Expriments on mechanical and physical characteristics peanut vine at harvest period

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Abstract: In order to understand the physical and mechanical characteristics of peanut vines during harvest period, and then provide theoretical data for the development of peanut vine related machinery. In this paper, physical and mechanical tests were performed using the water content, friction characteristics, density, and shear force of peanut vine during harvest period as indexes. The upper, middle and lower moisture content of peanut vines in harvest period is $W_{\text{upper}} > W_{\text{middle}} > W_{\text{lower}}$; the coefficient of friction between the vine and leather, plastic, stainless steel is about 0.6, and the friction coefficient between the vine and the glass was about 0.5; there is a large difference between the apparent density and the bulk density of the vine, the apparent density is about 1.3 g/cm³, and the bulk density is 1.1 g/cm³; as the feed rate is constant, the shear force changes steadily after the cutting velocity is more than 8 m/s; the research results can provide reference for the design of key components such as peanut vine wet harvesting device.

1. Introduction

Peanuts are important oil crops and cash crops in China and even the world, the global annual output of peanuts is about 46 million tons, of which China accounts for 28.3% of the world's total output with 13 million tons of peanuts, ranking first in the world [1-2]. The annual production of peanut vine in China is about 20-30 million tons, if peanut vine is calculated at a conversion rate of 30% and an silage product acquisition rate of 1: 0.4, 3.6 million tons of silage can be obtained each year [3]. The reasonable use of peanut vine can greatly alleviate the contradiction between "human and livestock competition for food" in China, and at the same time can fill the gap between supply and demand of domestic farmed feed to a certain extent, reduce the proportion of imported feed in the aquaculture production process, thereby reducing the cost of aquaculture.

In order to solve the waste of vine such as peanut vines, with the increasing emphasis on agricultural machinery research and development in recent years, scholars have begun to pay attention to the research on the physical and mechanical characteristics of agricultural materials. Chen Mingjiang et al. [4] analyzed the relationship between cotton stalk diameter and cotton stalk water content; Hou Jie [5] research found that the water content of corn stalks of different varieties was different in the same period; Lu Caiyun [6] found that the coefficient of friction of corn vine was greatly influenced by the part of the vine and the angle of contact; Hou Jie [8] used injection method to study the coefficient of friction of corn vine, the results showed that the water content of corn vine was 15%, 25%, 35% and the three contact materials of wood, iron plate, glass friction coefficient is not much different; Liu Qingting [8] made a comprehensive evaluation of the progress of the study of the mechanical characteristics of crop vine and established the system of mechanical model and...
mechanical index; Li Yudao [9-10] found that cotton vine had lower shear strength and shear strength when the water content was between 30% and 50%; Wu Ziyue [11] found that different cutting methods have the greatest influence on the cutting velocity of corn vine; Qiu Lichun's [12] found that the shear force required for corn vine decreased first and then steadily with the increasing water of the vine;

In summary, at present, the study of the physical and mechanical properties of crop vine is concentrated in corn, cotton and other crops, and less research on peanut vines; In addition, scholars use a single strain to study the physical mechanical properties of crop vine, the obtained data and the actual production status has a certain gap, the reference significance of mechanical design is weakened. Based on the mechanical performance requirements of the peanut combine harvester, this paper uses the experimental method to study the physical and mechanical characteristics of the peanut vine such as water content, friction coefficient, density, and shear force, so as to provide a theoretical basis for the design of the peanut combine harvester.

2. Test materials and equipment
For the purpose of measuring the physical and mechanical characteristics of peanut vine, the peanut vines with a growth period of 150 days were selected and not more than 24 after harvest, which were the main peanut varieties Haihua 6 and Hua 37 in Shandong Province. The main stem of flower Haihua 6 is generally about 35 cm in height, with 9-11 branches per plant, and the main stem of hua 37 is generally about 40.5 cm in height, with about 9 branches per plant, and selected as shown in Figure 1 the shape of uniform insect-free peanut worm. The test was conducted at the test base in Yanggu County, Liaocheng City in late September 2019.

![Figure1. Peanut vine](image)

In addition, the instruments used in the test include electronic balances (accuracy 0.001g, JA5003A type, Shanghai Jingtian Electronic Instrument Co., Ltd.), GZX-9240 MBE electric hot drum wind drying box, callipers (accuracy 0.02mm), friction angle measuring instrument, beaker, graduated cylinder, dry dish.

3. Test material and results

3.1. Determination of water content
Take the peanut vine 10cm segment is the lower part, 10cm to 20cm segment is the middle, the rest is the upper part, selected the peanut cranberry up, middle and lower each part of each 5 groups as a sample, with 5 groups of mean as the test results, the sample shown in Figure 2.
The test placed a clean aluminum flat weighing bottle in a 60 degree Celsius drying box and heated it for 1 hour after taking it out and cooling it in the dryer for half an hour, weighing the bottle after cooling, and repeating the process, drying to the two times before and after the mass difference of no more than 0.02g is a constant weight.

