Design of the gordon euryale seed automatic shelling machine

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Abstract: In this study, Aiming at the inefficiency of the manual shelling of Gordon Euryale seed, a new automatic seeding Sheller with simple structure and easy operation was developed to improve the efficiency. According to the shape and size of the Gordon Euryale Seed and the material characteristics of its hard shell, the mechanical structure of the machine were designed. It included the feeding mechanism, shelling device and separating device. Experiments showed that it had met the requirements of rapid shell peeling. The shell peeling rate was over 98% and the whole kernel rate was over 97.5%. It had reliable operation, fast speed and low failure.

1. Introduction
As one of the Eight Immortals in water, Gordon Euryale is commonly known as chicken head rice, and also known as ginseng in water, which is not only delicious but also has medical value. The shell of Gordon Euryale is hard and astringent and not suitable for eating, and should be peeled off when eating. At present, some existing Gordon Euryale shelling machine cannot completely shell and the pulp of Gordon Euryale is crushed. The quality of Gordon Euryale after processing is very poor, which affects the shelling amount and the taste of the Gordon Euryale. In addition, the shell is directly spilled on the ground, causing the environment of the site to be dirty, messy, poor, and very troublesome to clean up. Therefore, most growers still peel by hand. It is difficult to peel the hard shell by hand, and it takes a long time to peel the pulp, resulting in low output, high labor cost and high price [1].

In order to improve the market sales volume and reduce the price of Gordon Euryale, many experts and enterprises have conducted research on the shelling machine [2], but there are few researches on the technology of Gordon Euryale automatic shelling machine. Only Yan GU and Guanghe XIAO [3] applied for the patent of "A Gordon Euryale Shelling Machine" to peel off the surrounding and rear shells of Gordon Euryale, but the structure is complicated. Xiaoyan ZHANG [4] disclosed A Safer Peanut Shelling Machine, Xieqing XU, Honghui RAO, Tao LI [5] et al published the paper Design and Test of a Fully Automatic Lotus Seed Shelling and Peeling Machine. Mingquan LAI [6] invented A Fully Automatic Lotus Seed Cutting and Shelling Machine. Using these machines to shell and peel step by step, the operation is complicated, the sanitary conditions are poor, and the shelling quality is not high. In view of the above situation, this design proposes a shelling machine that can quickly separate the shell and the pulp without damaging the pulp of Gordon Euryale, which can achieve automatic shelling of Gordon Euryale instead of manual work.
2. Overall structure design and working principle of Gordon Euryale automatic shelling machine

2.1. Overall structural design
The overall structure of the Gordon Euryale automatic shelling machine consists of three parts: feeding device, shelling device and separating device. The feeding device is composed of a bin, a ring groove, and supporting members. The shelling device is composed of a servo lifting motor, a ring cutter holder, a ring cutter and an extrusion module. The separating device is composed of a chute, a vibrating screen, a shell box and a kernel storage box. The simple map of the overall structure is shown in Figure 1. The overall structure can be divided into upper, middle and lower layers, and the layers are connected and fixed by support frames and bolts. The uppermost layer is the bin mechanism, servo motor, and ring cutter holder lifting mechanism, and the middle layer is the ring groove, ring cutter, electric cylinder, and extrusion module mechanism; The lowermost layer is the separation mechanism, vibrating and screening net, shell box, and kernel storage box, etc..

![Figure 1. A simple map of Gordon Euryale automatic shelling machine](image)

1. Bin 2. Servo lifting motor 3. Connector 4. Ring cutter holder 5. Ring cutter 6. Gordon Euryale to be processed 7. Ring groove 8. Movable baffle 9. Fixed extrusion module 10. Chute 1 11. Vibrating screen 12. Chute 2 13. Kernel storage box 14. Shell box 15. Support frame 16. Movable extrusion module

2.2. Operating principle
The shelling of Gordon Euryale is completed in two processes. First, cut with a ring cutter, and then extrude and separate it. Wash the approximately round granular Gordon Euryale with shell (raw materials to be processed) and pour it into the bin in an even and orderly manner, start the automatic shelling machine, guide the raw material uniformly and orderly into the groove, and fix the raw material when the concave groove is filled. The servo motor drives the ring cutter holder to move down. Precisely control the cutting depth of the ring cutter, and delay for a period of time after cutting the opening. The movable baffle can be opened automatically. Drop the Gordon Euryale with shell that has been opened into the extrusion device module, which continuously separates the shell and the pulp of Gordon Euryale by extruding and kneading. The extrusion force can be detected by the pressure sensor and fed back to...
the system to adjust the extrusion pressure and speed. Finally, the separated shell and pulp are fed into
the vibrating screen through the chute, and the pulp is sent to the kernel storage box by vibration,
screening and filtration, and the shell of Gordon Euryale is separated into the shell box. Finally, the
kernel and the shell of Gordon Euryale are separated.

