Research on the key design and application of the device of opening cover and ring cutting and digging flesh of Mandari

Weichao Tan¹

¹Jiangmen Polytechnic, Jiangmen, Guangdong, 529090, China
*Corresponding author’s e-mail: 2111170107@email.szu.edu.cn

Abstract. Aiming at the problems of low efficiency and poor sanitation of manual cover opening and meat digging in the production of common orange tea, a multi station full-automatic meat digging machine for common orange tea is designed to realize the automatic cover opening and pulp separation device of green orange, so as to meet the production of common orange tea in Xinhui District of Jiangmen. The mechanism of peel stress and pulp separation damage of green citrus in the process of mechanical meat digging was studied. The state of peel contact deformation area of green Citrus under the extrusion of meat digging knife was analyzed by simulation, and the structural and operating parameters of de jacking and opening mechanism and meat digging mechanism were optimized. When the extrusion force was less than 35.6n, the peel damage rate could be minimized. Compared with manual operation, it reduces labor cost and production cost, saves processing time, and realizes automatic and rapid production.

1. Introduction

Citrus tea is a popular local specialty tea in Guangdong in recent years. According to the classification of Citrus tea, there are citrus embryo and green citrus in the market. Manual production process of Citrus tea: when making citrus tea, merchants make different types of Citrus tea according to the maturity of citrus fruit. First, We can put the citrus fruit in the citrus fruit cleaning tank for cleaning, open the cover on the top of green citrus, manually remove the pulp inside the citrus fruit, dig out all the internal pulp, and finally complete the cleaning process [1]. Most of the orange tea in Jiangmen is made manually, the meat removal efficiency is low, and the peel damage rate is as high as about 20%. At present, the domestic citrus meat digging machine mainly has the following two processes: the first is to cut the hole through the ring; the second is through the high-speed rotation of the cutter in the citrus hole and the high-speed collision between the cutter and the citrus peel. There are common problems such as high citrus peel damage rate and pulp residue, which requires manual secondary meat digging treatment, which increases the production cost. Based on this situation, an automatic capping and pulp separation device for green citrus was designed to meet the production of Citrus common tea in Xinhui District, Jiangmen. Taking this equipment as the research object, the separation mechanism of green citrus peel and pulp in the process of mechanical meat digging was studied, and the structural and operating parameters of the top opening mechanism and meat digging mechanism were optimized [2-5].
2. Overall scheme design

2.1 Overall structure design

The overall structure is mainly composed of rotary table mechanism, pressure plate mechanism, tool rest mechanism and air blowing mechanism. The rotary table is divided into four stations: loading, opening, meat digging and reclaiming. The citrus fruit rotating plate is divided into four groups. The rotary table is equipped with 30 citrus fruit seats, with eight stations in each group.

Working principle: put eight green oranges into the green oranges silica gel seat 4 at the loading station, start the servo motor 8 under the turntable and rotate it 90 degrees counterclockwise. After the green oranges reach the opening area, the green oranges pressing plate 3 presses down: the pressing plate moves down and presses and fixes the oranges through the orange fruit pressing seat, and the cover opening knife 9 moves up with the tool holder disc 5, extends into the orange fruit placing seat 4 and inserts them into the orange fruit, and rotate to realize the opening of the citrus fruit, take away part of the excess meat while withdrawing the knife, and the pulp is discharged from the discharge slope of the knife edge. Then, the cover opening knife 9 moves down from the citrus fruit placement seat 4 with the knife rest disc 5, the rotary table 2 drives the citrus fruit to continue to rotate above the meat digging knife 10, the meat digging knife 10 moves up with the knife rest disc 5, extends into the citrus fruit placement seat, inserts into the citrus fruit and rotates at a high speed, and the high-pressure gas is blown out from the air outlet, so as to blow down the pulp connected in the citrus fruit shell to complete the meat digging step. The meat digging knife moves down, and the rotary table continues to rotate to the next station, which can realize the automatic operation of citrus fruit opening and meat digging. Multiple citrus fruits can be operated at the same time, which has high production efficiency and reduces the production cost.
2.2 design of de jacking and opening mechanism

The size of green citrus is basically different, the shape difference is not particularly large, and it is ellipsoidal. The topping and capping mechanism is an important structure in the green citrus meat digging equipment. The purpose of topping and capping is to remove the top part of the green citrus peel and realize the opening, which plays a decisive role in the subsequent meat digging process and has an important impact on the flesh peeling rate and peel damage rate of the green citrus. This process has the relative movement of the cutter and the green orange. There are two main methods: one is that the cutter does not move and the green orange rotates driven by the mechanism; Second, the green orange does not move and the tool rotates. In this scheme, a special orange tank is used to fix the green orange, and the cover opener rotates to cut off the top peel of the green orange, so as to realize the opening [6-9].

