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Microscopic Structures Analysis and Experimental Research of Beak

X. Li*, K. Wu, Y. Ma

College of Agricultural Engineering, Henan University of Science and Technology, Luoyang, China

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ABSTRACT

To reveal the mechanism of the easy discretization and low damage in kernel dispersal, this paper analyzes the microscopic analysis of beak structures and finds that maxillary outside cells of the beak are dense and hard. Besides, the cuticle wrapping on maxilla of chicken's beak can reduce corn kernels damage in the discrete process of corn ear. From force test of corn ear, we found that value of x direction is the maximum, second is the y direction, and the value of z direction is the minimum. With reducing of water rate, the forces in three directions all decline. A 3D scanner is used to collect point-cloud data of rooster beak. Based on the point-cloud data, a roller is designed. Then the working process of discrete roller is analyzed. This research can provide a discussion for developing a corn thresher.

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1. INTRODUCTION

Corn is an important product in China. Since corn harvest mechanization had a late start, its development is relatively backward [1-3]. Corn threshing mainly involves impacting, kneading, brushing, rolling, and squeeze rubbing, among other processes. At present, corn sheller mainly uses impact principle to achieve the threshing task during harvest [4-6]. Although impact thresher has a merit of easy and low cost, it causes serious damage to corn kernels in the process of threshing. Damaged kernels not only influence the storage period, but also decrease the activity of seeds, thereby affect germination percentage of seeds. Therefore, studying low damage threshing of corn seeds has great economic and social benefits.

Bionic technology is currently widely applied in many different fields [7-12]. Some studies showed that creatures can adapt to their environment well after a long evolution. During the long evolution process, we found that rooster beak has developed an excellent ability to insert space between corn kernels. Moreover, the beak can efficiently disperse kernels with low damage. Beak pecks corn seed quickly, and in the process, it has forces on corn ear in different directions. By studying beak structure and forces of the beak, the mechanism of beak dispersing corn ear is revealed [13, 14].

In this paper, bone tissue microscopic characteristics of beak were analyzed [15, 16]. Then a 3D scanner was employed to collect external contour data of a rooster beak. The mechanism of rooster beak characterized by easy dispersion and low damage was discussed. Based on this principle, a discrete roller was designed. This paper has practical implication for developing a corn bionic thresher.

2. MICROSCOPIC ANALYSIS OF BEAK STRUCTURES

2. 1. Structure Characteristics of Beak Rooster beak is equivalent to a mammalian lip, which includes maxilla and mandible. The beak consists of two parts, namely, the bone portion and skin-derived cuticle. The bone portion contains 38.7% protein and 20.7% fat. The cuticle, which is mainly composed of 93.32% protein, is the outer sheath that protects the beak. The cuticle enwraps the maxilla and mandible. The beak is pyramidal and hard.

*Corresponding Author's Email: *aaalxp@126.com* (X. Li)

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The maxillary squeezes the kernels when the beak pecks a corn ear. The mandible shovels the kernels, which are then dispersed. The separation of kernels is mainly caused by the maxilla. Figure 1 shows the structure of a rooster beak. This paper mainly analyzed the microscopic structures of maxilla.

2. 2. The Process of Microscopic Analysis Through making horizontal and vertical tissue sections of beak, the arrangement characteristics of bone tissue cells was observed with microscopic analysis. The key to observe bone tissue cells is to make sections, whose quality will directly affect the results. The following steps are to make tissue sections;

- ❖ In order to facilitate observation, maxilla of the beak is fixed for 24 h by using FAA fixatives, whose role is to kill and fix cells.
- ❖ Tissue sections are placed through all night after washing. To avoid cells deformation caused by large dehydration, alcohol is used for gradient dehydration.
- ❖ In order to facilitate making tissue sections, paraffin is used to embed the tissue. LEICA BM2016 slicer is used for tissue sections, and slice thickness is set to 9 micrometer.
- ❖ Tissue sections are dyed, and then dried for 24h.

