0411

An Antibacterial Test by Using High Concentration of Phosphine in South China Region on Corn Storage

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Abstract: Some practical methods in stored grain including grain cooling, mechanical ventilation, and local ozone fumigation conventional technologies such as anti – mildew have achieved safe storage of corn in Guangdong Xinshagang depot, but some economic and efficient mode of operation of the corn custody have not yet been formed. Because high concentrations of phosphine can inhibit the growth of mould, a pilot usage initially explored the effective antibacterial concentration of phosphine and feasible methods of operation. It summarized the economics of the current corn storage conditions in Squat Wharfs in South China region.

Key words: south China region, PH_3, antibacterial, storing, corn

Introduction

China Grain Reserves Guangdong Xinshagang Depot (Xinshagrain) locates to the east of the Longhai, near the entrance of the Pearl River to the sea, which is a typical subtropical monsoon climate. There is a small temperature difference between day and night, with an average temperature at 22℃, an average relative humidity 79% and an average 1 800 mm of precipitation. According to the statistics of Xinshagrain station in 2007, the highest temperature was 36℃, lowest was 5℃, the average temperature above 25℃ was about 169 days, about 11 days below 10℃, the relative humidity waved from 42% to 100%. About 205 days' relative humidity were over 80%, of which 79 days were more than 90 %, and only 50 days below 65%.

Heating is caused by micro – organisms including the majority of the bacteria, fungi, yeast and plant pathogenic bacteria that are the dominant ones in grain. The greatest damage to stored grain are microbial mycophenolate in almost all microorganisms and temperature microorganisms, such as Penicillium and most Aspergillus. Moisture transfer or uneven grain moisture caused the rapid growth of microorganisms, which is the main reason for heating of grain. In recent years, there are two main kinds of corn storage heating in Xinshagrain; one is the local grain-like heating and another is the level of heat at certain depths. Heating is irregular. Heating at depth usually occurs in spring and summer, more than in the grain heating regions at 0.5 – 1.5 m (with the grain size and warehouse temperature, the original grain moisture levels, the depth of different interface heating), is the main reason for the spring and summer. Temperature rises rapidly, resulting in a grain stack "*cold core with surface heating*" phenomenon, when water temperature gradients cause increased grain surface water leading to increased microbial activity, thus caused local heating. In addition, different stages of the new and old grain warehousing level interface are one of the main forms of fever.

According to the trial in southern China's natural hot and humid climate, through analysis of the stored grain storage indicators in squat warehouses and storage characteristics of maize, a high concentration of phosphine inhibits microbial activities achieves safe storage of corn.

1 Materials and Methods

1.1 Test Warehouses and Control Positions

Test (Q43 storage) and control (Q45 and Q53 storages) are squat warehouse stores, diameter of 25 meters, 15.6 meters high with grain, with a total height 23.4 meters, design storage capacity 6,500 tons (in wheat). Experimental grain storage warehouses and control are 2006 Northeast-drying corn, moisture was 13.7%, 28.4 mg KOH/100g fatty acid value, bulk density of 720 g/L, 9.6℃ warehousing grain temperature, specific indicators and the corresponding methods followed as table1.

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Table 1. basic Comparison of Q43, Q45, Q53

No.	volume	moisture	density	Fat acid	Storage methods
Q43	5630t	13.7%	720g/L	28.4	fumigation
Q45	5584t	13.5%	723g/L	30.5	Fumigation, cooling
Q53	6504t	13.7%	720g/L	28.4	composite

1.2 Test Conditions and the Initial Preparations

1.2.1 Grain formation and keep a good janitorial positions. Corn warehousing in test positions had been ended in March 4 and grain formation had been end in March 10.

1.2.2 Additional grain surface temperature cables had been set. Under the grain surface temperature measuring 20 cm depth, an additional cable was set. Historical statistics show that local centres of grain with gathered impurities is the more regional site of heating, an additional temperature cable in the grain surface is helpful to strengthen the region's grain temperature tracking.