2.3. Analysis of physical properties of Gordon Euryale
For parameters closely related to this design, such as the geometric dimensioning, weight and shell
thickness of Gordon Euryale with shell, shell breaking force, geometric dimensioning of kernel, etc., are
calculated, providing an important basis for the structural design of the automatic shelling machine.
Take 5 specimens of Gordon Euryale with shell randomly for testing, measure the diameter of Gordon
Euryale with a vernier caliper, separate the shell by a sheller with digital display. After shelling, record
the shelling force once for each specimen, and record the size of the kernel. See Table 1 for the statistical
table.

| Table 1. Structural dimensions and mechanical properties of Gordon Euryale |
|-----------------|---|---|---|---|---|
| Parameter       | 1  | 2  | 3  | 4  | 5  | Average    |
| Shell size / mm | 20.11 | 18.52 | 19.42 | 19.54 | 20.13 | 19.544    |
| Shelling force /N| 28.52 | 24.30 | 25.43 | 24.82 | 29.21 | 26.456    |
| Kernel size /mm  | 10.01 | 9.52  | 9.96  | 9.58  | 10.12 | 9.838     |

3. Design of key parts mechanism

3.1. Design of feeding device
The feeding mechanism mainly comprises a bin, a feeding trough, a vibration device and a groove. Place
Gordon Euryale in the bin, and feed Gordon Euryale to the groove of the feeding trough through the
inclined leak hole of the bin. The eccentric mechanism vibrates to make Gordon Euryale uniformly and
orderly enter the shelling device. The gap between the leak hole and the groove is 2mm, to prevent
Gordon Euryale from being caught in the gap during the vibration when Gordon Euryale falls into the
groove.

3.2. Design of shelling device
The shelling device mainly comprises a guide trough, a ring cutter mechanism, an extrusion device, a
discharge port, etc.. Gordon Euryale reaches the bottom through the bin hopper. The sensor detects the
Gordon Euryale and turns on the vibrating motor. The Gordon Euryale is uniformly and orderly guided
into the ring groove under the action of slight vibration until the entire ring groove is filled and stops
vibration. The groove is tightened, and the Gordon Euryale is fixed by the tightening clamping force.
Under the action of the pulse signal, the servo motor controls the precise positioning of the ring cutter
to be directly above the Gordon Euryale. The ring cutter opens and rotates, and slowly approaches the
Gordon Euryale to be processed for cutting. The first process ends. The outer dimensions of the ring
groove and the center distance of the two-ring cutter are determined according to the shell size of Gordon
Euryale, which meets the requirements of shelling of Gordon Euryale. The structure diagram is shown
in Figure 2.
Figure 2. Structure diagram of the shelling device

According to the external characteristics of Gordon Euryale with shell, the sharp knife-shaped ring cutter is selected to cut the shell of Gordon Euryale. When the cutter touches the surface of the Gordon Euryale shell, the force analysis is performed, as shown in Figure 3.

Figure 3. Force analysis diagram of Gordon Euryale with shell

The positive pressure of Gordon Euryale with shell during cutting is \( F_1 = PS \), where, \( F_1 \) is the shelling pressure, \( S \) is the contact area between the cutter and the Gordon Euryale shell, and \( P \) is the compressive strength of Gordon Euryale shell. The axial force on the Gordon Euryale shell is \( T = F_1 / 2 \cot \theta \)

Where, \( T \) is the axial force exerted by the cutter on the shell, and \( \theta \) is the angle of the blade. When the positive pressure \( F_1 \) on the Gordon Euryale is greater than the critical value of \( F_2 \) (the binding force on the Gordon Euryale), the shell cracks. When the cutter moves, the axial force \( T \) shears the shell of Gordon Euryale. In order to achieve a better incision effect, the cutting force of the cutter to the Gordon Euryale shell is set to 29N and the cutting depth is set to 5mm according to the above analysis results of physical properties of Gordon Euryale.
After cutting treatment, the Gordon Euryale with shell enters the extrusion device for shell breaking treatment. The fixed extrusion module baffle is fixed, and the movable extrusion module is opened to the maximum, waiting for the Gordon Euryale after opening to fall into the extrusion area. The Gordon Euryale with shell entering into the extrusion area is taken as the object for stress analysis below. In the figure, force analysis is conducted on the eight Gordon Euryale with shell as a whole. The force diagram of the separation of the shell and the kernel is shown in Figure 3.

\[ G = F_4 \quad (G = mg) \]  
\[ F_5 = F - f_2 - F_3 - F_2 \]