The process of making tissue sections is finished. Then use OLYMPUS CX31 microscope to observe tissue sections. Observation system is shown in Figure 2.

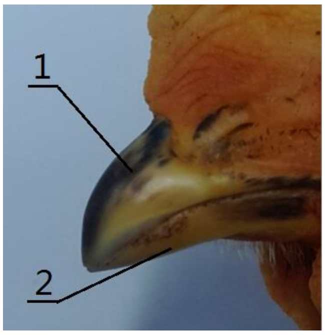
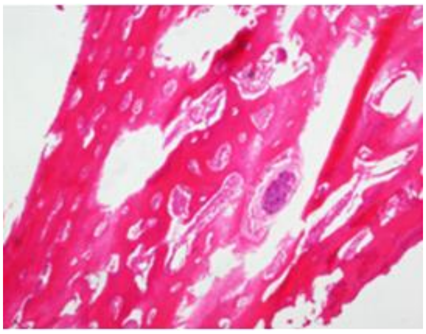


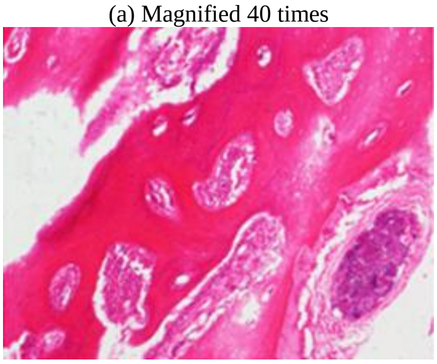
Figure 1. Structure of rooster beak, 1) Maxilla, 2) Mandible

Figure 2. Microscope system

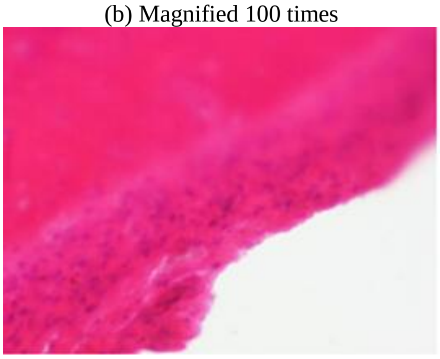
The maxillary tissue transverse section of beak is shown in Figure 3. Figure 3(a) shows the 40 times magnified tissue. From the whole photo, the maxilla is similar to skull of poultry. The maxilla contains air cavity, and connects to the nasopharynx. From Figure 3(c), it can be seen that the outside cells of maxilla are dense and compact.