1.2.3 Development of antibacterial fumigation programme. The average grain warehousing grain temperature is 9.9℃, and basically no insects, pests and mold in accordance with the regularity, fumigation was planned in May.

1.2.4 Fumigant prepared. The warehouse fumigation plans to use active ingredients for 56% of the total 108 kilograms of aluminum phosphide tablets, fumigate three times, the first dose of 54 kg and 27 kg for the following times.

1.2.5 Ready for some fumigation bags. In order to facilitate addition of fumigant, some fumigation bags should be prepared in accordance with quantity and recirculatory fumigation.

1.2.6 Do a good job in the concentration of phosphine, complete concentration table (see Table 2 Q43, Q45, Q53 concentration of fumigation circulation records).

Table 2. Q43, Q45, Q53 concentration of PH_3 in recirculatory fumigation DateQ43

Date	Q43wharf	Q45wharf	Date	Q53wharf
May,22	drug dosage	drug dosage	May,17	drug dosage
May,23	333	359	May,21	613
May,29	923	840	May,24	660
June,5	928	730	May,28	492
June,11	763	462	June,4	267
June,19	603	383	June,11	155
June,26	452	267	June,18	79
July,3	392	180	June,25	24
July,10	788	122	July,2	gas scattered
July,16	710	12/07		
July,24	613	gas scattered		
August,1	467			
August,7	363			
August,14	264			
August,20	190	31/08		
August,28	111	drug dosage		
September,4	491	>1000		
September,11	653	708		
September,18	550	505		
September,25	478	367	October 12	drug dosage
October,2	399	276	October 15	558
October,9	308	193	October 29	600
October,16	225	12/10	November 5	407
October,23	156	scattered gas	Nov. 12	253
October,30	scattered gas		November 15	scattered gas

1.3 Test Methods

1.3.1 Dosing conditions and determination dosage time.

Dose when there are signs of moldy grain or the general development of grain pest and insects. On April 16, 2 insects/kg *Liposcelidate* were found near the west gate of the warehouse and 1 insects/kg *Tribolium castaneum* in the east gate. On May 14, mould had been sighted in the surface of grain with a slight odd smell; pest inspection found 4 insects /m^2 *Sitotroga cerealella*, larvae appeared on the warehouse wall. On May 22, a high concentration of warehouse fumigation operations had been implemented with a dose of 6g/m^3; the total dose was 54 kg per fumigation, administered mainly in the ventilation channels of the warehouse, airtight doors, and on the grain surface. The application methof for the dose was natural dynamic deliquescence.

1.3.2 Conditions, methods and the time set to increase the amount of drugs

When the concentration of PH_3 in the warehouse was below 350 ppm, fumigant should be added from the entrance of axial flow fan which was on the roof of warehouse, fumigant should be divided as parts by plastic bags, grain surface should be also uniformed. According to phosphine concentration reference data, about 27 kg fumigant packed in 18 bags had been put into grain surface on July 3 for the first, while another 27 kg fumigant had been added in the same way on August 31.

1.3.3 Concentration detection and tracking

For the first 12 hours after fumigant circulation, circulating about 24 hours, checking the concentration of stores in 36 hours, when the concentration of PH_3 were twice higher than 500 ppm while the gap was less than 100 ppm, circulation would be stopped. (It could be inferred that the concentration of phosphine in warehouse was nearly in balance, deliquescence of ALP began to slow down). After a week's circulation, each about 12 hours, the concentration had been checked in the following morning before shutdown as specific data in table 2. Data in the table shows that on May 22 for fumigant tests, on May 24 has risen to concentrations above 320 ppm, the scheduled effective inhibitory concentration is close to 350 ppm, to July 3, the concentration was attenuated to 380 ppm initially, according to weekly concentration decay rate, some more fumigant had been added on July 3. There was a maximum concentration of 780 ppm on July 10, after that, then began to gradually decline. On August 7, the concentration attenuated to 360 ppm. In order to find positions at the actual situation, no more drugs had been added then, and the attenuation concentration declined to 190 ppm on August 20. People with air respirator entered the warehouse and inspected grain. It turned out that grain was basically stable. On August 31, fumigant was added twice, the highest concentration of 650 ppm was on September 11, it declined to 220 ppm on October 16, gas had been scattered on October 30 until grain inspection (specific data Table 3).

