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## **The Study on Technologies and Practical Application of the Green Storage of Corn**

### **Abstract**

Corn plays an important role in the world grain production and consumption, for which the proper storage would provide a strong guarantee on food security of a region, a country or even the whole world. This article gives a brief overview on the present research and development of the green storage of corn in China, investigates the application of green storage technologies in warehousing operation and puts forward the realization of efficient, green and scientific grain storage by means of green storage technologies.

**Key Words:** Corn; Green Storage; Internal Circulation temperature controlling technology

The people are the foundation of the country, and the grain is the people's life. (The State Council Information Office of the People's Republic of China, 2019) Food bears on the well-being of the country and people's livelihood, and food security is an important foundation for national security. China has put forward to improve the way to ensure national food security by focusing on "sustainable farmland use, agricultural technology innovation, and storage among the people". (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2023)

Corn is one of the most important grain and cash crops in China. It not only ensures food supply, but also serves as an important feed and industrial raw material. In 2022, China's corn output reached 277.2 billion kilograms, an increase of 4.65 billion kilograms over 2021, or a year-on-year increase of 1.7 percent. (Wang, G., 2023) The increase in corn production undoubtedly raises the requirement for grain storage. Compared with wheat, the market price of corn is more volatile, so it is of great macro significance to keep a certain amount of corn reserve to effectively respond to market changes and stabilize prices. The embryo part of corn is large and the fat content is high, which increases the risk of moisture and heat transfer and make it susceptible to pests and mold infection. (Peng, J., et al., 2016) Therefore, it is urgent to develop green storage technologies to avoid the deterioration and pests, ensure the quality of storage corn and reduce storage waste.

In this paper, the green storage of food refers to the use of science and technologies (especially low energy consumption, high efficiency, no pollution technologies) in the process of food storage, the use of effective ecological means to avoid chemical pollution, reduce the damage caused by pests, mildew and other food quality and quantity consumption, in order to meet the public's demand for food products with no pollution and high nutritional value. The researcher chooses

corn as the research object. The current corn green storage technologies and practice were investigated and studied, and its development prospects were analyzed and prospected, in order to ensure the national food security in corn storage.

## **1 The green storage technologies of corns**

Corn grains themselves contain high water content, which makes them susceptible to pests and mildew during storage. Compared with wheat, rice and other crops, corn has more stringent storage conditions.

### **1.1 Ventilation technology for reducing moisture content**

The moisture content of corn grains is high. If the humidity of storage environment is not properly controlled, it will easily lead to mildew of corn grains. At the same time, the increase of humidity also enhances the respiration of corn grains, accelerates the consumption of nutrients, and damages the edible quality of corn.

The corns should be ventilated during warehousing and storage. Horizontal ventilation technology of cottage warehouse is widely used at present, that is, ventilation pipes are set up on both sides of the eaves wall of the granary, and pressure difference is made by the machine to make the air flow through the grain pile. (Zhang, Y., 2019) This technology can effectively improve the efficiency of mechanical operation, reduce labor intensity, energy consumption and grain storage loss, but there are also some problems. For instance, it's inconvenient to deal with abnormal situations- like when temperature is higher than usual and needs to be checked by the conservator- and it's difficult to deal with high moisture grain storage, which is a technology limitation.

### **1.2 Temperature controlling technologies**

Temperature is an important factor affecting the storage quality of corn. Especially in summer, the room temperature in northern China reaches 25°C~30°C, which provides favorable conditions for the survival of penicillium and other molds. Therefore, it is necessary to maintain the low temperature in the granary to inhibit the growth of bacteria.

Temperature controlling technologies often take many forms or are used in combination with other technologies. Guo Xu et al.(2022) compared the advantages and disadvantages of using air conditioning temperature controlling technology, “air conditioning temperature controlling technology + internal circulation temperature controlling technology” and “air conditioning temperature controlling technology + nitrogen gas regulation technology” in eastern Henan Province, and believed that the integrated application of air conditioning temperature controlling technology and internal circulation temperature controlling technology could have a good effect in temperature controlling and significantly reduce energy consumption. These technologies combine corn storage with intelligent system application, and effectively achieve “sci-tech grain storage”, which take an advantage of the rapid development of the technologies and studies in agriculture, biology and chemistry fields.

