Study on The Effect of Chestnut Shattering and Mechanical Shattering Mode

Xueyin Yang
School of Mechanical and Vehicle Engineering, Linyi University, Shandong, China

*Corresponding author: yangxueyin@lyu.edu.cn

Abstract. In the shelling contrast test, different shelling force and feed displacement of chestnut were tested under different water content, size and loading speed. The main influencing factors were obtained through variance analysis, which provided theoretical basis for the selection of shelling tool and feed displacement of chestnut. The results showed that among the three peeling methods of compression, shearing and kneading, the peeling effect of kneading was the best, followed by shearing and compression.

Keywords: Chestnut, Breaking force, Displacement, Breaking the shell effect; Rub.

1. Introduction
Chestnut is one of the famous dried fruit products in China, known as the "king of dried fruit" reputation. However, due to the shortcoming of chestnut storage impatience, the annual loss of chestnut due to mildew, insects and germination in China is 35% ~ 50% of the total output, which is a great waste of resources, and sales and consumption are also subject to serious seasonal restrictions [1]. Therefore, the problem of deep processing of chestnut is imperative. The shelling of chestnut is the first process of chestnut processing, and it is also a technical problem of deep processing.

At present, the main machine shell method on chestnut processing, but the chestnut shell, the factors affecting the size of the breaking strength of the study also is less, this research mainly aims to under the different mechanical hulling method [2], study of the influencing factors of chestnut shell force, it is concluded that the main factors influencing the chestnut breaking force, efficiency of shell under different breaking way of comparison, it is concluded that effect is the best way to moult his shell.

2. Materials and methods

2.1. Test materials
The variety of chestnut is Mengshan chestnut produced in Feixian County, Shandong Province. After screening, there is no moth-eaten and no damage. After picking, the chestnut is stored at 2℃ for 15 days. Before the test, the size is graded. 100 chestnuts were randomly selected and weighed using an electronic balance (accuracy: 0.01g). The size of chestnuts ranged from 4 to 15g. According to the different sizes, the chestnuts were divided into three different grades: A, B and C.
2.2. Test equipment
RG2000-2 microcomputer controlled electronic universal testing machine was used in the test. KWY-500 electric drying oven, XMD temperature sensor; Chestnut classification using 500g range of electronic scale, accuracy of 0.01g.

2.3. Test methods
Tests using three kinds of commonly used different mechanical breaking fixture: flat head, cutting tools and rubbing tools, under each fixture, the experiments include: single factor experiment, by the prophase research [3] factors that influence efficiency of chestnut shell including the moisture content of different shape, different, different size, different loading rates and different loading direction; The orthogonal combination of the main factors affecting the cracking of chestnut in LIANG was carried out in the multi-factor experiment to test the cracking force and the cracking effect among different influencing factors.

3. Test of three different mechanical chestnut shell breaking modes

3.1. Design of mechanical chestnut shell cracking fixture

3.1.1. The compression tool [1]. Adopts a flat head with a diameter of 80cm and a thickness of 20cm, as shown in Figure 1. When working, the universal test bench provides power for the breaking of chestnut shell, in which the upper plate pressure head 1 is installed at the upper fixed chuck of the universal test bench (see Figure 1), and the lower plate pressure head 3 is installed at the lower fixing place. The clearance between the two indenters can be changed by the up and down movement of the beam 7. Put chestnuts 2 tablets under the center of the three, flat head on the role of exerting pressure on the Chinese chestnut, the deformation of the size of the breaking strength and breaking respectively by force sensor and strain sensor signal transmission to the PC, after transformation module, analysis software available to draw corresponding breaking force of different deformation value, namely the force deformation curve.