1.3.4 Grain change tracking.

A combining method of temperature changes detected mainly through the grain system and inspection personnel in the silos had been used during the grain fumigation tracking. In this test, a tentative 38.0℃ is the extreme temperature, which reached the unconditional opening of temperature checks and handling grain. On August 22, temperature data shows that the pilot wharf cable 5#S7 – temperature warehouse slightly higher than that of warehousing, reach to 34.8℃. Since no gas had been scattered, for the sake of safety of stored grain, grain inspection done by person under the premise of security, there was a slight heating in the site about 3 – 5 m^2 grain surface with the remaining part of normal sensory quality. On August 31, 27 kg fumigant had been added for the second time. Temperature was controlled in the heating site and began to decline slowly on September 10.

The experiment began in May, ended in the early November, all – grain warehouses test measures had been carried out smoothly as planned. During the test, the whole situation was basically stable except there was a light heating when the concentration attenuated to 200 ppm in warehouse. As for the contrasts, there were many sites to be fever and the cooling machines had been used to reduce grain temperature. Test warehouse tracking and control positions have been shown in Table 3.

1.4 Results and Analysis

1.4.1 Test results

Data show that phosphine concentration attenuation to about 350 ppm on August 7; on August 22, cable 5#S7 point indicated abnormal warming; there are signs of microbial activity about 15 days after the concentration of phosphine attenuated below the effective inhibitory

concentration. If no additional aluminum phos-

Table 3. Q43, Q45, Q53 custody measures and cost comparison

Q43 Wharf	Q45 Wharf	Q53 Wharf
February 10 to March 2 grain warehousing		
On April 16, some liposcelidate and Tribolium castaneum	On April 23, an anarsia/m^2.	On May 17, the use of 42 kg drug for fumigation,
On May 14, sitotroga cerealella 4/m^2	On May 19, 2 # S7 point 35.1℃, handling grain artificially	On July 2, fumigation scattered gas.
May 22, fumigation, the use drugs of 54 kg	On May 22, fumigation, 45 kg drugs has been used	On July 5, grain fever, the first cold – energy consumption 2 580 kWh
On July 3 additional drugs 27 kg	July 12, gas scattering	On August 2, grain cooling twice, handling local warehouses fever, energy cost 6 038kW. h
On August 22, local minor fever	On July 12, local fever in grain surface, 3 540 kWh energy consumption	On August 7, water spray on warehouse roof for temperature control
On August 31, add 27 kg drugs	On August 6, 20, 27, three single – tube handle local heating ventilation	On August 15, September 21, 25, single tube ventilation handling local anomalies point of grain
On September 10, hot temperature began to drop	On August 31, fumigation, 36 kg drugs had been used	On September 27, the third times cold treatment, abnormal heat, energy consumption 2 280 kWh
In early October 5, gas concentrations below 350 ppm	On October 12, for the second time drug fumigation, the use of 52.5 kg drugs	On October 12, scattered gas.
October 17, unusual warming signs started in grain surface.	On October 12, daily entire warehouse centrifugal fan ventilation, effective	On October 29, roof insulation by water spray ended
Test basically completed by the end of October, fatty acid value was prepared to be checked on November 22		
PH_3 consumption: 108 kg of aluminum phosphide dosage:	81 kg aluminum phosphide	aluminum phosphide consumption: 94.5 kg
Grain cooling 0, electricity: 0	Grain cooling electricity: 3 540 kWh	electricity for three times grain cooling: 10 898 kWh
Single – frequency ventilation tube: 0	0 – frequency ventilation tube: 5: 00 meeting.	Single – frequency ventilation : three times. Water spray roof positions: 82 days.
Tons of grain cost: 0.58 ¥/ton	tons cost of grain: 1.27 ¥/ton	cost: 2.43 ¥/ton

