

# Research on intelligent storage technology of agricultural products -- taking soybean as an example

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**Abstract.** As an important cash crop, soybeans are often used to squeeze oil and as high-quality livestock feed, providing residents with high-quality vegetable oil and meat supplies, and play an important role in improving the health of the national diet. At present, the yield of soybeans in China is low, and many demand loopholes rely on high-quality soybeans imported from abroad to fill, so safe storage is particularly important. Based on this, this paper excavates and analyzes the problems existing in the traditional soybean storage method, and takes targeted measures according to the problems exposed by the traditional soybean storage, and constructs a real-time monitoring system for the soybean storage environment in the warehouse by using a variety of new storage technology means to improve the safe storage capacity and national living standards of soybeans in China.

**Keywords:** Soybeans, storage, temperature and humidity control.

## 1. Introduction

Soybean is an important cash crop, rich in protein and oil. It can not only be used to make various kinds of soybean products and serve as food rations, but also often used to extract oil and serve as high-quality livestock feed. It provides residents with high-quality vegetable oil and meat supply, and plays an important role in improving the health level of the national diet. According to statistics, the consumption of soybeans from 2017 to 2020 exceeded 100 million tons, of which a large part was dependent on import business. At present, the domestic soybean production is low and the oil yield is low, which can not meet the domestic demand, leading to many demand loopholes to be filled by imported high-quality soybeans. In addition, China's soybean yield is relatively low, and the planting cost is much higher than that of other soybean producing countries in the world, resulting in the lack of market competitiveness of domestic soybeans, which seriously dampens the enthusiasm of soybean farmers. Although the state also provides subsidies to soybean farmers, it is only a drop in the bucket. According to statistics, China's soybean import dependence is nearly 90%, and the international soybean price trend is rising. In order to save resources, save funds and avoid waste, we need to pay more attention to the research of soybean storage technology. In order to improve this situation, in addition to ensuring a stable supply of soybeans, we should also pay attention to the storage methods of soybeans, reduce the damage rate of soybeans, maximize the use of soybeans, and ensure the living standard of residents. Based on this, this paper has conducted in-depth research and Analysis on the characteristics of soybeans, the traditional storage methods of soybeans and the problems existing in the traditional storage methods, and put forward corresponding intelligent storage technologies for the problems, which has played an important role in the safe storage of soybeans and the improvement of national living standards.

## 2. Storage characteristics of soybean

### 2.1 Storage characteristics of soybean

The seed coat of soybean is thin and smooth, with large porosity and hard grain, which has strong resistance to insects and mildew. However, due to the rich hydrophilic colloids such as protein and fat, the soybean has strong hygroscopic capacity, which is prone to hygroscopic mildew and oil discoloration during the storage period of soybean, resulting in the decline of the whole quality of soybean, loss of germination power and poor storage stability [1].

## **2.2 Main factors affecting soybean storage**

### **2.2.1 Temperature and humidity**

The control of temperature and humidity is the precondition of soybean storage. First of all, as an organic organism, soybeans are breathing all the time. In the process of breathing, soybeans use their own protein, fat, sugar and other organic substances to oxidize and decompose to generate energy to maintain their basic biological activities and forms. During this period, soybeans will continuously release heat to the outside world. Therefore, during the transportation and storage of soybeans, It is very easy for the heat generated by the respiration of soybeans to accumulate continuously, resulting in the overall high grain temperature. In turn, the high grain temperature will intensify the respiration of soybeans, forming a vicious cycle, causing soybeans to caking and deteriorate, and affecting the quality of soybeans. At the same time, soybean is rich in a large amount of affinity colloids such as protein and has strong moisture absorption capacity. It is very easy to be affected by moisture in areas with high air humidity. Under the condition of appropriate temperature, it is very easy to cause soybean denaturation, germination, mildew and blackening, which seriously endangers the storage safety of soybean.

