0412

The Study on Low Concentration Carbon Dioxide Controlled Atmosphere Storage

Liang Anyu

Abstract: The CO_2 controlled atmosphere granary in Shanghai Grain Depot (China State Grain Reserve) was built in 2003. The minimum value of gas impermeability test in empty/full granary is 5.75 min and 4.87 min respectively. These values meet the design requirement. Furthermore, a package of methods to deal with gas impermeability solves the problems of soft groundwork and arch bar rips, which result from the sedimentation of full granary. On April 4th 2005, we began a study on wheat reserve under CO_2 controlled atmosphere. Specifically, this work took placce in a CO_2 controlled atmosphere granary and a normal granary. Through comparison, it found that: 1. In the wheat granary with the content of more than 3000 tonnes, it took 56 days for the content of CO_2 to decrease from 81.3% to 34.1%. This data can meet the requirement of maintaining effective CO_2 concentrations over the required duration. 2. In the reserved wheat under CO_2 controlled atmosphere, no pests were found, including immature stages. Furthermore, no poison was left. Consequently, it was feasible to use CO_2 as an innoxious insecticide. 3. In a following study, CO_2 was decreased; under the environment of about 30% CO_2, if the duration was more than 60 days or 80 days it could still restrain insects effectively. As a result, insect pests could be inhibited with the long CO_2 duration and the cost could be reduced. In comparison with a normal granary, the CO_2 controlled atmosphere granary has longer-term prevention of insect pests and slower quality deterioration of reserved wheat. 4. The cost of a CO_2 controlled atmosphere granary is higher than in a normal granary. But if CO_2 is held in low concentration and long duration, the cost could be reduced. Compared with phosphine, CO_2 controlled atmosphere can not only kill insect pests but also avoid the harm and pollution of chemical fumigants.

Key words: carbon dioxide, controlled atmosphere, storage grain pest, control, stored grain quality, low concentration

Introduction

Carbon Dioxide gas used for stored grain truly meets the new green theme of application technology security, coordination, and development.

Shanghai locates in the centre of north-south coastline, the eastern part of Changjiang delta, and faces to East Sea at east. Its climate is semi-tropical seasonal wind and has high temperature and moisture for the whole year, which militates against grain storage. In 2003, the state grain reserves Shanghai depot began a study on CO_2 controlled atmosphere granary. It is very difficult to reserve corn in the Shanghai area, especially in high temperature, where corn will heat easily and cause quality deterioration. It is therefore more meaningful to study corn reserve under CO_2 controlled atmosphere in this situation, to make more rational use of facilities and solve the problem of the high temperature of reserved grain. In summary, it can increase the ability to reserve grain in the Shanghai area.

1 The Experiment on CO_2 Controlled Atmosphere to Store Wheat

The technology of CO_2 controlled atmosphere storage is applied, which lies in guaranteeing that the gas dense quality (gas-tightness) of the storehouse satisfies reasonable demands. The gas dense quality test of empty and filled storehouses was used to obtain the design requirements; after wheat is taken into the storehouse, the gas dense quality of the storehouse is maintained, and the contrasted research and application of CO_2 controlled atmosphere storage is conducted. .

1.1 Survey of Controlled Atmosphere Storehouse

The gas dense quality of empty and filled storehouse of CO_2 controlled atmosphere was tested: the lowest of the empty storehouse's gas dense quality is 345 seconds and the longest is 761 seconds, the gas dense quality of solid storehouse averages 308 seconds. It is provided with provision and equipment gas system out-

The State Grain Reserves Shanghai Deport, No. 255 Tonghai Road, Minhang, Shanghai, 200241, China

side of the storehouse, and equipped with a grain storehouse CO_2 automation measurement system.

1.2 Methods on Treating with Gas Dense Quality of Storehouse

(1) The gas-tight treatment of controlled atmosphere storehouse emphasizes on choice, installation and sealing doors and windows. Make all equipment gas-proof.

(2) make gas-tight the chord juncture below the arch board of the controlled atmosphere storehouse. Chooses airproof seam glue, polyammoniaester materials to implement board sew fill and treatment to airproof the storehouse tip.