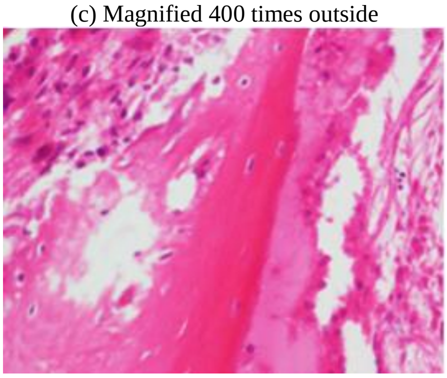
(a) Magnified 40 times



(b) Magnified 100 times



(c) Magnified 400 times outside



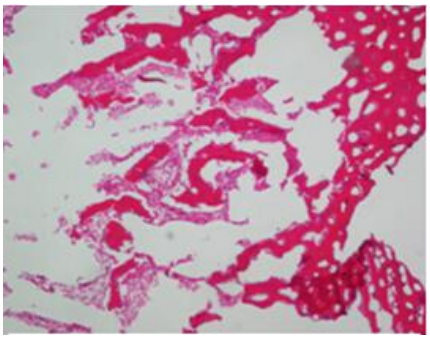
(d) Central magnified 400 times

Figure 3. Transverse section of maxilla

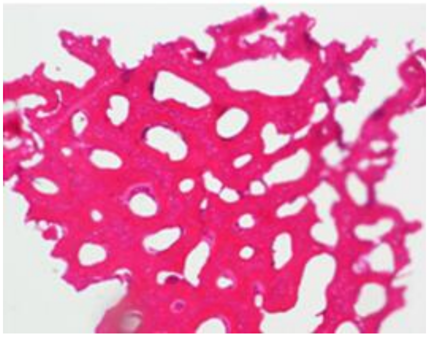
Figure 3(d) shows that the central cells of maxilla are loose. Maxillary air cavity reduces the weight of the beak and arrangement characteristic of dense outside cells and loose central cells not only increase the intensity but also absorb a certain impact to protect the beak during pecking corn ear kernels. The cuticle wrapping on maxilla of chicken's beak has a certain flexibility, which can reduce corn kernels damage in the discrete process of ear.

The maxillary tissue longitudinal section of beak is shown in Figure 4. Compared with Figure 3 (a), the arrangement of maxillary longitudinal tissue are looser than that of horizontal cells, however, the outside cells are relatively tight, as shown in Figure 4(d). Maxillary longitudinal air cavity system of beak is more obvious.

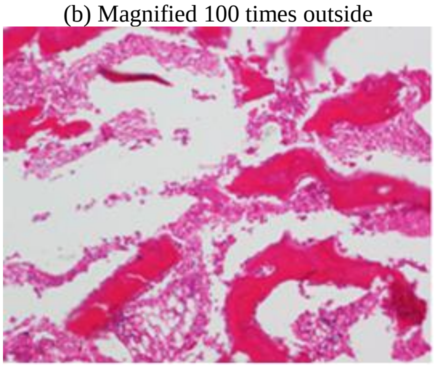
On the basis of transverse and longitudinal slices, we can presume that maxillary outside cells of the beak are dense and hard. The maxilla contains large amounts of air cavities, and mainly distributes along its longitude.



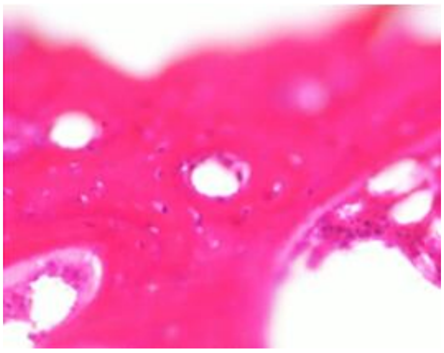
(a) Magnified 40 times



(b) Magnified 100 times outside



(c) Central magnified 100 times



(d) Magnified 400 times outside

Figure 4. Longitudinal section of maxilla

3. FORCE TEST ANALYSIS OF CORN EAR

3. 1. Experimental Devices and Experimental Methods

In the process of beak dispersing corn ear, due to the short impact of beak, the force measurement is a short-term dynamic measurement process. Transient impact sensors can achieve dynamic force measurement. Sensor principle is that impact can be converted into an electrical signal through the corresponding measurement circuit. Then the electrical signal is transmitted to the high-speed measurement and analysis instrument. The instrument will output standard analog signal that is easy to collect by signal conditioners, and then through the AD module, voltage is converted to a digital signal, and communicate with a computer through USB2.0 high speed interface, thereby achieving the collection of instant force. Based on this principle, a test-bed is designed. The structure of test-bed is shown in Figure 5.

Dent Zhengdan 958 (dent corn), which is widely grown in Henan Province, is selected as an experimental material; 5 water classifications in total. Corn ear is fixed on the fixture. The sensor system is installed and debugged, the distance between the test-bed and the cage is adjusted, then the force test software is opened, and force values in three directions of x, y, z during discrete process are noted.