Then weigh 2g to 10g specimen into the weighing bottle and the specimen height does not exceed 10 mm, weighed and put in a drying box of 60 degrees Celsius drying 2 h to 4 h, remove and put into the dryer to cool for half an hour after weighing, weighed and then put in a 60 degree Celsius drying box drying about 1 h, remove and put into the dryer to cool 0.5 h Weigh. And repeat the above operation to the two before and after the quality difference of not more than 0.05g is constant weight. Record data, the water content is calculated as follows:

$$W = \frac{m_1 - m_2}{m_1 - m_3} \times 100\% \quad (1)$$

Where is $W$-sample moisture content; $m_1$ is Mass before the weighing bottle and specimen are dried, g; $m_2$ is Mass after drying of weighing bottles and specimens, g; $m_3$ is The quality of the weighing bottle, g.

The results of the experiment are shown in Figure 3.

It can be seen from figure 3 that the water content of each part of the peanut vine is $W_{upper} > W_{middle} > W_{lower}$. The water content of the upper part of Haihua 6 is about 68%, the water content in the middle is about 64%, and the water content in the lower part is about 57%. The water content of each part of the vine of Hua 37 was lower than that of the corresponding part of Haihua 6 by 0.1%. Because the harvested peanut plant sample is at the end of its growth cycle, the lignification of the lower peanut vine is more serious than the other two parts, resulting in lower water content, and the upper vines are mostly new shoots and young shoots. Therefore, its water content is high.

3.2. Determination of friction coefficient

The sliding friction angle indicates the friction characteristics between the cranberry and the contact
surface when the peanut slug is sliding relative to the contact solid, and its tangent value is the sliding friction coefficient. Using the method of moving the peanut cranberry relative to a given friction surface to determine the sliding friction angle and coefficient of friction, the peanut slug is placed on the slope of the oblique instrument, the light rocker handle makes the slope angle gradually increase, when the cranberry begins to slide relatively to the slope, the angle of this oblique is the sliding friction angle[13].

The straight Haihua 6 peanut vines were evenly cut into a test pattern with a length of 4 cm. They were divided into 5 groups of 10 sample sections, and the average of 5 tests was the test result. The experimental results are shown in Table 1.

| Material     | Friction Angle (°) | Friction Coefficient |
|--------------|--------------------|----------------------|
| Stainless Steel | 34.2               | 0.680                |
| Glass        | 26.4               | 0.496                |
| Leather      | 31.0               | 0.602                |
| Plastic      | 29.1               | 0.556                |

3.3. Determination of density

The density of peanut vine is an important parameter in the design of peanut vine cutting machinery and pneumatic conveying system. In order to obtain the exact density of peanut vines, this paper uses the drainage method and the vibrating and stacking method. Each method is repeated 3 times to obtain the average value.

The drainage method, the Haihua 6 cut into a length of 4 cm sample weighed as M, weighed as M, and placed in a graduated cylinder with a volume of V₁ (100 ml) of salad oil with tweezers, As shown in Figure 4 (a), when the sample completely invades the salad oil, take a reading. At this time, the volume of the liquid level rise is the sample volume V₂. The density obtained by the drainage method is the apparent density, and the apparent density value is the value of the M ratio (V₂-V₁) [14]. In the vibratory stacking method, the same variety of peanut vines were cut into samples with the same diameter as the vines. They were placed in a clean beaker that had been weighed and stacked to 100ml, shaking and shaking, as shown in Figure 4 (b). It is required that the top surface of the pile should be flat with the scale line, flat and no protrusions and no depressions. Weigh therecord, and the ratio of the mass of vines to the bulk volume is the bulk density [15].

![Figure 4. Schematic diagram of density test](image)

The results of the experiment is about 1.3g/cm³ of the apparent density and 1.1g/cm³ of the bulk density. Because the harvest situation is similar to the vibrating and stacking method, it is more applicable to use the bulk density as a reference when designing peanut machinery.

3.4. Determination of Shear Force

The traditional research method of crop vine shear force is carried out by the universal test machine, the universal testing machine uses a V-shaped knife to cut the fixed vineat both ends. In the actual
harvesting process, a rotary cutter is used to clamp and cut on one side. There is a big difference between the actual harvest cutting process and the universal testing machine cutting process, so the measurement results are far from the actual.

In order to overcome this problem, a measuring device for the shearing force of the vine under a large-scale feed state was designed to obtain the shearing force of the peanut vine.