(3) Pay attention to treatment of craftwork hole, which is easily neglected in the controlled atmosphere storehouse, adapting to have good seal completely to glue knot and touching to change characteristic of high bear to the case of grain; examine pipeline and so on to make gas-tight. .

(4) Introduce general observation, audition, fire candle, instruments and solvent inspection and other measures to find a deficiency.

(5) When testing the gas dense quality of empty and filled storehouse, check the area of leak on the spot, analyze the reason, and clear up and modify at the time.

1.3 Test a Storehouse Circumstance

The trial storehouse is the No. 82 storehouse and No. 81 is the comparison storehouse. Each contained wheat (Table 1).

Table 1. the schedule of controlled atmosphere storehouse and comparison storehouse.

item (unit)	82Camalig	81Camalig
Camalig type	An one – storied house	An one – storied
The valid camalig (t)	3715	3715
Actual quantity(t)	3211	3771
The grain heap physical volume(m^3)	4623	4705
The food heap height(m)	5.6	5.7
Food species	White wheat	White wheat
Habitat	Anhui	Anhui
Go into camalig time	2003	2003
Food grade	2	2
Moisture (%)	13.5	13.1
Miscellaneous quality content(%)	0.9	0.9

1.4 Solid storehouse charge and CO_2 attenuation

The temperature of CO_2 is controlled at ± 5℃ below the storehouse temperature, using low pressure (50 – 150Pa) flow into No. 82 controlled atmosphere storehouse. In order to assure the equality of CO_2 in each quarter of the storehouse and good space distribution, circulate the CO_2 to make its concentration attain relative equality. Everyday we use CO_2 concentration automation check systems to note changes in CO_2 concentration. After charging, the initial average concentration is above 80.0%. After 56 days, the average concentration in the whole storehouse still reached above 34%. As fig. 1 shows, in 2005 and 2006 respectively the time of CO_2 concentration kept above 35% exceeded 15 days, satisfying the requirements of concentration and duration.

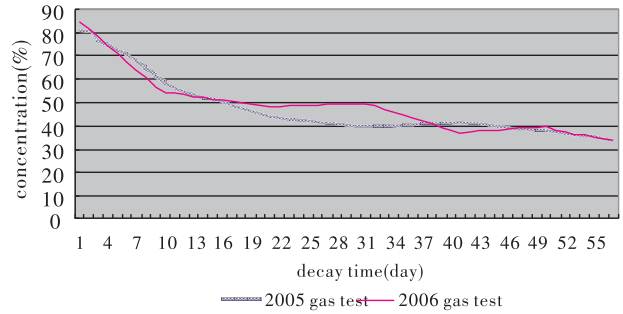

Fig. 1 The average concentration attenuation of CO_2 on wheat in a controlled atmosphere storehouse

1.5 Keep the Grain Pest Prevention and Cure Experiment

We adjusted a trial camalig to the No. 82 controlled atmosphere storehouse to carry on the sampling of the original sample and sample for insect efficacy.

(1) Experiment insect species

Three kinds of main stored grain insects are sensitive to phosphine-corn weevil, lesser grain borer and rust red flour beetle;

Three kinds of main stored grain insects are resistant to phosphine-rice weevil, lesser grain borer and rust red flour beetle; their pH_3 resistance factor is 196, 204 and 8 respectively.

Prepare 10 groups of above-mentioned 6 kinds of stored grain insects (imago and mixed insect form, such as ovum, Aurelia, grub). Every group has above-mentioned 6 kinds of standard imago (2 weeks age) of 20 tested insects respectively and mixed insect forms.

Furthermore, establishing a comparison group, every group contains above-mentioned 6 kinds of standard imago of 20 tested insects respectively and mixed insect forms. After one

month, examine their death rate.

(2) Methods

Place above-mentioned 10 sets of tested insects of 1 – 6 sets 2 meters apart from the wall. Group 7 – 8s tested insect to put in the air-vent neighborhood, Group 9 – 10s tested insect to hang one meter on the grains. Seal to put to go into before the camalig, take out after venting gas. Take out and examine the mortality on 6 kinds of tested insects (the PH_3 sensitive and resistant).