Note: aluminum phosphide 30.00 ¥/kg; tariff 1.00 ¥/kWh; ventilation every single point, three one day 3 kW ventilation fan 36 hours about $3 \times 40 + 3 \times 36 = 228$ ¥; 8.3 tons per day water, 5.2 units of electricity, water priced 1.5 ¥/ton

phide had been added, some localized heating may have occurred in grain. Since more ALP was added twice by the end of August, with the rapid rise in phosphine concentration abnormal temperatures began to fall and were eventually brought under control. This shows that when the heating is still at the preliminary stage (low heat) and microbial activity has started, high concentration of phosphine gas can naturally penetrate into the heating region, so as to effectively curb the momentum of heating. On the contrary, if no dose of AlP had been added timely at this point, microbial activity could not be effectively controlled, with rising temperatures. Temperature control would then be very limited because of the greater difficulty of the gas in penetrating into heated regions. The practical experiences in maize storage work of 2003 in Xinshagrain had been fully confirmed.

On October 2, concentration of phosphine declined to 400 ppm; according to the decay rate, it was speculated it would be reduced to below 350 ppm on October 5. Actually, on October 17, there was an abnormal high temperature on the grain surface (The temperature of #14 cable S6 point did not drop with the warehouse temperature, which reached 32.3℃) and the time interval was 12 days. PH_3 gas had been

scattered until October 31 when the concentrations was below 100 ppm. The following grain inspection found a slight heating area within the radius of the central from the grain surface, about 50 centimetres depth, yet no obvious microbial activity could be seen. It was in an early heating period which was about 25 days after the PH_3 concentration attenuated below the effective concentration. The test had been completed in early November when temperatures gradually declined.

There were no phenomenon of grain storage temperature above the warning temperature (38℃) during the whole test and the whole situation in grain was basically stable. Both the local minor heat anomalies happened 15 days later after phosphine concentration had declined below 350 ppm. If the abnormal temperature was no more than 35℃, it could be effectively controlled by a timely replenishment of concentrations of phosphine.

By contrast, there were significant heating in contrast warehouse before phosphine concentration had been attenuated to 100 ppm.

Quality inspection was also included in test and control positions in warehouses in October and early December, data shown in Table 4: Q43, Q45, Q53. The fatty acid value in the pilot position was 3.3 units higher than in the control store Q53 Wharf, and 0.8 higher than inQ45 warehouse. Further follow-up testing should be conducted since the reproducibility was very poor.

Table 4. Q43, Q45, Q53 Wharf corn fatty acid value comparison

table Wharf	the detection time			
	2007.03	2007.08	2007.10	2007.12
Q43	28.4	–	38.5	41.9
Q45	30.5	38.0	40.7	41.1
Q53	28.4	36.5	38.5	38.6

1.4.2 Test results in accordance with the concentration changes in the drawing concentration of phosphine. According to Table 2 data, mapping changes in the concentration diagrams are as Fig. 1.

1.4.3 Cost analysis: Fumigant, water consumption, electricity consumption, services.

108 kg of AlP costs 3 240.00 ¥; no – cooling, single – tube ventilation and temperature control spray operations; total cost about 0.55 ¥/ton;

81 kg of AlP in Q45 wharf, cost 2 430.00 ¥; grain cooling operating once, power consumption 3 540 kHz, cost 3 540.00 ¥; single tube ventilation 5 – point times, with an average of 3 people/day/point, with 3W ventilation fan 36 hours, that is, each point of the 3 × 40.00 + 3 × 36 × 1.00 = 228.00 ¥ (circles), or 1 140.00 ¥; total cost 1.27 ¥/ton;