### 3.4.1. Design and working principle of shear test bench

Shear test benches include racks, power and transmission systems, vine fixtures, and data acquisition systems. The cutting saw plate of the vine is mounted on the upper side of the beam and the power of the cutting device is provided by the cutting motor. The driving wheel with the belt transmission is connected to the main axis of the cutting motor, the driven wheel is connected with the saw plate, the transmission ratio with the transmission is adjusted by changing the belt wheel, and the spacing between the vine and the cutter blade holder can be freely adjusted. Different harvest velocities are simulated by changing the number and arrangement of vine in the vine grip. The process of peanut vine cutting is simulated by rotating saw plate and the cutting velocity is adjustable, and the forward velocity of the harvester holding chain in the field harvesting process of peanut stalk is simulated by adjusting the feed velocity of peanut vine.

The test bench workflow is shown in Figure 5. Fix the fixture of peanut vine on the workbench before the experiment. The tester controls the feed motor to drive the feed at different velocities through the feed system of the gantry planer and the inverter 2. At the same time adjust the inverter 1 to control the cutting motor velocity, velocity by belt transmission to the cutting saw plate for vines cutting. The cutting state is shown in figure 6. The power of the cutting motor under different cutting conditions is recorded by the data acquisition device (ammeter, voltmeter).

![Flow chart of the shear test](image1)

![The shear test of peanut vine](image2)

### 3.4.2. Analysis of Shear Test Process and Results

Samples of Haihua 6 peanut vines with the same conditions in the above test materials were selected. The peanut combine harvester mainly uses one ridge-two rows and two ridges-four rows. The harvest efficiency at one ridge-two rows is 0.2 hm² / h, and the harvest efficiency at two ridges-four rows is
0.4 hm²/h. The positive and inverted feed velocities of the test benches were measured at 0.43 m/s and 0.26 m/s, while the actual harvesting velocities of the harvesters were 0.8 m/s and 0.5 m/s. In order to ensure the same as the actual situation, this experiment doubles the amount of the cranberry, such as a row of two lines with a misplaced 4 lines instead.

After the vines are clamped, place the vines clamp on a planer and fix it. Adjust the height of the saw disk with a diameter of 300 mm to 15 cm above the ground. Set the cutting motor frequency to 50 Hz at a voltage of 400 V. After the motor runs stably, turn on the machine's feed system and cut the vines. After the current meter is stable, record the data, adjust the velocity and feed rate, and repeat the test three times.

In order to obtain the shearing force, the stress analysis of the vines in the shearing state is performed. The vines is mainly subjected to the shearing force, the feeding force and the knife resistance during shearing. The velocity of the knife resistance in the direction of the knife is zero, so the force does not do work, so the cutting power is composed of the work done by the shearing force and the feeding force on the vines. The feed force is much smaller than the shear force, and the work done by the feed force only accounts for 2% ~ 3% of the cutting power, so the cutting power of the vines can be calculated according to the formula [16].

\[ P_c = F_c v_c \]  \hspace{1cm} (2)

Where \( P_c \) is the cutting power, W; \( F_c \) is shear force, N; \( v_c \) is cutting velocity, m/s.

In addition, the cutting power of vine can be converted by the power of the cutting motor, the formula can be expressed as:

\[ P_c = U I \eta \]  \hspace{1cm} (3)

Where \( U \) is cutting motor working voltage, V; \( I \) is cutting motor working current, A; \( \eta \) is transmission efficiency, take 0.75 ~ 0.85.

The formula for calculating the shear force can be obtained by formulas (2) and (3).

\[ F_c = U I \eta / v_c \]  \hspace{1cm} (4)

The shear force test data is shown in figure 7.
In order to better predict the change of the shear force with the cutting velocity, a polynomial fitting of the shear force curves at different feed velocity is performed. As shown in Figure 7 (a), when the feed velocity is 0.52m/s, the relationship between the shearing force of the vine and the rotation velocity is \( y = 3.2174x^2 - 63.905x + 396.74 \); As shown in Figure 7 (b), when the feed velocity is 0.86m/s, the relationship between the shearing force of the vine and the rotation velocity is \( y = 4.2901x^2 - 83.056x + 492.32 \); As shown in Figure 7 (c), when the feed velocity is 1.2m/s, the relationship between the shearing force of the vine and the velocity is \( y = 5.5211x^2 - 101.82x + 563.9 \). Combined with the fitting polynomial, it can be seen that when the feed velocity is constant, the shearing force of seedlings decreases with the increase of the cutting velocity. When the cutting velocity is greater than 8m / s (rotating velocity of the saw disk is 509 rad / min), the change in force leveled off.

