Review and prospect for development of fumigation machinery in China

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Abstract
This paper reviewed the history of grain fumigation machinery development in China, described present situation of grain fumigation machinery for the warehouses and silos and gave out views for future development of grain fumigation machinery technology.

The History Review of Grain Fumigation Machinery Development in China

Annual grain production of China has been about 500 million tons. It is a very important problem related to the needs of peoples’ lives and improvement of living standard, that makes grain production, storage, processing and sales fast development. It is the most effective way to ensure safe storage and decrease losses of stored grain to apply the fumigants to kill insects in stored grain. The use of fumigants has been done in China for several decades, but the development of grain fumigation machinery is just a new thing in recent years. With the continual development in Chinese grain industry, grain fumigation machinery has made great progress. It has played and is playing the increasingly important role in foundation and perfection of Chinese grains distribution system, keeping grain quality, decreasing grain loss and raising grain distribution efficiency.

Development and application of chemical fumigants

The history of applying chemical fumigants to prevent and kill insects in stored grain has been several decades or more than 100 years\(^1\). Carbon disulfide (CS\(_2\)) was first applied to grain fumigation in France in 1854. Chloropicrin and methyl bromide were used in France in 1917 and 1932. Hydrogen phosphide (PH\(_3\)) began to be used in Germany in 1935. The principle of fumigation is that, poisonous steam produced by easy-evaporate chemical fumigants is mixed in air and reaches a certain concentration. This gas enters inside of insect’s body through respiratory system or body film of insect. After a period of time, the insects are poisoned to death. At present, fumigants widely used in China are mainly hydrogen phosphide, methyl bromide, chloropicrin, ethylene oxide, carbon disulfide etc. Methyl bromide began to be produced in china in 1954 and was applied for grain fumigation in 1955. Pellets of AIP were developed in 1963. The pellet and powder of AIP were widely used in Grain industry. Now AIP is the fumigant that is the widest in application and the most in production.

Development of grain fumigation machinery

The development of grain fumigation machinery is far behind of development of fumigants. There was no progress in grain fumigation machinery in 1950's - 1970's. The main reasons are as follows: (1) Most grain warehouses in China are flat warehouses. These warehouses are poor in tightness and lower degree in mechanization. The requirement for fumigation machines in these warehouses is not very urgent. (2) Policy of 'prevention in front of killing' is paid more attention in grain-stored methods so it is as to decrease the usage of fumigant. In fumigation, operations are mainly manual operation. (3) During a period of after foundation of new China, the industry basis of the county was backward, and this field not been paid more attention. The research and development of grain fumigation machinery did not carry out in China until the late 1980's. PH\(_3\) generator was the first one developed by Northeast Suburban Grain Depot in Beijing. Tianjin Junliangcheng Rice Mill developed methyl bromide fumigation technology in concrete silo in the middle of 1980's. Zhengzhou Grain Science Research and Design Institute under Ministry of Internal Trade developed the circulation system and technology in large grain silos\(^2\), which was a key project of state 7th 5-year science-technology plan. Grain fumigation machinery was vigorously developed in 1990's. The Nan County in Hunan province developed Double-recychng fumigation and aeration system\(^3\) Rongchang county in Sichuan province developed 'Side combing circulating fumigation system used for flat warehouse'\(^4\). Zhejiang Grain and oil Storage Company developed 'PH\(_3\) circulating fumigation technology in grain silos'\(^5\). Zhongzhou Grain Collage developed "Multi-function fumigation system"\(^6\). Zhengzhou Grain Science Research

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and Design Institute under Ministry of Internal Trade developed Automatic AIP pellet dispenser. All these machines have made positive contributions to safe storage grain and development of grain fumigation machinery in China.

**Present Situation of Grain Fumigation Machinery in Flat Warehouses**

Flat warehouse are about 80% of total grain storage in China, most of which are used for reservation. Because of poor seal of flat, less machines and insufficient technical knowledge of laborers, fumigation used before was mainly manual operation in flat warehouses. There were many difficulties for fumigation in flat warehouses, so that the development of fumigation machinery was very slow. The fumigation machinery having better effect includes side combing circulating fumigation system used for flat warehouse and double-recycling fumigation and aeration system. Brief introduction is given as below.