#### **1.2.1 Air conditioning temperature controlling technology**

Air conditioning temperature controlling technology is a commonly used temperature controlling

technology, that is, air conditioning refrigeration equipment is placed in the granary, which is opened or closed at regular intervals to control grain temperature and warehouse temperature. This technology is more conventional and is mostly used in southern areas in China, where the environment is of high temperature and humidity. However, the energy consumption is large, which leads to the concern on resource conservation and environment protection.

### 1.2.2 Internal circulation temperature controlling technology

The internal circulation temperature controlling technology refers to the technology which contains the storage of cold sources in winter to reduce grain temperature, and the use of low-power fans in summer to draw out the cold air inside the grain pile from the vent and send it to the storage space through the insulation air pipe to effectively reduce the temperature gradient of the warehouse and grain pile. It is considered environmental-friendly because it reduces the costs and energy consumption of air conditioning by making use of the seasonal weather conditions.

## 1.3 Isolation technologies

In this paper, it is considered that the technology (such as nitrogen gas regulation technology) that can isolate grains from normal environment, create a special and stable storage environment, comprehensively control temperature, moisture, pests and other factors, and have significant advantages in quality and preservation, belongs to the isolation technology.

### 1.3.1 Grain surface capping technology

Grain surface capping technology, that is, cold air bag, heat insulation board, rice husk are covered on the surface of each grain layer, which can effectively slow down the air and grain piles' heat and humidity exchange, thus reducing grain temperature significantly, which is more common in hot and humid areas. It is considered the one of the simple and effective methods.

### 1.3.2 Nitrogen gas regulation technology

Nitrogen gas regulation technology refers to the technology to fill high purity nitrogen into the granary in order to isolate oxygen and thus slow down the deterioration of corns and eliminate pests. Wang Yusheng et al. (2017) studied the effect of nitrogen gas regulation technology on corn quality, and concluded that nitrogen gas regulation storage could effectively delay the change rate of grain quality and prevent grain pests and mold. However, maintaining high concentration nitrogen filling in grain silos will increase storage costs, so optimizing this technology to reduce costs has become one of the current research directions.

## **2 Application practice of corn green storage technology**

### 2.1 Basic information of granary

The research warehouse belongs to Central Reserve Grain Xingtai Direct Warehouse Co., LTD., located in Xingtai, Hebei Province, China (belonging to the Huang-Huai-hai summer corn planting area). It is a tall bungalow warehouse with a designed capacity of 6,100 tons and a building area of 1,479 square meters. The researcher chooses to take the Central Direct Warehouse as a sample because it shows the standards and the general situation of corn storage in Hebei, making the research more representative.

## 2.2 Corn green storage process and practice

### 2.2.1 Scattered corn storage after harvest

After harvest, the corn is preliminarily treated by the farmers, and then uniformly received by the villagers for threshing, airing and other operations, waiting for storage warehouse procurement. At this time, the grain precipitation degree is low and the precipitation is uneven, which make it easy to be attacked by pests.

Promoting the popularization of scientific and rational grain storage technology in rural areas can effectively improve the quality of corn and facilitate the storage of grain in reserve warehouses. In the current situation, the reserve needs to strictly screen the corn applied for storage to avoid the loss of grain storage.

### 2.2.2 Corn checking before storage



**Figure 1 Grain warehousing inspection station**

After the initial treatment, the grain is sent to the storage warehouse for inspection. Preparation for warehousing includes: designating warehousing plan, emptying storage capacity, clearing empty warehouse equipment, accepting empty warehouse, inspecting equipment, verifying measuring instruments, determining acquisition standard, etc. A fixed sampler (as shown in Figure 2) is used to sample the grains (27 sampling points in total). The samples are passed through the grain suction pipe to the inspection department for sample numbering and sampling record.



**Figure 2 Prototype of the fixed sampler**

The laboratory inspects the sample and carries out all kinds of screening in accordance with the national standards (as shown in Table 1 below). The qualified corns will be checked for weight, sampled for quality at warehousing, and delivered to warehousing after passing the inspection.

