearing energy
It was found that the specific shearing energy had also decreased towards the upper regions (Figure 4). When the angle of the knife bevel was increased from 20 to 40 degrees, the shearing energy at a moisture content of 17.67% w.b. and the specific shearing energy were found to increase. These values varied from between 36.48 – 60.82, 36.17 – 54.14, and 26.15 – 40.23 mJ/mm² for the lower, middle, and upper regions, respectively. Due to the accumulation of more mature fibres in the stems, the values were greater in the lower regions.

![Figure 4: The specific shearing stress energy trends](image)

4. Conclusions
This research examined the effects of moisture content and knife bevel angle on the shearing properties of cassava stems. The five levels of moisture content, which were studied, included 64.27, 48.20, 24.06, 17.67, and 8.93% wb. Moreover, the five studied levels of knife bevel angles were 20, 25, 30, 35, and 40 degrees. The results indicated that the shearing stress and specific shearing energy were at a minimum when the knife bevel angle was 20 degrees. Conversely, a knife bevel angle of 40 degrees was found to have the maximum amount of shearing stress and specific shearing energy. In conclusion, the knife bevel angle of 20 degrees and the moisture content of 17.67 %wb were determined as the recommended design for building a cassava stem cutting machine in order to produce the fuel pellets for a further study. For shearing stress and the specific shearing energy had depended on a decrease in the moisture content and an increase [13] in the angle of the knife bevel.

When considering the shearing stress and specific shearing energy, there were big differences between the highest and the lowest moisture contents and the angles of the knife bevels. The results indicated that chopping cassava stems with certain moisture contents and certain angles of knife bevel can be recommended in order to reduce the shear and cutting power requirements. Therefore, in light of practical agricultural operations, establishing the appropriate time for chopping is a very important factor in determining how the stems will respond.

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