Where, \( G \) is the total gravity of Gordon Euryale, \( m \) is the total mass of 8 Gordon Euryale, \( F_4 \) is the support force of the support plate to the 8 Gordon Euryale, and the two forces are a pair of equilibrium forces in the vertical direction. \( F_5 \) is the shell breaking force, \( F \) is the extrusion force of the movable extrusion module on Gordon Euryale, \( f_2 \) is the total friction force of the support plate to all Gordon Euryale, \( F_3 \) is the pressure of the fixed baffle to the Gordon Euryale with shell, \( F_2 \) is the binding force of the Gordon Euryale with shell. When \( F_5 \) is greater than 0, the shell can be separated, but to completely separate the shell and the kernel, according to the previous analysis of the shell breaking force, it has been tested that the breaking effect is optimal when \( F_5 \) is set to 28N. See Figure 4.

**Figure 4.** Force diagram of the separation of the shell and the kernel

3.3. Design of separating device
The separating device is mainly composed of a blowing port, an air flow channel, a fan, a vibrating screen, a kernel storage box, a shell box, etc. In the separation process, the shell and the pulp are separated by controlling the wind speed of the fan to generate an air flow channel according to the difference of the specific gravity and the wind receiving area between the shell and the Gordon Euryale. The specific gravity of the pulp of the Gordon Euryale is relatively large, and the wind receiving area is small, so it is not easy to be blown away by the air flow, but slides down into the vibrating screen because of its own weight. The larger shell that cannot be blown away by the fan also slides down into the vibrating screen together with the kernels. Through slight vibration, screening and filtration, the kernels of Gordon Euryale are sieved down to the kernel storage box below, and the larger shell of Gordon Euryale is sent to the shell box through chute 2.

4. Design of control system
The control system requires PLC (programmable controller) as the controller and the touch screen HMI as the upper computer to realize the control of the vibration motor, the shelling motor, the ring cutter and the fan, receive the signal of the force sensor, and control the cutting force and extrusion force after analog signal processing; The touch screen monitors the running status of each motor in real time, gives real-time feedback, displays the cutting force and extrusion force in real time, and displays fault and alarm information at the same time. The touch screen uses TPC7062KS to transmit data to PLC (programmable controller) and PC (computer) through USB data cable. Mitsubishi PLC’s GX software programming is used to achieve the control of feeding and vibration motor, start and stop of the fan, system extrusion pressure and precise positioning control of the ring cutter. PLC collects the input information of the system through various sensors, and compare the deviation between the output value and the given value after logical operation and PID algorithm, thus achieving the final control function.
5. Analysis of test results
The test result indicators are selected as: Stripping rate, kernel breaking rate, processing efficiency. The test sample is Gordon Euryale, which has a long growth period. During the test, 30 jin of raw materials are taken, and comparative analysis is conducted with the manual shelling of 5 skilled workers. This test mainly studies the two main factors: ring shear force and extrusion force. With the stripping rate and the damage rate as the test index, the stripping rate is \( \delta = \frac{(M_1 - M_2)}{M_1} \times 100\% \), where \( M_1 \) is the total mass of Gordon Euryale; \( M_2 \) is the mass of unshelled Gordon Euryale. The damage rate is \( \eta = \frac{M_3}{M_4} \times 100\% \), where, \( M_3 \) is the mass of the kernels of Gordon Euryale that has been shelled; \( M_4 \) is the mass of damaged kernels. At present, the standard stripping rate of the shelling machine industry is \( \geq 98.00\% \), and the damage rate is \( \leq 4.50\% \) [7]. Add 15kg of Gordon Euryale each time, and weigh the mass of the shelled kernels, the mass of the unshelled and the mass of the damaged kernels. According to the analysis of test results [8], the processing speed of the automatic shelling machine is 60kg per hour, the stripping rate is above 98%, the rate of perfect kernel is above 97.5%, the unshelling rate is below 2%, the kernel breaking rate is below 2.5%, the processing quality and the manual shelling quality is the same, the cleanliness of the processing environment is even higher than manual shelling, the processing efficiency is nearly 20 times faster than manual processing. The machine is relatively small, easy to maintain, long life, easy to carry and change the site, which is suitable for family farmers to purchase and use.

6. Conclusions
A fully automatic Gordon Euryale shelling machine [9] has been developed. The shelling machine has a reasonable structure, simple shape, easy to carry, and suitable for family use. Key technology: the shelling rate of Gordon Euryale is over 98%, and the kernel breaking rate is below 2.5%. The quality of processed kernels is the same as that of manual shelling. There is no damage and raw material waste. This device can completely replace manual shelling, with reliable work and low cost, and is favored by growers [10].

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