On the premise of the same rotating speed, the tooth shape of the knife edge affects the opening effect of green citrus, and the sliding cutting angle of the triangular inclined knife shape $\alpha$ and blade inclination $\beta$ equal ($\alpha=\beta$), In the process of opening the cover, the sliding cutting angle changes evenly, and a constant size notch can be effectively obtained. Therefore, the inclined knife shape shown in Figure 4 is adopted in this design scheme.

![Figure 3. Analysis of the opening edge](image)

![Figure 4 Principle of removing top and opening cover](image)

Working principle: when the citrus fruit rotates to the top of the capping knife, the upper capping
pressure plate pushes the clamping cover to fix and position the green citrus, the capping knife is embedded in the green citrus peel, the capping knife moves down with the knife rest plate, extends into the citrus fruit placement seat, inserts into the citrus fruit and starts to rotate, so as to realize the opening of the citrus fruit. The capping pressure plate plays the role of fixing the blade and installing the ejector rod. The silica gel seat and material clamping cover of citrus fruit have certain elasticity, which can adapt to green citrus with little change in height and size. When the knife is retracted, part of the excess meat is taken away, and the pulp is discharged from the discharge slope of the knife edge.

2.3 meat digging mechanism design
The knife rest is composed of eight open knives and eight meat digging knives, which are driven by a group of reduction motors through transmission large gears, and the rise and fall of the knife rest is realized by three cylinders. When the green orange rotates to the meat digging area, the meat digging pressure plate compresses the green orange, the main blade of the meat digging is clamped into the green orange pulp, the driving motor under the rotary pressure plate starts, the meat digging knife starts to rotate at the same time, and the air cylinder is pushed up by the knife holder to send the meat digging knife to the green orange for meat digging. The meat digging main blade rotates 360 degrees, and a high-speed blow hole is set in the main blade. The high-pressure gas enters from the air inlet and then is discharged from the high-pressure air outlet smaller than the air inlet. At the same time, it rotates driven by the gear to push the excess pulp inside the green orange out of the green orange hole. In the pushing process, because the diameter of the opening knife is larger than that of the meat digging knife, it is blown out from the air outlet, so as to blow the pulp connected between the orange shell and the inner wall off. Therefore, it is convenient to discharge the remaining pulp from the opening below. When the upper push cylinder of the knife rest drops to the lower limit, the knife rest is parallel to the waste groove of the shell, the high-pressure air pipe supplies air, and the high-pressure air groove blows high-pressure gas around to blow the excess pulp residue falling on the knife rest into the waste groove of the shell.

![Figure 5 Principle of digging meat](image)

When the work is completed, the pushing cylinder on the tool holder drops to the lower limit, and the green orange pressing cylinder rises to the limit. In the whole process, the continuous rotation of the meat digging knife can reduce the resistance of the meat digging knife, and the assembly line operation can make the meat digging more thorough and improve the processing efficiency.
3. Analysis of stress characteristics of green Citrus

In this experiment, the small green citrus produced in Xinhui Area of Jiangmen from August to September was used. The fruit transverse diameter was between 20-30mm and the quality of green citrus was between 30-50g. According to the principle of the meat digging mechanism, the cover opening pressure plate pushes the clamping cover to fix and position the green orange. The direction of the force is parallel to the radial direction of the small green orange. The force of the cover opening pressure plate is perpendicular to the opening of the small green orange. The cover opening pressure plate compresses the small green orange radially. The force change of the green orange is shown in Figure 6.

![Figure 6. Change chart of stress of Mandarin](image)

The total deformation $D$ of green citrus at the contact point when squeezed by the open cover pressure plate is obtained from the Hertz theory of elasticity

$$D = \left[ \frac{9}{16} \cdot \frac{R_1 + R_2}{R_1 R_2} \left( \frac{1 - \mu_1^2}{E_1} + \frac{1 - \mu_2^2}{E_2} \right) \right] \frac{F}{q_0}$$

(1)

$$q_0 = 0.918 \frac{C^2}{D^2}$$

(2)

Where: $E_1$ and $E_2$ are the elastic modulus of cover opening pressure plate and silica gel seat respectively; $\mu_1$ and $\mu_2$ is the Poisson's ratio of cover opening pressure plate and silica gel seat respectively, the maximum radius of curvature of $R_1$ and $R_2$ at the contact position, $C$ is the comprehensive elastic constant value, and $F$ is the contact load.

The yield point of green citrus is between elastic deformation and plastic deformation. According to the characteristics of elastic deformation stage, the stress mechanism of green citrus peel is analyzed, and the yield limit of green citrus is calculated with the above formula. As shown in Table 1, the relationship between total deformation $D$, contact load $F$ and peel damage at the contact position can be analyzed.
4. finite element analysis of green citrus peel stress damage in order to study the peel damage.