(3) Results

For 6 kinds of main stored grain insects of diversified stages (including imago and insect form, such as ovum, Aurelia, grub), the effect of prevention and cure of CO_2 controlled atmosphere storage attains 100% and has no F1 progeny. It destroys insects 100%; it will not produce harmful residues. CO_2 has no harmful effects.

1.6 Compare the Change of Stored Wheat Quality

Both in No. 82 and No. 81 wheat entered into the storehouse in 2003, and in 2004 was more than one year of the press camalig period. In 2005 – 2006, the change of stored wheat quality was compared in CO_2 controlled atmosphere with normal storage.

Table 2. Wheat quality index by CO_2 controlled atmosphere and normal storage

Examination Time	Gluten absorbs water quantity (%)		Viscosity (cSt)		Taste a grade point value	
	82#	81#	82#	81#	82#	81#
2004.3	206	202	8.4	8.0	76	76
2004.9	200	200	8.0	7.8	78	78
2005.4	216	220	6.8	7.1	79	79
2005.8	218	216	6.1	6.7	76	76
2006.3	208	194	4.4	4.3	76	74
2006.9	197	185	4.3	4.1	75	73

From table 2 we can see that: in the short time storage process, the quality of wheat has been improved to some extent through both CO_2 controlled atmosphere and normal storage because of wheat physiological and technical after-harvesting ripening. With longer storage, CO_2 controlled atmosphere will defer the decrease of wheat quality when compared with normal storage, for example absorption of water by gluten. In view of the good endurance to storage of wheat and better conditions in No. 81 storehouse, the pollution caused by chemical reagent will be avoided and thus the social benefit increased. There are benefits when CO_2 controlled atmosphere storage lasts three years, though there is no evident difference in the short term.

2 Test of Low Concentration CO_2 Over Long Durations

Some related researches indicated that under the condition of 20℃, CO_2 can kill all of the pests in the pile of grains when its concentration is above 60% for 10 days or above 35% for 14 days. We noted that most of the CO_2 controlled atmosphere storage kept the concentration of CO_2 above 60% for less than 10 days, but kept almost all the concentration of CO_2 above 35% for more than 14 days. The average concentration of CO_2 decreased quickly at first and then slowly after charging. In the first 10 days or within 25 days, the concentration of CO_2 decreased at a 2% – 5%/day rate, which made the average concentration of CO_2 decrease from 80% to a lower content, between 30% and 45%。 After that, the average concentration of CO_2 decreased at a distinctly slower rate, thus the average concentration of CO_2 maintained between 30% and 45% for a long time. In the subsequent storage process, we have tried the experiment of low CO_2 concentration and long duration.

2.1 Test Warehouse Situation

Gas test for the No. 82 warehouse stores, Reference the No. 83 warehouse stores, are stored grain corn varieties, casual forms of stored grain, as shown in Table 3.

Table 3. corn Gas warehouse stores basic information and the control list

item (unit)	82#	83#
Camalig type	An one – storied house	An one – storied house
The valid camalig (t)	3715	3715
Actual quantity(t)	3421	3332
The grain heap physical volume(m^3)	4891	4788
The food heap height(m)	5.9	5.8
Food species	corn	corn
Habitat	Jilin	jilin
Go into camalig time	2006.4	2006.4
Food grade	2	2
Moisture (%)	14.2	14.5
Miscellaneous quality content(%)	0.7	0.7

2.2 Low Concentration of CO_2 and CO_2 Attenuation after Long Pressure Test

By the end of March 2007, 82 positions were Kongcang air tightness test, through warehouse inflatable, the Warehouse 60 Pa pressure after the inflatable, attenuation period of 351 seconds. June 18, 2007, all 82 positions filling CO_2, to August 6, after 49 days, the average CO_2 concentration was 42.1%, the slow decay to October 4, the average concentration of CO_2 remains in the low concentration of 25.4% level (Fig. 2): After an inflatable, CO_2 concentrations remained in a relatively low concentration levels for more than 60 days, the average concentration of CO_2 was more than 30% up to 90 days.