The steps above are one of the most important parts of corn storage as it makes sure the corns coming into storage are of average quality so that the process of keeping them in the granary would be easier to be accessed. Good quality means longer storage time and more diverse uses after the corns are sold out of the granary, which will provide more economical benefits for not only the company but also the whole industry while safeguarding the national food security, as the indexes still meet the standard for feedstuff or industrial raw materials, etc.

**Table 1 Quality index of corn**

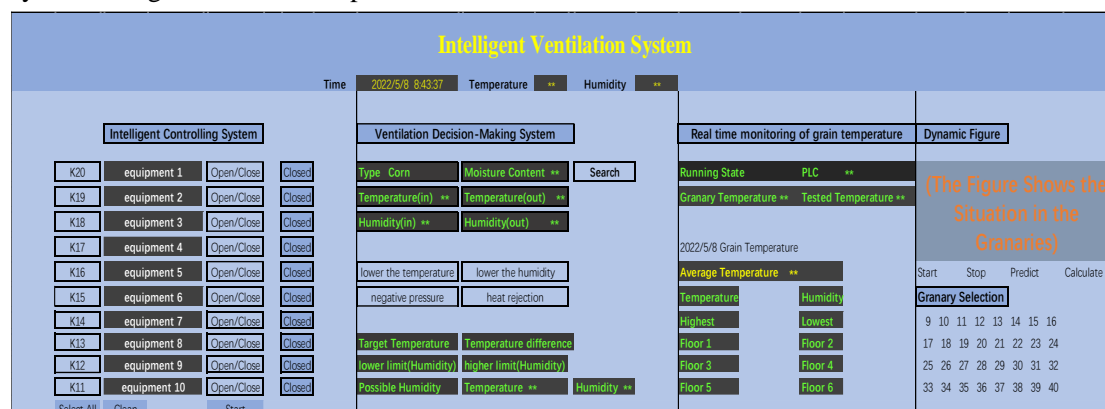
Grade	Unit Weight g/L	Unsound Kernel Content %	Moldy Kernel Content %	Impurity Content %	Water Content %	Color and Smell
1	≥720	≤4.0				
2	≥690	≤6.0				
3	≥660	≤8.0				
4	≥630	≤10.0	≤2.0	≤1.0	≤14.0	Normal
5	≥600	≤15.0				
Excluded	< 600	—				

**Note:** "—" stands for no requirement.

### 2.2.3 Green storage technology of corn in grain depot

#### 2.2.3.1 Grain condition detection system

Intelligent monitoring system is applied in the granary for research. Take the intelligent ventilation system in Figure 3 as an example.



**Figure 3 Legend of controlling panel of intelligent ventilation system**

(\*\* are used to replace data)

The temperature measurement and humidity measurement cables are layered, which can monitor the temperature and humidity of the grain everywhere in the granary. If there is abnormal grain temperature and humidity, the monitoring system will remind technical personnel through the screen panel, and then ventilation and other temperature and humidity control measures are timely used, which can effectively prevent accidents in the warehouse.

The intelligent monitoring system is widely accepted and used in the company's storage mission

because it is convenient, practical and intuitional, which provides a strong guarantee for monitoring the real-time situation of grain and sending personnel to deal with abnormal phenomena according to the data provided by it, and ensuring the safety of granaries.

#### 2.2.3.2 Mechanical ventilation technology



**Figure 4 Internal circulation machine outside the granary**

According to the classification of technical means, ventilation can be divided into natural ventilation and mechanical ventilation. Natural ventilation refers to the use of natural wind for ventilation, while mechanical ventilation refers to the ventilation through switching fans, regulating air ducts and other mechanical means. The granary we see is mainly ventilated by mechanical ventilation. According to the purpose of ventilation, ventilation can be divided into drying ventilation and cooling ventilation. As shown in the control panel of intelligent ventilation system in figure 3, corresponding operations should be carried out according to the data of warehouse temperature and humidity, and different fans should be started (as shown in Figure 4) to form an internal circulation system. During the initial ventilation operation after the grain was put into the warehouse, it was observed that the temperature and grain surface decreased significantly in various places (as shown in figure 5).