In addition, when the feed velocity is 0.52m/s, 0.86m/s and 1.2m/s, the cutting velocity is 7.62m/s to 8.75m/s that is the rotating velocity of the saw disk 485rad/min to 557rad/min cutting current is minimal, the shear force change is minimal, the best cutting effect on the cranberry. In the design of the peanut cranberry cutting device, the cutting velocity can be set to 8m/s, that is, rotating velocity of the saw disk is 509rad/min to improve the performance of the vine cutting device.

4. conclusions
The main conclusions are as follows:

1) In order to provide parameter basis for the design of machinery such as peanut vine harvesting device, the physical and mechanical properties of peanut vine were studied by experimental method, and the water content of the parts of the peanut vine saffron was measured by the drying method. The water content of each part of the peanut vine is \( W_{\text{upper}} > W_{\text{middle}} > W_{\text{down}} \). The water content of the upper part of Haihua 6 is about 68%, the water content in the middle is about 64%, and the water content in the lower part is about 57%. The water content of each part of the vine of Hua 37 was lower than that of the corresponding part of Haihua 6 by 0.1%.

2) According to the method of moving the peanut seedlings to the friction surface, it is known that the friction coefficient between the seedlings and leather, plastic, stainless steel and other materials is about 0.6 and that between the seedlings and glass is about 0.5; the apparent density is about 1.3g / cm\(^3\), and the bulk density is 1.1g / cm\(^3\).

3) Through the homemade test bench, it is learned that the shear force of the vine has a great relationship with the cutting velocity, and when the feed velocity is constant, the cutting velocity is greater than 8m/s and the shear force changes slowly.

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References

[1] Dahunsi S O, Oranusi S, Efiongbohkan V E. Pretreatment optimization, Process control, Mass and Energy balances and Economics of anaerobic co-digestion of, Arachis hypogaea, (Peanut) hull and poultry manure[J]. Bioresource Technology, 2017, 139: 260-275.

[2] National Agricultural Statistics Service. Crop production[R]. United States Department of Agriculture, 2018.

[3] Qin li. A review on utilization of peanut vine and peanut shell in animal feeds [J]. Pratacultural Science, 2011, 28(11): 2057-2060.

[4] Chen mingjiang, Song deping, Wang zhenwei, et al. Research on the Cotton-Stalk Uprooting Resistance[J]. Journal of agricultural mechanization research, 2016(06):64-68.

[5] Hou Jie. Related study on Mechanical Characteristic and Physicochemical Property of Corn Straw[D]. Harbin: Northeast Agriculture University, 2013. (in Chinese with English abstract)

[6] Lu caiyun, Zhao chunjiang, Meng zhijun, et al. Straw friction characteristic based on rotary cutting anti-blocking device with slide plate pressing straw[J]. Transactions of the Chinese Society of Agricultural Engineering, 2016, 32(11): 83-89.

[7] Hou Jie. Related study on Mechanical Characteristic and Physicochemical Property of Corn Straw[D]. Harbin: Northeast Agriculture University, 2013. (in Chinese with English abstract)

[8] Liu qingting, Ou qinggang, Qing shangle, et al. Study Progress on Mechanics Properties of Crop Stalks[J]. Transactions of the Chinese Society for Agricultural Machinery, 2007, 038(7): 172-176.

[9] Li Yudao. Rotary Experimental Study on Development of Cotton Stalk Cutting Test Bench and Experimental Investigations[D]. Taian: Shandong Agricultural University, 2012. (in Chinese with English abstract)

[10] Du Xianjun. Cotton Stalk Mechanical Characteristics Research and Development of Cutting Test Bench[D]. Taian: Shandong Agricultural University, 2011. (in Chinese with English abstract)

[11] Wu ziyue, Gao huanwen, Zhang jingbo. Study on cutting velocity and power requirement in maize stalk shopping process [J]. Transactions of the Chinese Society for Agricultural Machinery, 2001(2):38-41.

[12] Li xiaodong, Qu lichun. Experimental investigation of physical mechanics characteristics for coin straw [J]. Agricultural science & technology and equipment, 2011(02):70-72.

[13] Yang zuomei, Guo yuming, Cui qinglaing, Li hongbo. Experimental study on friction characteristics of broomcorn millet with different moisture content[J]. J. SHANXI AGRIC, UNIV, (Natural Science Edition). 2016, 36(7):519.

[14] Qin yu, Liuyun, Wei guoyu, Wen lihua. Study on the bark density and the timber basic density of acacia mangium and acacia crassicarpa[J]. Journal of Anhui Agri, 2013(7): 2993-2994.

[15] Tang tianzong, Huang xin, Zhang cuntao. A calculation method of packing density of sand in the mortar[J]. Beton Chinese Edition——Ready-mixed Concrete, 2007, (2):29-32+87.

[16] Zhang Xuxiang. Fundamentals of machinery manufacturing [M]. Beijing: Higher Education Press, 2012.