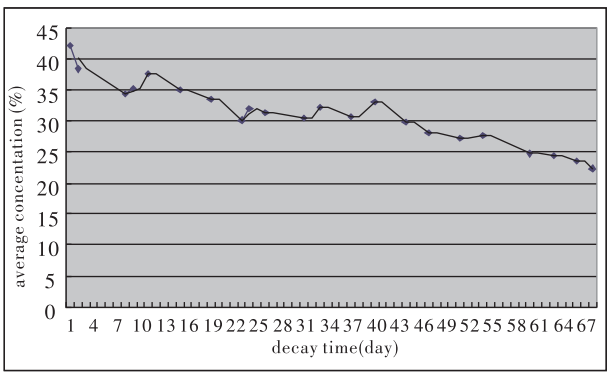

Fig. 2 Gas warehouses average concentration of CO_2 attenuation map

Main factors influencing air-tightness: the warehouse doors and windows sealed warehouses flattened performance and seamless. Improve sealing of windows and doors more easily done, spend relatively less cost and lower warehouse flattened crevice. So in the process of gas transfer, improving warehouse sealing of slowing the average concentration of CO_2 attenuation one of the important factors, but also conducive to the average CO_2 concentration to low concentration level of attenuation should be able to maintain a longer period of time to retard the decline in the quality of stored grain provide favorable conditions.

2.3 maize compared changes in the fatty acid value

82 warehouses and 83 stores are maize in April 2007 warehousing. In 2007, the CO_2 gas-storage and storage of conventional corn changes in the fatty acid value comparison found that the short-term storage, each average value of the fatty acid positions were little changed, their differences are not obvious.

Table 4. CO_2 gas storage and transfer of conventional corn storage fatty acid value test results

Detection time	Fatty acid value (mgKOH/100g dry basis)	
	82#	83#3
2007.5	40.9	41.3
2007.10	42.1	43.7

3 CO_2 Gas Cost Analysis for Stored Grain

Gas warehouse and choose the same kind of warehouse-stored grain costs for conventional warehouses. Analyze only operating costs during the trial period of the two storage; their common costs, such as management fees and staff salaries, are not analyzed.

3.1 Wheat ballast during the CO_2 gas-stored grain fumigation with conventional Comparative analysis of grain storage

Table 5. CO_2 gas-stored grain stored grain and conventional cost analysis table (yuan: RMB)

item (unit)		81#	82#
Variety		wheat	wheat
Grain stack height (m)		5.7	5.6
The actual number (t)		3 771	3 211
The main material costs (yuan)	CO_2	0	5 950
	PH_3	1 092	0
Supplementary material (yuan)		117	117
Grain-grain film costs (yuan)		1 708	0
Grant application (yuan)		48	0
Electricity costs		15	750
Warehouse maintenance costs (yuan)		/	/
Operating costs (yuan)		2 972	6 817
Annual gas consumption per tonne of grain (kg)		0	2.18
The annual cost per ton grain (yuan)		76	76
Annual operating costs per tonne of grain (yuan)		0.79	2.12
Annual operating costs per tonne of grain/The annual cost per ton grain		1.04%	2.79%
Expected proceeds tons of stored grain (yuan)		0	50
Annual Expected proceeds per ton of stored grain (yuan)		0	12.5

As gas was introduced after the new positions were put into use, the trial does not include warehouse maintenance costs and gas-testing equipment maintenance costs. If we consider the test itself, the warehouse maintenance costs 1 657 yuan/year, gas-testing equipment maintenance costs 8 704 yuan/year; conventional tons of stored grain warehouse, the operation cost will be 0. 79 yuan/ton, up from 1. 23 yuan/year tons of gas transfer tons of stored grain warehouse in operating costs will be 2. 12 yuan/ton, up from 5. 35 yuan/ton,

3.2 stored grain corn CO_2 gas fumigation and conventional comparative analysis of grain storage

Corn warehousing, maintenance of a warehouse to store two years of normal maize, produced a warehouse maintenance costs 2 485 yuan/year; Gas positions related equipment maintenance and test, a test maintenance costs 8, 704 yuan/year together were analyzed, as shown in table 6.