### **2.2.2 Mildew and insect damage**

Mildew and insect damage are also major factors affecting the quality of soybean during storage. There are all kinds of bacteria in the nature all the time. There are many kinds of fungi that can infect soybeans and cause soybeans to become moldy, including the notorious *Aspergillus flavus*, which produces aflatoxin, which is a highly carcinogenic substance. Once soybeans are infected with this mold, it means that soybeans have basically lost their edible value and can only be destroyed. During the storage period of soybean, in addition to the prevention of mildew, the prevention of soybean pests should also be emphasized. The reason for soybean insect damage may be that conventional pest control methods did not completely eliminate all insect eggs in soybeans before they were stored in the warehouse, resulting in some insect eggs being stored in the warehouse together with soybeans. It may also be that the insect control operation in the early stage of soybean storage has completely eliminated the insect eggs, but in the subsequent storage process of soybeans, for other reasons, such as periodic periodic inspection during the storage period of soybeans, The inspectors of the warehouse did not operate according to the standard, which led to the infection of foreign insect eggs on the soybeans in the warehouse. Under the appropriate environment in the warehouse, these insect eggs would hatch the larvae harmful to soybeans and corrode the soybeans in the warehouse. Moldy and insect pests are highly infectious and have a wide range of damage. If they cannot be found in time during storage, they may even cause the loss of economic value of the whole warehouse of soybeans.

## **3. Problems of traditional soybean storage**

The traditional soybean storage method usually controls the influencing factors exposed in the whole process of soybean storage. However, the ability to respond to the potential hidden risks is low, and it can only go back and forth in the cycle of "emerging problems - solving problems". We never know what problems will occur during the storage of soybeans, and the prevention space is insufficient. Moreover, it is very passive to control the whole storage process of soybeans. The process of traditional storage mode is as follows:

Take a warehouse importing a batch of soybeans from Brazil as an example. Soybeans are bulk commodities and are generally transported by sea. Although the loading capacity of sea transportation is large, the disadvantage is that the transportation time is long, and the transportation time limit is generally about 1 month. As Brazil is located in the tropical region, the local temperature is generally high and the air humidity is high, which has a certain impact on the grain temperature and moisture content of soybeans when they are loaded. When the moisture content of soybeans exceeds 13%, the soybeans will soften with the increase of temperature, and then the color of the two cotyledons of soybeans near the embryo will turn red, which is commonly known as "red eye". After that, the

internal red of soybeans will deepen and gradually expand, resulting in "red change". In serious cases, The cotyledons are waxy and transparent, and there is also oil soaking and peeling [2]. After the arrival of soybeans in Hong Kong, the quality of soybeans shall be inspected first to detect the current temperature and humidity of soybeans, and check whether there are signs of mildew and insect damage, so as to avoid receiving soybeans with high damage rate. After receiving the soybeans, the preparations before the soybeans are put into the warehouse should be started. First of all, the soybeans to be put into storage are dried. Generally, the moisture content of soybeans is directly reduced through the open air exposure. After the moisture content of soybeans reaches the warehousing requirements, they can be recovered to the shed where soybeans are temporarily stored. Then, the blower is used to accelerate the air circulation to realize the rapid cooling of soybeans. After the temperature also meets the warehousing requirements, the soybeans can be transported into the granary. Some enterprises may also use phosphine as fumigant to kill insects in order to prevent insect pests. However, some warehouses of grain enterprises do not grasp the insect period properly, and unscientific and unreasonable use of drug fumigation has caused serious drug resistance of stored grain pests. Moreover, unscientific and unreasonable use of phosphine will also cause a large amount of pesticide residues on grain, which will affect people's health after entering the market. After the soybeans are successfully put into the granary, it is to arrange the granary management personnel to regularly check the changes in the granary according to the characteristics of soybeans and previous experience, so as to prevent accidents in the storage process of soybeans. From the example, we can see that the traditional storage method can be divided into five steps, namely, drying, cooling, impurity removal, fumigation and management during storage. The first three steps of the traditional storage method are the conventional requirements of soybeans before warehousing, which is the guarantee for safe storage of soybeans [3]. However, the abuse of insecticide in the fourth step and the storage period management in the fifth step highlight the shortcomings of the traditional storage mode. The traditional soybean storage mode is difficult to achieve real-time prediction of the storage environment of the granary. During the storage period of soybeans, the environmental factors in the granary are constantly changing slightly. However, the intelligent traditional soybean storage is lacking, and the periodic inspection plan is only developed based on the previous storage experience, The warehouse management personnel are arranged to track and update the storage status of soybeans. The storage information lags behind seriously, and a vacuum area for storage monitoring is formed during the period from one cycle to the next. All kinds of major grain storage accidents may occur during this period, seriously endangering the overall storage quality control of soybeans. In summary, the main problems affecting the storage safety of soybeans are as follows:

### **3.1 Abuse of chemical pesticides**

The residual insect eggs in soybean storage are also a major hazard factor in soybean storage. If the soybean is not treated with necessary insecticidal treatment before it is put into storage, it is easy to cause insect damage to the soybean in the later stage. At present, many enterprises mainly use chemical agents to prevent and control pests and mildew. However, due to the improper use of pesticides, most pests have developed drug resistance. Although new technologies have been used for circulation fumigation in recent years, and the amount of drugs used has been reduced, some of them are unscientific and unreasonable in mastering the insect period, and some grain depots do not follow the fumigation standard of "fumigation only once a year", There are even a few who use the direct dosing method. In order to cope with the general survey, some grain enterprises increased the number of chemical dosing, the most of which were fumigated more than three times a year, causing serious drug resistance of stored grain pests. Moreover, the resistance of grain pests is still on the rise, and the efficacy of phosphine application is decreasing. Moreover, the increased use of phosphine for many times will cause a large amount of pesticide residues on grain and affect people's health. In addition, if these residues are not properly handled, they will cause new pollution to the atmosphere, soil and water sources.

### **3.2 Imported soybeans are heated and mildewed seriously during storage**

Due to the shortage of high-quality soybeans in China, the number of high-quality soybeans comes from imports. Soybeans are mainly imported from the United States, Brazil, Argentina, Uruguay and other countries. Soybeans are characterized by high basic grain temperature during shipment and long sea transportation before warehousing. During the sea transportation, the means of transport are basically always exposed to the sun and the sea water vapor is large. If the storage environment in the cabin of the means of transport does not meet the requirements or does not operate according to the specifications, the breathing of soybeans in the cabin will be intensified, the flora will be vigorous, and there will be abnormalities such as fever, mildew and caking. It often causes qualitative changes in soybeans during transportation [4], but the lack of support from modern intelligent storage technology makes these problems unable to be found and solved in time, and it is difficult to guarantee the quality of soybeans in the early stage of storage.

### **3.3 The storage environment of the granary is unpredictable**

Time is the catalyst for all variables. During the long enough storage period of soybeans, the factors affecting the storage of soybeans in the granary are also accumulating. Unlike smart storage, the traditional storage mode lacks or does not have a storage network composed of automated and intelligent storage facilities. It has poor perception and slow response to changes affecting soybean storage factors, and is still in the stage of excessive reliance on human resources. For example, in the monitoring of temperature and humidity factors in the warehouse, traditional temperature and humidity meters are still widely used. The temperature and humidity environmental information reflected by these traditional thermometers requires the warehouse to arrange personnel to regularly observe and collect records to obtain the environmental conditions in the warehouse at a certain time. However, there is a long-term information vacancy in the warehouse before the data collection is completed and the next detection cycle comes, so that the grain enterprises can not accurately grasp the storage status of soybeans in the whole granary in real time, and the early warning time is short, which affects the adjustment of the storage Countermeasures of the grain enterprises.

## **4. Advantages and difficulties of soybean intelligent storage technology**

Intelligent storage technology refers to the use of industrial automation, informatization and intelligence, the use of Internet of things, cloud computing and other means to transform the changes of various factors in the warehouse during grain storage into useful information, and reflect them in the form of data, so that the storage conditions in the warehouse can be visualized, such as the temperature and humidity level, ventilation conditions, and the probability of mildew. Make use of the characteristics of the Internet to change the original static storage into dynamic storage, so that the warehousing personnel can timely, quickly and accurately grasp the changes in the granary, and respond in a timely manner. Compared with traditional storage methods, intelligent storage has the advantages of real-time control of the inside of the grain warehouse, and can keep all the conditions in the warehouse during the grain storage in the form of data, which provides an important basis for the follow-up improvement of grain storage countermeasures. At present, the disadvantages of traditional soybean storage methods are increasingly obvious. It is of great significance to study new intelligent storage methods of soybean to promote the upgrading of soybean storage systems in China.

### **4.1 International commonly used smart storage technology**

#### **4.1.1 Low temperature grain storage technology**

Temperature is an important factor affecting the safe storage of grain and oil. When the moisture and oxygen conditions are suitable, the pests, microorganisms, grains and other biological components in the grain pile must be within a certain temperature range to carry out normal life activities. If the temperature of stored grain is reduced in different ways without freezing the grain, the vigorous life activities of various biological components in the grain pile can be suppressed, the

loss of dry matter of the grain during storage can be reduced, the original quality of the grain can be maintained to the maximum extent, and the aging speed of stored grain can be delayed. It is an ideal green grain storage technology. Low temperature grain storage has a very long history. It is the most safe, reliable, reasonable and environmentally friendly grain storage technology recognized in the world. It can not only delay the aging of grain, but also has a certain preservation effect. It is also the most widely used pest control method at home and abroad [5].