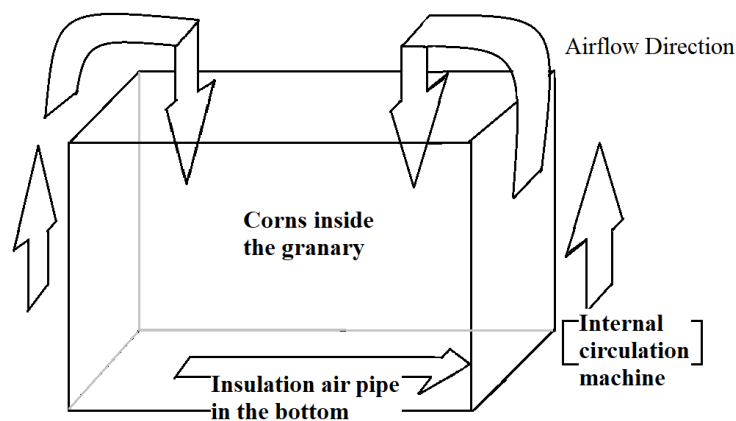


**Figure 5 The height of grain surface decreased after the initial mechanical ventilation**  
(Note: The initial height of grain surface of the granary is shown by the red line on the wall)

### 2.2.3.3 Circulation fumigation technology

In addition to cooling and precipitation ventilation, the internal circulation system is also used for grain fumigation. At present, phosphine fumigation technology is used in the research warehouse. With the help of the adjustment of the internal circulation ventilation system, sufficient fumigation of seeds in the warehouse can be realized, and effective pest controlling can be achieved.

Although it provides great facilities and circulation for exterminating pests, the safety of this technology combined with fumigation remains a concern. The custodians must enter the granary in groups and wear gas masks to check the situation after the circulation is over. Due to the lack of safety awareness, there have been cases of poisoning all over the world.



**Figure 6 Schematic diagram of internal circulation technology**

### 2.2.3.4 Grain cooling technology

The research site is located in the northern region of China, where the climate feature is different from the high temperature and humidity in the south, so there is no need to use the air temperature controlling technology with high energy consumption. Basic cooling can be accomplished by mechanical ventilation through physical means, which avoided a lot of energy consumption.

### 2.3 Corn rotation mechanism

The rotation of aged grain in the warehouse is based on the storage years and grain quality, and the government gives certain rotation subsidies. Under normal circumstances, the storage warehouse will rotate 20 to 30 percent of the total number of grains every year. Spring and autumn censuses are carried out in March and September every year to check unit weight, moisture, impurities, etc.

On the one hand, rotation promotes the sustainable development of enterprise warehousing operation. On the other hand, it adds vitality to the market. Sufficient financial support provides a good guarantee for the implementation of green corn storage technology.

## **3 The development prospect of corn green storage technology**

### 3.1 Adhere to the development of "four-in-one" green grain storage technology

During the investigation of the research warehouse, it was found that the "four-in-one" grain storage technology (grain condition detection system, mechanical ventilation technology,

circulation fumigation technology, grain cooling technology) could realize effective grain storage. Based on the information obtained through interviews about the process of entry and exit and the rotation mechanism, the researcher believe that the technology can provide conditions and guarantee for the green storage of grain.

### 3.2 Actively search for alternatives of chemical fumigation methods

Phosphine fumigation is often used in the traditional storage methods, which has achieved good results and protected grain from the damage of storage pests in a certain period of time. However, due to the excessive application of this technology, stored grain pests have developed widespread resistance to it. In addition, due to its chemical nature, phosphine fumigation method will inevitably cause some pollution and affect the quality of corn. Therefore, the search for alternative methods of chemical fumigation should be the future development direction.

### 3.3 Actions should be taken to rise economic dynamism in the industry

In the investigation and interview with the Supply and Marketing Department, the investigators found that the grain storage industry usually has a loss, and the state finance bears part of the expenses. However, through the example of this reserve, we find that when the company pays attention to the market situation and carries out the operation of buying and selling under the premise of ensuring the safety of the grain storage, it can win profits for the company and arouse people's enthusiasm.

The country should formulate relevant policies to encourage relevant companies to use the market economy system to create more income, so as to provide a source of income for the research and development of new green grain storage technology, and drive the development of the entire industry. The benefits of doing so are not only for the company itself, but also for ensuring national food security, which China attaches great importance to.



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