**Double-recycling fumigation and aeration system**

Double-recycling fumigation and aeration system was developed on the basis of thin plastic film cover. It mainly consists of air inlet box, air outlet box, recycling pipes, fan, plastic film cover on grain pile, monitor instrument for grain temperature and control system, etc. For inside recycling system, air blown by fan pushed fumigation gas into grain pile, then passed through the recycling pipe and entered fan inlet again. After 2 - 3 times of circle, fumigation gas is evenly distributed inside the grain pile. Switch off fan and seal the grain pile to get a goal of killing insects in grain pile. For outside recycling system, suitable dry and cool air is drawn into grain pile through air inlet box. Then the air absorbing heat and damp is removed from grain pile through outlet box. By this means, the aim to drop the temperature and moisture content of stored grain is achieved. The practice for many years has proved that double-recycling fumigation and aeration system has good effect for killing insects in grain pile and for ventilation to drop temperature and moisture content of stored grain. It has the good benefit in saving manpower and energy. It is a big progress for grain storage technology in flat warehouse.

**Side combing circulating fumigation system used for flat warehouse**

The side combing circulating fumigation system was developed in Nan County of Hunan province and was used for fumigation in flat warehouse. It consists of two parts: main equipment and pipe networks. Main equipment includes fan, PH₃ generator, manual AIP dispenser, air direction transfer, gas sampler and moving vehicle etc. Pipe network includes inlet pipe network, outlet networks and sealing valves. Sealed grain pile is also a component of the system. Inlet and outlet networks are formed by connecting steel pipes installed in equal distance on both sides of flat warehouse. The pipes must be located under the surface of grain pile. The pipes are sealed at one end, and there are many small holes on pipes. The form of installed system is like a comb. Pipe networks are guided out of warehouse and connected with main equipment by ball valve. The flowchart and connection of whole system is shown in Fig. 2.

![Diagram](image-url)

Fig. 1. Double-recycling fumigation and aeration system.

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1-grain surface  2-outlet networks  3-inlet pipe networks  
2-4 fan  5-sealing valves  6-PH₃ generator
The system is constructed on the basis of the principle of recycling fumigation to make fumigant spread evenly and quickly in grain pile, and is not affected by temperature ladder. It prolonged the time in treatment and raised the efficiency of fumigant, resulting in better effect of killing insects. It also shortened the time of spreading fumigant and improved the working efficiency. Fumigation process is carried out under sealed environment, thus the safety of fumigation personnel can be guaranteed.

Present Situation of Grain Fumigation Machinery in Grain Silos

Grain silos are quickly being developed in China, because this technique has some obvious advantages, such as vast storage capacity, small land usage and high mechanization, etc. There is very high of grain pile in silo, so that natural diffusion of fumigant gas is very slow. Fumigant gas could not evenly spread in grain pile. To control insects in grain silos has been very difficult for a long time. Only after a variety of special fumigation machines were developed, fumigation in grain silos and safe storage of grain may be guaranteed. In recent ten years, some fumigation machines suitable for grain silos were developed. They all obtained very good result in killing insects in grain silos. A brief introduction is described as follows.

Circulating fumigation system equipment in large grain silos

Circulating fumigation equipment in large grain silos (Fig. 3) developed by Zhengzhou Grain Science Research and Design Institute under Ministry of Internal Trade was a key project of ‘7th 5-year science and technology plan’. It was awarded ‘Second Prize for Science and Technology Progress’ by Ministry of Internal Trade in 1991. Circulating fumigation equipment for large grain silos consists of vaporizer, valves, airtight fan, recycling pipe, dust remover, air inlet and outlet, etc. The working principle of the equipment is as follows: vaporizer, valves, airtight type fan, recycling pipe, dust remover, and air inlet and silo are connected together to form a close recycling circuit. Before fumigation, open all valves on recycling circuit formed with silo 501 and close others. Switch on the fan and open the valve of fumigant bottle. Fumigant (may be methyl bromide, PH3, or carbon dioxide, etc.) was introduced into vaporizer to form fumigation gas and was blown into grain pile from bottom of silo. Fumigant gas went up along whole section of silo through grain pile and escaped out of grain surface. By the action of fan, the gas containing fumigant returned to the inlet of fan again through recycling pipe and dust remover. Thus, a circle was ended. A scale measured the amount of fumigant applied. While the given amount was reached, the valve of fumigant bottle was closed. After several cycles, fumigant gas was evenly spread in grain pile. Switch off fan, close upper and lower valves of silo 501 and keep silo 501 to be sealed. Then, open upper and lower valves of silo 301, start fan, measure the amount of fumigant applied, close valves and seal the silo. Fumigation was carried out silo by silo, until all silos to be fumigated were fumigated. After being sealed for 48 h, open upper and lower valves of silo 501, start fan, open inlet and outlet valves of fumigation equipment, and exhaust fumigant gas in silo and recycling pipe out of silo. Silo 501 was ventilated for 2h. Next, close upper and lower valves of silo 501, open upper and lower valves of silo 301. Then the silo 301 is also ventilated in 2h. Fumigation and ventilation were
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carried out as above-mentioned silo by silo. After the last fumigated silo was ventilated, fumigation was finished.