![Fig 1. Apron compressive chunk 1. Top plate 2. chestnut 3. The bottom plate](image1)

![Fig 2. The base 1. Fixed end 2, 3, 4 screw holes 5. Bottom 6. The chute 7. Adjustable end 8. Turn the handle](image2)
3.1.2. Base. In the cutting and rubbing test, the cutting tool blade, the auxiliary tool and the lower rubbing tool of the kneading tool all need to be fixed. A fixed base with adjustable clearance should be designed, as shown in Figure 2. The base is fixed at the position of the lower fixing plate 5 in Figure 2 of the test bench by screw 4. By rotating the handle 8, the adjustable end 7 can slide in the chute 6 to adjust the size of the gap between the fixed end of the base and the adjustable gap end.

3.1.3. Shearing tool [1] The shearing tool is axisymmetric about the center, as shown in Fig. 3. When working, the plate press heads 2 at the upper end is fixed on the beam by the 4 in Figure 2, the two symmetrical structures of the auxiliary device 4 at the lower end and the cutting blade 5 are respectively fixed in the screw holes of 2 and 3 on the base with screws. The clearance between the cutting tools can be adjusted according to the size of the chestnut by rotating the handle of the base 8. Its working principle is: by adjusting the gap and put the chestnuts to guide 4, because of breaking universal testing machine to make flat head downward movement of block by the blade, when shear knife blade 5 and half arc produced fruit shell parts in contact with the effect of shear force, as the stress continues to increase, making fruit shell cracking, until the Chinese chestnut shell [5].

3.1.4. Rubbing the tool. Rubbing cutting tool design as shown in figure 4, its working principle is: the rub on the knife by the clamping part 1 on the universal material testing machine fixed clamp 4.

Rubbing tool knife rub through screws on the base (see figure 2) adjustable end of July 3 screw holes, according to the size of the Chinese chestnut, it can move through the rub knife to adjust the gap between the two rub knife. At work, the beam of the testing machine 7 driven on the knife 2 upward stretching movement, so that sandwiched in 2, 4 between the knife 5 chestnut by the knife sawtooth rubbing action, so that the chestnut upward to do the turnover movement, at the same time by the role of torsion force, nut shell in rubbing force and torsion force under the joint action of force cracked shell.

Fig 3. The tongs of shearing 1. Fixed shaft 2. Plate press 3. Chestnut 4. Guide device 5. Cutting blade 6. Fixed screw hole

Fig 4. The kneading tongs 1. Clamping part 2. Upper the blade 3. Blade 4. under the blade 5 chestnut 6. Fixed screw hole
Fig 5. Compression test of Chinese chestnut from three different directions of X, Y and Z

3.2. Cracking efficiency test of chestnut under different cutters

According to the previous studies on the factors affecting the mechanical properties of chestnut shattering [22], the main factors affecting the shattering force of chestnut are the moisture content, the size of chestnut and the loading direction. Moisture content and loading rate were the main factors affecting the cracking effect of chestnut.

3.2.1. Compression test analysis.

1) Relationship between deformation and force during compression

As shown in Figure 5, curves 1, 2 and 3 respectively compress chestnut in X, Y and Z directions with flat plate head, it can be seen from the figure that in the process of compression, the loading force of chestnut increases linearly with the increase of deformation when the speed is constant. As the amount of deformation increases, the chestnut will break, as shown in figure A, B, C, this is the so-called biological yield point. When the deformation is further increased, the relationship between the deformation of the chestnut and the loading force is no longer linear, and the chestnut will crack until crushed. The results showed that the compression damage of chestnut was related to the amount of deformation, and the damage would occur when the amount of deformation reached a critical value.

2) Relationship between size, speed, moisture content and shell breaking force of chestnut

In the multi-factor experiment, an orthogonal experiment was designed to study the relationship between the influencing factors of chestnut size, moisture content, loading rate and shattering force. The results of the experiment were shown in Table 1, Analysis of Variance.

The regression analysis was performed on the orthogonal table, and the following regression equation was obtained

$$Y = -1083.604 - 8.490X_1 + 0.913X_2 + 25.623X_3$$  (1)

In the formula, $Y$ is the shattering force (N), $X_1$ is the chestnut grade (value is -1, 0, 1), $X_2$ is the loading rate (mm/min), and $X_3$ is the moisture content.