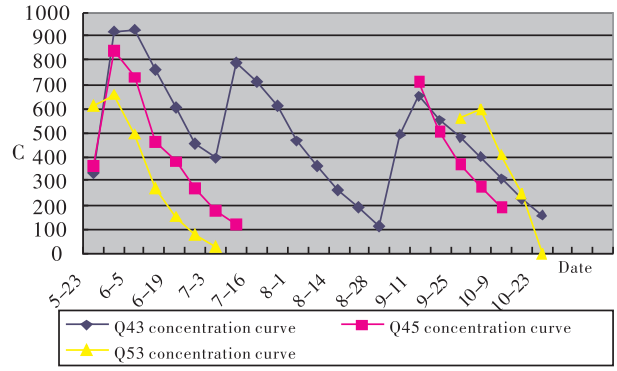

Fig. 1 Phosphine concentration curve

94.5 kg of AlP in Q53 Wharf, cost 2 835.00 ¥; grain cooling operating three times, 10 898 kHz, electricity cost 10 898.00 ¥; partial single tube ventilation 3 – point times, , and about 684.00 ¥; spray 8.3 tons of water daily, 1.5 ¥/ton, pumps, power consumption about 5.2 ¥, a total of 82 days Spray, 8.3 × 1.50 × 82 + 5.2 × 82 = 1 447.30 ¥, the total cost of individual 15 864.30 ¥, the total cost unit is about 2.43 ¥/ton. (Specific data in Table 3: custody measures and cost comparison of Q43, Q45, Q53)

2 Conclusions

2.1 Under the Experimental Conditions, It is Safe and feasible to Control Corn Heating By the High Concentration of Inhibitory PH_3

If the overall temperature is low in grain (about 10℃), there are no obvious mildews, moisture of the corn is about 13.7%, the use of high concentrations of phosphine inhibitory to control corn heating is safe and feasible. Although there were two slight local increases in temperature during the test, these were caused by the activity of microorganisms after the drug concentration decayed below the effective concentration. If the effective concentration of phosphine is maintained above inhibitory levels, safe storage of corn is feasible.

2.2 The Effective Concentration of Phosphine in corn (moisture 13.7%, Temperature about 10℃) to inhibit heating is about 350 ppm for Safe Storage in Summer

Preliminary tests indicate that the effective

inhibitory concentration of phosphine on corn is 350 ppm; when it is below the value, the inhibitory effect will be less or failure will occur. For example, on August 7, the concentration of phosphine is close to the critical value, after half month (on August 22), there appeared abnormal points (5 # cable S7) increasing in temperature, this concentration has been reduced to phosphine about 150 ppm. Also on October 9, the concentration has already begun lower than 350 ppm, to October 16, it has been close to 220 ppm; on the October 31 grain inspection small-scale heating was found.

2.3 With corn Moisture Storage, In Crease of Temperature, Impurity Content, Warehousing Grading Degree of Increased the Inhibitory Concentration Required for Control

There are about six years of experience in the storage of corn in Xinshagrain, which has shown that the higher the moisture in grain, and the quicker heating occurred in grain after storage, the grain surface level under the local aroma ly in the more shallow depth, the higher the concentration of PH_3 required for antibacterial control. The more extraneous matter and broken grains, the worse the effect of infiltration of phosphine; PH_3 inhibitory capacity will be worse, a higher concentration of phosphine is required to reach the same control of effective.

3.4 High Concentration of Antimicrobial Drugs Should be Accurately Used Timely

Practice shows that the inhibitory effect of high concentration and the time of application and fumigation methods are closely related. For example, if the local former fumigation has been obvious fever, even if multiplied increase dosage, antibacterial effects were not evident even failure, it is estimated that with the proliferation of poison gas by the temperature gradient effects.

3.5 High Concentration of Antibacterial Must Maintain the Continuity of Phosphine Fumigation

Historical data show that, partial abnormal heating during high concentration fumigation, and scattered gas treatment used again after the abnormal high concentration of antibacterial storage, often results in poor or worse conditions. The reason may be that the increased oxygen after gas scattering promotes the activities of microbes in grain.

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