The peel stress is analyzed. The peel is mainly squeezed by the fruit cover and the meat digging knife. The blowing pressure, pore diameter and rotation speed of the meat digging knife affect the integrity and damage of the peel. When the green citrus is in contact with the equipment parts, the elastic modulus of equipment components is greater than that of green citrus. The extrusion effect of fruit cover and meat digging knife on green citrus is simplified. The loading load of the model is between 20-100n. The maximum stress and displacement of peel are obtained through analysis. From the displacement nephogram, the maximum displacement is 9.260mm, and the displacement is at the bottom of the lower cover. From the model stress nephogram, the maximum stress of 0.03757mpa is located on the vertical pole.

The squeezing force of the fruit cover and the meat digging knife on the green orange simplifies the stress applied by the upper and lower surfaces at the same time. Here, the upper part of the top cover is set as a fixed constraint, the inner cylindrical surface of the green orange is set to move only along the axial and radial direction, the cylindrical surface of the lower cover is set to move only along the axial direction, and the cylindrical surface of the column is set to move only along the axial direction. The improved Lagrangian algorithm is selected, and the contact condition is surface contact. Considering that Qinggan is a circular fixture, it may not be stable, soft spring is used to stabilize it.
When the initial stress is small, the contact between peel, fruit cover and meat digging knife is line to surface contact. When the extrusion force gradually increases, the contact becomes surface to surface contact. When the stress intensity of green citrus reaches the compressive limit of green citrus, there is damage, as shown in Figure 8. The damage area is indicated in red. It can be seen that the bottom of green citrus is damaged or even broken under the condition of large load of meat digging knife. As shown in Table 1, when the extrusion force $F < 35.6n$, the pericarp of green citrus is basically undamaged.

### Table 1 Finite element analysis of peel damage of Mandarin

| Extrusion force (N) | Internal stress change (Mpa) | Damage of green Citrus |
|---------------------|------------------------------|------------------------|
| $F<35.6$            | Vonmises$<0.085$              | No damage              |
| $F\geq35.6$        | Vonmises$\geq0.508$          | Peel damage            |

### 5. conclusion

The project innovatively designs the key mechanical parts of the citrus tea machine, designs a more reasonable topping and opening mechanism and meat digging mechanism, adopts oblique tooth cover opening knife and special meat digging knife, and establishes the corresponding green citrus peel damage finite element model on the developed machine. When the extrusion force $F < 35.6n$, the green citrus peel will not be damaged. Combined with the finite element analysis, The peel damage model was verified. The success rate of flesh digging was more than 94%, and the peel damage rate was only about 5%. The research of this project provides a theoretical basis and reference for the research and development of peel and pulp stripping equipment in green citrus processing industry, and improves the success rate of Citrus general tea.

For the future outlook, it is necessary to improve the effect of cover opening and meat digging, reduce the damage to the peel, optimize the cover opening device and meat taking device, increase the citrus fruit cleaning device, reduce the use of gas and reduce energy consumption in the later stage, and meet the development concept of green and low-carbon in the world.

### References

[1] Zheng YY, Guo F. (2018) study on HPLC fingerprint of Xinhui Mandarin tea [J]. Zhongnan pharmacy, 16 (06): 721-725
[2] Chen H, Yu B. (2015) optimization of process parameters of roll peeling device of wide skinned citrus peeler [J]. Journal of agricultural engineering, 31 (04): 293-298
[3] Pan HB, Wang ZY. (2015) design and test of wide skinned citrus double roller peeling machine [J]. Journal of agricultural engineering, 31 (12): 239-245
[4] Tang SX, Tan Q, Liang GE. (2019) development of a new efficient and energy-saving automatic meat extractor for Mandarin tea [J]. Modern manufacturing technology and equipment, 08:29-30
[5] Yue DH, Tu Q, Wu HT. (2019) design and control parameter optimization of Citrus peeler [J]. Food and machinery, 35 (06): 100-103 + 107
[6] Huo YL, Zhang LY. (2018) design of automatic rotary citrus mechanical picker [J]. Internal combustion engine and accessories, 11:24-25
[7] Zhang SB, Chen L. (2012) study on mechanical characteristics of Citrus Based on robot picking [J]. Journal of Zhejiang University of technology, 40 (03): 340-344
[8] Chen Y, Wang JH. (2016) finite element prediction and experimental verification of Citrus robot clamping damage [J]. Journal of South China Agricultural University, 37 (05): 98-102
[9] Fan DF, Chen H. (2016) design and test of topping and ring cutting device of wide peel citrus peeler [J]. Journal of Hunan Agricultural University, 42 (06): 686-692