Table 1. Multivariate analysis of variance table

| Sources of variance | Sum of squares | Degrees of freedom | Mean square | F value |
|---------------------|---------------|--------------------|-------------|--------|
| Return              | 301919.199    | 3                  | 100639.733  | 15.876 |
| The remaining       | 202853.401    | 32                 | 6339.169    |        |
| The sum             | 504772.600    | 35                 |             |        |

Note: F0.05(3,32) = 2.90, F0.01(3,32) = 4.46
Test the significance of the regression equation, because $F=15.876 >; F0.01(3,32) = 4.46$, so the regression equation is extremely significant. According to the equation, the higher the moisture content, the larger the chestnut, the larger the chestnut shell breaking force, the higher the loading rate, the smaller the needed shell breaking force.
3.2.2. Shear test analysis

![Fig 6. Searing test deformation-strain](image)

As shown in Fig. 6, the curve is a curve of deformation and force during shearing. It can be seen from the figure that in the process of shear, the shear stress increases with the increase of deformation, and when the deformation reaches a certain degree, the shear force reaches the maximum, and as the deformation continues to increase, the shear force decreases. It can be seen from the curve jitter that there is no linear relationship between shear force and deformation during the whole shear process.

1) Relationship between moisture content and shearing shattering force

It can be seen from the experimental data that there is a significant relationship between the shearing shattering force of chestnut when the moisture content is changed. Regression analysis was conducted on the collected data, and the relationship between loading rate and shearing cracking force was obtained as follows:

\[
Y = 968.244 + 23.583 \times X \quad (41.06 < X < 100)
\]  

(2)

Where \( Y \) is the breaking force \((N)\) and \( X \) is the water content.

![Fig 7. Histogram of displacement](image)

| Sources of variance | Sum of squares | Degrees of freedom | Mean square | F value |
|---------------------|---------------|--------------------|-------------|---------|
| Return              | 64376.630     | 1                  | 64376.630   | 10.623  |
| The remaining       | 163626.641    | 27                 | 6060.246    |         |
| The sum             | 228003.271    | 28                 |             |         |

Note: \( F_{0.05} (1, 27) = 4.21 \) \( F_{0.01} (1, 27) = 7.68 \)
The significance of the equation was tested, as shown in Table 2, where \( F = 10.623 > F_{0.01(1,27)} = 7.68 \), so the equation is extremely significant.

It can be seen from the equation that the intercept of the equation is negative. In order to make the equation meaningful, the water content should be greater than 41.06%.

From the equation, it can be seen that the shell breaking force increases linearly with the increase of water content [5]. This is in good agreement with the experimental results.

3) Range of displacement during shearing
The data of all displacements in the shear test are analyzed. The analysis is shown in Table 3.

### Table 3. Displacement statistical results

| N  | Range | Minimum | Maximum | Mean   | Std.  | Variance |
|----|-------|---------|---------|--------|-------|----------|
| 101| 7.25  | 2.14    | 9.39    | 6.4967 | 1.6646| 2.771    |

It can be seen from the results that the maximum displacement is 9.39mm, the minimum displacement is 2.14mm, the average displacement is 6.4967mm, and the standard error of the average displacement is 0.16564. The histogram of data made by SPSS is shown in Figure 7.

It can be seen from the histogram that the shear displacement is mainly distributed between 3.5-9.5mm. This result shows that chestnut can break its shell smoothly in the shear displacement of 3.5-9.5mm.

3.2.3. Rub test analysis
When the material testing machine is started, the upper chuck pulls the chestnut for rubbing under the action of tensile force. Chestnut in the whole process, there are two kinds of movement: 1) the chestnut between the two chuck friction movement, until the chestnut shell tears; 2) Chestnut in the chuck between the constant rotation, until the chestnut shell.

The data recorded in this test is the maximum tensile force and the displacement corresponding to the tensile force. Because of the complex force situation of rubbing, the data can only be qualitatively analyzed in the case of rubbing, the force situation of chestnut and the displacement of rubbing.