Circulating fumigation system equipment in large grain silos has following features: a) Fumigation can be done quickly with high efficiency. b) The lethal rate of insects in grain pile reached 100%. c) Operation is safe and reliable and there is few residue of fumigant in treated grain. d) The equipment can be used for ventilation to drop the temperature of grain in silos.

Fig. 3. Circulation fumigation equipment in large grain silos.

Multi-function aeration and fumigation system (Fig. 4) was developed by Zhengzhou Grain Collage. The procedure is as follows: Special equipment is fixed in the center of silo. Its upper is connected with grain inlet and bottom is connected with grain outlet. It combined many functions (such as ventilation, fumigation, decreasing classification and reducing dynamic loads when unloading) together. Silos equipped with this system are much better than other silos. The features of this system are as follows: (1) Loading and unloading through central pipe may effectively decrease automatic classification and raising the stability of stored grain. (2) Unloading through central pipe may distinctly reduce grain blast loads on silo wall, protect cable and other facilities in grain pile from damage, improve load situation of silo and prolong the working life of silos. (3) Ventilation can remove heat and damp in grain pile out of silo, balance the temperature both inside and outside of silo, prevent grain spoilage and keep the quality of stored grain. (4) Combination of fumigation and ventilation formed a inside recycling, made fumigant gas evenly spread in grain pile and was able to kill insects with less fumigant.

Automatic phosphate pellet dispenser

Automatic AlP pellet dispenser is recently developed by Zhengzhou Grain Science Research and Design Institute under Ministry of Internal Trade. It is a new fumigation machine used in grain silo. The machine is mainly composed of pill container, mechanism for putting in order and numeral delivering system. This machine is installed at proper place on the intake conveyer on top of grain silos. When entering grain, pills will automatically go out from the machine according to given dosage, fall in the conveyer and enter in silo along the grain stream. Silo is sealed after loading grain. AlP pills absorb damp in grain pile and produce phosphine gas. Fumigation will be finished after one month (depend on real temperature and moisture content of grain) Then open the ventilation hole on top of silo to pull out exhaust gas. When concentration of PH3 in silo is lower than a given value (0.05ppm), the stored grain may be taken out.

Fig. 4. Multi-function aeration and fumigation system.

Automatic AlP pellet dispenser used for silo fumigation has more advantages as follows: simple equipment, convenient use and less investment. Its drawback is longer fumigation time. If it is used in coordination with fan, fumigation time will be shortened.

Development Trend of Grain Fumigation Machinery in the Future

The world is going into 21st century. Science and technology are forging ahead and will bring about changes day after day. Grain fumigation machinery is also developed toward new and high technology. General developing trend of Chinese grain industry is toward two poles. One is grain...
distribution system with high speed, large capacity, unobstructed fast and convenience. Another is more stable grain reservation. In order to fit the need of this trend, the development of grain fumigation machinery should pay attention in following points:

1. To construct fast fumigation facility with good airtightness at grain terminals and transfer depots with large throughput. This facility should be used in both of silos and squats. Once insect damage happens, fumigation can be done in time to prevent infection by insects, especially quarantine insects. It will not only ensure safety of agricultural products, but also keep high operation efficiency of grain distribution system.

2. Low dosage fumigation method can be used for flat warehouse and reservation warehouse with normal airtightness. This technique combined with controlled atmosphere (to reduce the content of oxygen and add that of carbon dioxide), will restrain the activity, reproduction and spread, up to kill insects and keep grain quality.

3. For long-term stored grain, protectant may be used to prevent insect infection.

4. Some controlled atmosphere warehouse should be built. They will apply the technique of removing oxygen by filling nitrogen or with nitrogen maker or molecule sieve, or filling carbon dioxide to control active growth of insects and mold. This technique will not only keep grain quality, but also reduce the amount of fumigant applied, which is very beneficial for environment protection.

References