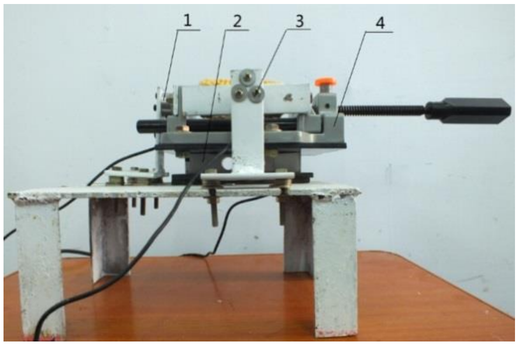


Figure 5. Structure of test-bed, 1) Sensor 1, 2) Sensor 2 3) Sensor 3 and 4) Fixture

Cartesian coordinate system is established based on the right-hand rule. Sensor in horizontal direction of fixture is set as x direction, longitudinal direction is set as y direction, and sensor below the fixture is set as the z direction.

3. 2. Experiment Analysis The test results of beak dispersing corn ear are recorded, as shown in Table 1.

From Table 1, with reduction of water rate, the forces in three directions all decline. The reason is that due to the natural drying of corn ear, moisture rate of kernels declines, and connection between corn kernels and fruit stalk becomes brittleness and the connection force reduces. The squeeze pressure between kernels also decreases with the reduction of moisture rate. Therefore, the smaller moisture content of corn ear, the less force is required for dispersing corn ear.

Under the same corn variety and moisture rate, value of x direction is maximum, second is in the y direction, and the value of z direction is minimum. This shows that force in x direction plays an important role during beak dispersing corn ear. This also means that in the discrete process, through inserting force perpendicular to the gap between kernels, beak has a push force on kernels. The gap will increase, and kernels are easier to be dispersed. The y direction, which is the longitudinal axis of corn ear, still shows large value. Except the main force of x direction, there still has axial push forces on kernels of corn ear, whose main role is to expand the axial gap between kernels and facilitate dispersing. The minimum force is in the z direction, which primarily destroys connection between kernels and fruit stalks. These characteristics are conducive to disperse corn ear with low damage.

The x direction is the major force for dispersing corn ear, so by selection of the moisture content, force value in the x direction is used to fit equation. Its first derivative is solved and the result is shown in Figure 6. The first derivative represents the change degree of force with moisture content.

From Figure 6, the first derivative of x value curve first increases and then decreases with decreasing of water rate, which suggests that the change speed of Zhengdan 958 corn ear in x direction first increases and then decreases.

TABLE 1. Force value statistics of Zhengdan 958

Sensor	Moisture rate				
	25.0	20.7	16.5	13.0	9.2
X	23.81	21.95	14.11	5.00	5.21
Y	5.10	2.65	4.90	2.25	2.68
Z	2.25	1.96	2.06	1.37	1.18

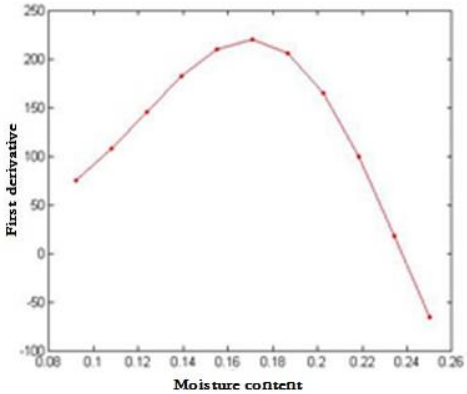


Figure 6. First derivative of x direction force value curve

4. DESIGN OF DISCRETE ROLLER

Point-cloud data of a rooster beak (Figure 7) were collected with a Handy SCAN 3D-handheld scanner (Creaform). A 3D model of the rooster beak was reversed based on the point-cloud data, which was planned to design a discrete unit. This paper reports a 3D model of a discrete roller, as shown in Figures 8 and 9, based on the discrete unit. A discrete roller is then designed. The maximum diameter and length of the discrete roller is 180 and 242 mm, respectively. The widths of two concave surfaces used to decorate the discrete units are both 53 mm. By considering the factors of optimal discrete effect and processing, 12 rows of discrete units are arranged along the discrete roller circumference and intervals of 2 or 3 discrete units are arranged alternately in each row.