Tensile force data in the rolling test are statistically analyzed, and the results are shown in Table 4:

### Table 4. Statistical results of tensile force

| N  | Range | Minimum | Maximum | Mean  | Std.  | Variance     |
|----|-------|---------|---------|-------|-------|--------------|
| 72 | 131.62| 31.69   | 163.31  | 84.580| 3.928 | 1110.605     |

It can be seen from Table 4 that in the rolling process, the range of tensile force is 31.69-163.31N, the range is 131.62, the mean of tensile force is 84.580N, the mean error is 3.928, the standard deviation is 33.326, and the variance is 1110.605.

As can be seen from the histogram in Fig.8, during the rubbing process, the tensile force is mainly concentrated between 35 and 150N.

From the statistical results, it can be seen that the stretching force in the process of chestnut rubbing is relatively dispersed, and the range of stretching force is relatively large, from 35N to 150N. This statistical result shows that there is no significant rule of chestnut rubbing force in the process of chestnut rubbing. The main reason for this phenomenon is that the force of chestnut in the process of chestnut rubbing is relatively complex and there are many influencing factors.
The data of rolling stroke in the rolling test are statistically analyzed, and the results are shown in Table 5:

**Table 5. Statistical results of rolling stroke**

| N  | Range | Minimum | Maximum | Mean   | Std.  | Variance |
|----|-------|---------|---------|--------|-------|----------|
| 72 | 33.62 | 4.58    | 38.20   | 13.236 | .706  | 5.990    | 35.886   |

It can be seen from Table 6 that: in the rolling process, the range of rolling stroke was 4.58-38.2mm, the range was 33.62, the mean value of rolling stroke was 13.236mm, the mean error was 0.706, the standard deviation was 5.990, and the variance was 35.886.

As can be seen from the following kneading stroke histogram 9, the kneading stroke is mainly concentrated between 5 and 17.5mm during the kneading process.

In general, in the rubbing process, the force of chestnut is more complex, chestnut rubbing tensile force and travel are relatively scattered. From the statistical results, the tensile force is mainly concentrated between 35-150N, and the stroke is mainly concentrated between 5-17.5mm.
3.3. Comparison of shelling efficiency of three loading methods

To compare the shelled efficiency of compression, shearing and kneading, the evaluation methods are shelled rate and kernel rate.

In the process of compression, chestnut shell cracking phenomenon occurs after the action of compression force, although the shell is broken, but not shelled, so the compression shelled way is not ideal, shelled rate and whole kernel rate is relatively low.

In the process of shearing and kneading, the peeling effect is good. The test data of these two methods are statistically analyzed, and the results are shown in Table 7:

| Test way | Total number | Number of shells | Hulling rate | Kernel number | Whole kernel rate |
|----------|--------------|------------------|--------------|---------------|------------------|
| Shear    | 101          | 85               | 84.16%       | 83            | 82.18%           |
| Knead    | 72           | 69               | 95.83%       | 65            | 90.28%           |

It can be seen from Table 7 that both the raking rate and the whole kernel rate are higher than that of shearing, which indicates that using the raking method can obtain relatively high raking rate and the whole kernel rate. Therefore, when designing the mechanical chestnut raking machine, the raking tool is the best choice.

4. Conclusions and discussions

Under the compression mode, the higher the moisture content, the larger the chestnut, the larger the chestnut shell breaking force, the higher the loading rate, the smaller the needed shell breaking force.

Under shear loading, the shattering force of chestnut was significantly related to the moisture content and shear rate of chestnut, but not to the size of chestnut. The regression equations of shearing force, water content and shearing rate of chestnut under specific conditions were established, and the shearing force under specific conditions could be predicted by using the equations. The crack displacement under shear loading mainly concentrates between 3.5-9.5mm.

In the rubbing mode, the force of chestnut is complex, the rubbing tensile force is mainly concentrated between 35-150N, and the rubbing displacement is concentrated between 5-17.5mm.

Among the three shelled ways, kneading has the best shelled performance, which has a high shelled rate and kernel integrity rate, followed by shearing, and compression is the worst.

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