#### **4.1.2 Controlled atmosphere storage technology**

At present, the CA storage technology mainly includes vacuum storage, N<sub>2</sub> filled CA storage, CO<sub>2</sub> filled CA storage, etc. due to the impact of practicality and economy, CO<sub>2</sub> CA storage is widely promoted and applied. Scientific research has proved that if the oxygen concentration in the grain pile drops to about 2%, or the carbon dioxide concentration increases to 40% ~ 60%, the vast majority of stored grain pests in the grain pile will die, the aerobic mold will be suppressed, and the respiratory intensity of the grain itself will be significantly reduced. Controlled atmosphere storage method has been adopted in many countries, and his method of controlling stored grain pests by air conditioning and air control has been paid more and more attention.

### **4.2 Advantages of soybean smart storage technology**

#### **4.2.1 Real time temperature and humidity monitoring**

In the past, grain storage basically relied on years of accumulated experience to judge the state of grain storage. The intelligent granary established by means of computer network technology, software technology, sensing technology, automatic control technology and Internet of things technology can not only realize the automatic collection of temperature, humidity, gas, insect situation and other data in the granary through the grain situation monitoring and control system, but also realize the intelligent control of ventilation, fumigation, temperature regulation and other grain and oil storage operations through the intelligent decision model [6]. So that the grain storage information can be accurately and real-time transmitted to the granary administrator, so that the whole grain storage process can be followed.

#### **4.2.2 Data tracking source**

The smart storage mode connects closed and independent individuals, realizes the common transfer of grain itself and grain data in grain trading, and forms a dynamic data chain between upstream and downstream enterprises. For downstream enterprises, through the storage data of grain in warehouse and out of warehouse provided by upstream enterprises, the current situation of grain can be quickly and accurately understood, and data support can be provided for downstream enterprises to formulate the optimal storage scheme. At the same time, quality problems such as storage accidents during grain storage can also be traced through this data chain to clarify the responsible parties.

#### **4.2.3 Create a soybean smart storage system**

With the help of industrial automation, informatization and intelligence, the Internet of things, cloud computing and other ways, we will create a regional and systematic soybean storage system. Make the whole soybean storage process highly informative and transparent. The establishment of the smart storage system can not only strengthen the real-time grasp of the status of soybean storage in the warehouse, promote the trust of the downstream enterprises in the soybean industry chain to the upstream soybean raw material suppliers, but also help the state to control the status of soybean storage in China.

#### **4.2.4 Facilitate the establishment of the national grain monitoring and early warning system mechanism**

Intelligent storage is of great significance for government departments to monitor and warn the grain situation. As a country with a large population and food production, China's food security is

related to the international people's livelihood. Not only for China, but also for any country in the world, food security is of great strategic significance. We attach great importance to the construction of food monitoring and early warning system. On June 15, 2015, the national development and Reform Commission, the Ministry of Finance and the State Food Administration jointly issued the construction plan for the safety guarantee project of grain collection, storage and supply (2015-2020), which proposed for the first time that the national grain monitoring and early warning system mechanism should be established, and a grain monitoring and early warning system including information collection, alarm analysis and information release should be established. The promotion of intelligent storage technology will greatly promote the construction of this set of grain monitoring and early warning system.

### **4.3 Difficulties in popularizing soybean smart storage technology**

#### **4.3.1 Capital and technology**

The fundamental reason why smart storage technology is difficult to popularize rapidly is the problem of funds. Smart storage uses a variety of modern information technologies and has high requirements for software and hardware facilities. In hardware, such as various intelligent and automatic equipment, and in software, such as storage system module design and logic chain design. In addition, many smart storage technologies are protected by national patents, and the direct use of existing smart storage technologies requires high patent fees. Many domestic small enterprises, due to their small scale, have no funds and no power to support their use of smart storage technologies and realize smart storage.