Table 6. grain CO_2 gas and conventional grain cost analysis table (yuan: RMB)

item (unit)		81#	82#
Variety		corn	corn
Grain stack height(m)		5.8	5.9
The actual number (t)		3 332	3 421
The main material costs (yuan)	CO_2	0	7 845
	PH_3	3 050	0
Supplementary material (yuan)		117	117
Grain – grain film costs (yuan)		1 708	0
Grant application (yuan)		48	0
Electricity costs		19.5	870
Warehouse maintenance costs (yuan)		2 485	2 485
Verification maintenance costs (yuan)		/	8 704
Operating costs (yuan)		7 427.5	20 021
Annual gas consumption per tonne of grain(kg)		0	2.29
The annual cost per ton grain (yuan)		76	76
Annual operating costs per tonne of grain(yuan)		2.23	5.85
Annual operating costs per tonne of grain/The annual cost per ton grain		2.93%	7.70%

In comprehensive tables 5 and 6 can be seen, consider the storage cycle of corn is shorter than that of wheat and the annual cost higher.

4 Conclusion

The state grain reserves Shanghai depot using CO_2 gas-stored grain, and through a series of warehouse hermetic security measures, three air tightness tests had good results. CO_2 gas – stored grain was 100% effective against to the six major insect pests in stored grain. A pollution-free pesticides method is a green way for grain storage. CO_2 gas used for long-term storage of wheat can delay the decline in the quality of stored grain, playing the role of food preservation. For short term storage of wheat and corn, there was no significant difference between controlled atmosphere storage and conventional storage in improving the quality of stored grain. By improving warehouse sealing of windows and doors, and other measures, raising gas-sealing of warehouses, stores can be maintained with an effective insecticide CO_2 gas concentrations; appropriate extension of the average concentration of CO_2 not only served the purpose of killing pests in stored grain, but also delayed decline in the quality of stored grain. As CO_2 gas costs are high, using CO_2 gas-stored grain storage costs more than conventional treatments. Take into account the normal short storage period of maize, compared to gas-storage maize has a high cost. By improving the air tightness of the warehouse, CO_2 gas consumption can be appropriately reduced, lowering the cost. As people gradually change the concept of consumption, there is increased demand for green products. Allowed under the premise of the policy, through allocation of reasonable market sales channels, the sale price of grain under CO_2 will have certain advantages. In Shanghai, and other high-temperature, high humidity areas, using gas-storage technology will not only bring social benefits, but some potential economic benefits.

Acknowledgement

We thank Dr. Jim Desmarchelier for help with the manuscript.

References

[1] Liu Wei, Guo Lin, Yan Xiaoping, etc. . CO_2 gas-storage control pests of stored grain. Grain storage, 2004 (2) 10 – 14

[2] Gao Ying, Yang Jianxin, Liu Ru – chi, etc. . CO_2 gas – stored grain after the unsealing of the reasons for the changes in the quality and control methods. Grain storage, 2004 (2) 38 – 40

[3] Tu Jie, Guo Road, and Wang Lin, such as double. The state grain reserves Mianyang Deport CO_2 gas – grain the construction of the project. Grain storage, 2002 (4) 43 – 47

[4] Deng Yongxue, go – modulus, of Long Li. High concentration of CO_2 gas – to – marine and miscellaneous Valley bootlegging research. Grain storage, 2002 (1) 3 – 6

[5] Ma Zhongping, Ma Honglin, such as how Le. Carbon dioxide in the atmosphere storage technology in our deport outlined in the application. Grain storage, 2006 (3)13 – 16

[6] Kongxiaoling, Wu Jiang, Jiang Yun, etc. . CO_2 gas – stored grain pest control test Wharf Development and Application. Journal of Agricultural Machinery, 2006 (6):73 – 77