The working process is shown in Figure 10. At the beginning of the test, corn ear entered the discrete space formed by the discrete and differential rollers. This part of the differential roller was bare, which mainly supported and pushed the corn ear. The discrete roller then destroyed the arrangement rule between kernels of the entire corn ear, thereby dispersing corn kernels.

Figure 7. Point-cloud data of rooster break

Figure 8. Discrete unit

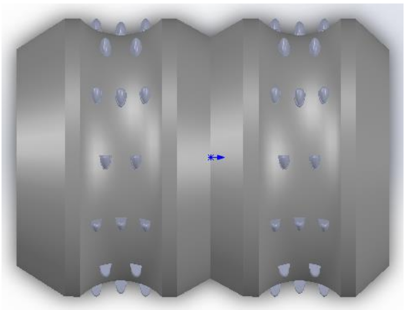


Figure 9. 3D model of discrete roller

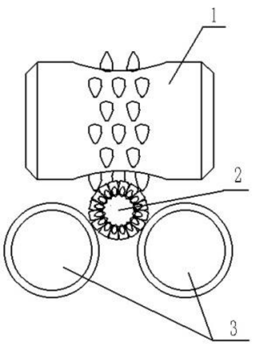


Figure 10. Working process of discrete roller, 1) Discrete roller, 2) corn ear and 3) differential roller

An experiment was conducted on the discrete test-bed to verify the effect of discrete roller. Zhengdan 958 is selected as corn variety, and the moisture content is 11.8%. Optimal parameters were determined as discrete roller speed of 250 rev min^{-1}, and differential roller speed of 100 rev min^{-1}. Experiment with optimum parameters was conducted. The experiment results are shown in Table 2.

Table 2 shows that the average discrete and damage rates of corn ear were 65.71% and 0.17%, respectively. Thus, the discrete effect is better with low damage rate, and corn kernels were loosened after dispersion, which provided the basis for further full threshing. Meanwhile, the results indicated that the geometrical characteristics of beak are suitable for dispersing corn ear.

TABLE 2. Experiment results

Number	Damage rate	Discrete rate
1	0.15	68.56
2	0.13	65.32
3	0.12	63.25

5. CONCLUSIONS

Through microscopic analysis of beak structures, we found that maxillary outside cells of the beak are dense and hard. The maxilla contains large amounts of air cavities, and mainly distribute along its longitude.

Force test of corn ear shows that value of x direction is the maximum, second is the y direction, and the value of z direction is the minimum. With reducing of water rate, the forces in three directions all decline. These characteristics are conducive to disperse corn ear with low damage.

Experimental results show that discrete roller has better discrete effect on corn ear with low damage, and the geometric structure of rooster beak is suitable for dispersing corn kernels from cobs.

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چکیده

برای نشان دادن مکانیسم گسسته‌سازی آسان و کم آسیب در پراکندگی هسته، این مقاله به تحلیل تجزیه و تحلیل میکروسکوپی سازه منقار می‌پردازد و در می‌یابد که سلول های خارج فک بالای منقار متراکم و سخت است. علاوه بر این، پوشاندن پوسته در فک بالای منقار مرغ می تواند آسیب به دانه های ذرت را کاهش دهد. از تست نیروی سنبله ذرت متوجه شدیم که نیروی جهت x حداکثر است، دوم در جهت y، و مقدار جهت z حداقل است. با کاهش نرخ آب، نیروها در هر سه جهت کاهش می‌یابد. از یک اسکنر ۳ بعدی برای جمع آوری داده های نقطه ابری از منقار خروس استفاده می شود. بر اساس داده های نقطه ابر، یک غلتک طراحی شده است. پس از آن روند کاری غلتک گسسته تحلیل می شود. این تحقیق می تواند زمینه سازی مبحثی برای توسعه یک خرمن کوب ذرت فراهم کند.

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