#### **4.3.2 Geographical factors**

Due to the different climate and environment in different regions, the demand for soybean storage is also different. China's north-south span is large, and the climate change is also large. Some advanced intelligent storage technologies are only for a certain region. If you want to find a suitable storage method, you need to consult experts and give the best scheme.

#### **4.3.3 Market competition**

Enterprises using smart storage technology to store soybeans need to spend money to consult experts and give solutions. At the same time, they also need to purchase advanced equipment and train operators to maintain the smart storage system, which leads to a straight-line rise in storage costs compared with other enterprises using traditional soybean storage methods, which easily puts them at a disadvantage in market competition and is not conducive to enterprise market competition. Therefore, even though the disadvantages of the traditional storage mode are exposed, the traditional storage mode is still the choice of most enterprises from various aspects.

## **5. Popularize soybean intelligent storage technology to solve the traditional soybean storage problems**

### **5.1 Promote the application of smart storage technology in temperature and humidity**

The reason why there is drug abuse in soybean storage is that it is difficult for grain enterprises to grasp the environmental conditions in the warehouse during the storage of soybeans, and there are too many unknowns. It is a "reasonable" method to solve the hidden dangers of pests once and for all. The main factor affecting the occurrence of pests during the storage of soybeans is the temperature and humidity environment in the granary. The solution to pests in intelligent storage is mainly aimed at the control of temperature and humidity during the storage of soybeans, highlighting the concept of pest control with prevention as the main factor and medicine as the auxiliary factor. It is recognized that drug pest control is only an emergency treatment means. Through a variety of advanced storage technologies and methods, To make the influencing factors of soybean pests transparent and provide basis for preventing and solving pests. There are many storage technologies and methods to deal with

pests. For example, we can use high-temperature drying method, infrared temperature measurement technology, electronic temperature sensor technology and gas analysis technology to prevent soybean pests [7]. The so-called high-temperature drying method is to dry the soybeans with high humidity for 10 minutes at a high temperature below 160 °C in the early stage of warehousing and storage, and then detect the moisture of the soybeans. If the humidity is not within the safe range of soybean storage, the high-temperature drying is carried out again until the moisture is controlled within the safe range of soybean storage. After the high-temperature drying, the humidity of soybeans has been reduced to the safe range of storage. However, due to the high-temperature drying, the grain temperature at this time is very high. It is necessary to stack soybeans in a cool and dry place, and cool the soybeans by air conditioning or fan. At this time, the infrared temperature measurement technology can be used to measure the temperature of the surface of the soybeans, so as to quickly grasp the temperature status of soybeans. When the temperature and humidity of the soybeans fall to the appropriate range, the soybeans are put into the granary. However, before putting into the granary, we still need to arrange some electronic temperature sensors in the warehouse. Take the traditional circular warehouse as an example, because the sensor sensing range is limited, we need to arrange multiple sensor arrays in the warehouse to realize the real-time monitoring of the temperature of soybeans in the whole warehouse during storage [8]. On the basis of temperature and humidity control technology, pest activity detection technology, such as electronic nose technology, Electronic nose technology is a technology that can make a keen analysis of the gas composition in the warehouse by imitating the olfactory system of living things. In the process of insect pest activities, excreta and waste gas will be accumulated in the barn. Through the electronic nose technology, we can quickly detect whether there are pests in the current barn, and even identify the type of pests, the spatial range of pests and the population number through the detected odor concentration. Through these storage technologies, the transparency of the situation of soybeans in the warehouse during storage can be significantly improved, and the confidence of grain enterprises in the storage of soybeans can be enhanced. Even if pests inevitably occur during the storage period of soybeans, grain enterprises can respond quickly in advance and formulate solutions. This fundamentally solved the problem of abuse of insecticides in traditional soybean storage.

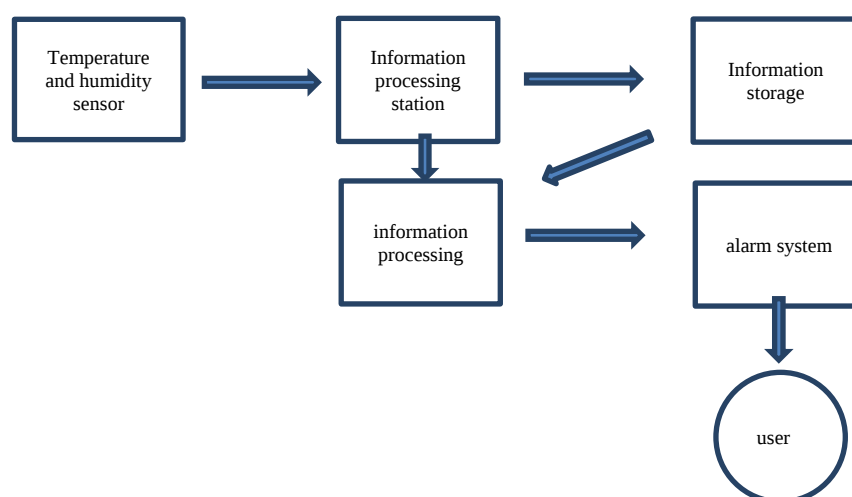
## **5.2 Promote the application of Internet + in temporary storage of soybeans**

For soybeans imported from abroad, for domestic grain enterprises, the storage period of soybeans also includes the storage time on the way to Shanghai. The soybean exporting countries in the world are mainly distributed in the north and South America, which is far away from the mainland of China in terms of geographical location, and the time of sea transportation also increases. There is great uncertainty in the whole soybean situation from the export country to the port of our country. Some quality changes may occur in the transportation of soybeans, but it is difficult to see from the surface. In addition, soybean export enterprises will deliberately hide or minimize the problems for their own interests, This makes it possible for enterprises to take over these seemingly no problem soybeans under the guidance of wrong information, affecting the later storage of soybeans. To solve this problem, domestic grain enterprises need to use intelligent storage technology, especially Internet technology, to build a data network on "soybean health" with foreign grain enterprises, break the information barrier, realize the transparency of soybean transportation and storage process, so that domestic grain enterprises can timely grasp the quality changes during soybean transportation, and provide support for grain enterprises to formulate reasonable operational countermeasures before warehousing [9].

## **5.3 Promote the establishment of monitoring system in the granary**

Traditional storage is difficult to predict the storage environment in the granary. To solve this problem, we can use intelligent storage technology to establish a set of such systems: (1) intelligent temperature and humidity sensors are placed in the granary. The sensor system is designed to be in low energy consumption state and emergency state, and a "safe period and dangerous period" of

temperature and humidity are set for the sensor. When the temperature or humidity in the granary is in the "safe period", When the temperature and humidity sensor is in the low energy consumption state, it only retains the basic temperature and humidity measurement function. When the temperature or humidity in the granary changes to the "danger zone", the transmitter of the temperature and humidity sensor will be automatically triggered to transmit the danger signal to the outside. (2) For the signal transmitted by the temperature and humidity sensor, an information relay station needs to be established to specially receive the signal transmitted by the temperature and humidity sensor. And send the received signal to the information processing center and the information storage center through simple transcoding and coding. (3) The information processing center and the information storage center will receive the signals from the information transfer station at the same time. The information processing center will automatically retrieve the historical data of the information storage center according to the latest information data for summary and re analysis, assess the current situation of the environment in the warehouse, predict the future trend of the environment in the warehouse, and automatically trigger the alarm system to remind the user if the current or future environment in the warehouse develops to the "dangerous section", If the overall condition in the granary is good, the alarm will not be triggered, and only the system analysis results of the current environment in the granary will be presented to the user [10]. A simple diagram can be used as follows:



**Fig 1.** Granary monitoring system

## 6. Concluding remarks

In the final analysis, the research on the intelligent storage technology of soybeans is aimed at the control of the factors affecting the temperature and humidity changes in the warehouse during the storage period of soybeans. For soybean storage, temperature and humidity control is the premise, and mildew and insect damage are the results. The so-called intelligent storage technology is essentially to achieve more effective, faster and more scientific control of temperature and humidity during soybean storage by using modern intelligent, information, network and data-based methods. As a country with a large population, China's food security is still a sharp blade hanging on the head of the country. The safe storage of soybeans is an important part of the strategy to ensure China's food security. At present, China relies on imported soybeans to maintain the balance of domestic soybean consumption. However, in the current stage of COVID-19 epidemic, the global soybean output is affected to varying degrees. The promotion of intelligent storage technology can improve the storage efficiency of domestic grain enterprises, reduce the probability of storage accidents, reduce waste, and maximize the economic benefits of soybeans. In addition, the disadvantages of the current traditional storage methods are increasingly prominent, It continuously endangers the storage safety of soybeans in China, and also shows the importance of promoting smart storage research.

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