Application of nitrogen controlled atmosphere in grain storage in China

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Abstract

This paper describes the application of nitrogen controlled atmosphere (N2-CA) in grain storage in China, including the principles and the effects of N2-CA in grain storage, controlling storage pests, inhibiting storage fungi, and delaying deterioration of grain quality. Also described N_2-CA storage for different grains, the requirements to maintain grain quality, and gas-filled timing, establishment of relevant standards, and the costs compared to other green grain storage technologies.

Keywords: nitrogen controlled atmosphere（N_2-CA）in grain storage, green, inhibition fungal and control pests, grain quality

1. Introduction

China is a major grain-producing country and also a major food consumer. Fluctuations in food production and the continuity of food consumption requires the state to maintain a certain grain reserves to protect the food supply and to maintain a stable grain market. Chemical methods are used to reduce the loss caused by stored grain insects and fungi. Low-temperature and controlled atmospheres are internationally recognized green grain storage technologies. Low temperature control is not effective in southern China, due to the long summers. Controlled atmosphere treatment is a technology suitable for grain storage in southern China.

2. Nitrogen controlled atmosphere (N_2-CA) applications

From the late 1960s, China has carried out research on low-oxygen grain storage technology using either hermetic storage or introduction of nitrogen into the grain mass. Beginning in 2004, some of China's grain storage depots began large-scale application of nitrogen in stored grain, and results show success with insect control. Some of these results were presented at the 2008 International Conference on Controlled Atmosphere and Fumigation (CAF 2008) in Chengdu. China invested in 9 depots for N_2-CA treatment and gradually expanded the scale. By the end of 2012, storage capacity that could be treated with N_2-CA was more than 10 million tons.

3. Effects of nitrogen controlled atmosphere (N_2-CA) in grain storage

N_2-CA in grain storage involved introducing a high concentration (99.5%) of nitrogen to displace oxygen so that long-term grain storage conditions were 96% nitrogen concentration and 4% oxygen. Existing laboratory tests and practical storage practice has shown that N_2-CA can control insects and fungi.

3.1. The control of stored-grain pests

3.1.1. Pest resistance to PH3

Phosphine resistance is increasing, as documented by the Chengdu Grain Storage Research Institute (Fig. 1). The number of highly-resistant strains is increasing.

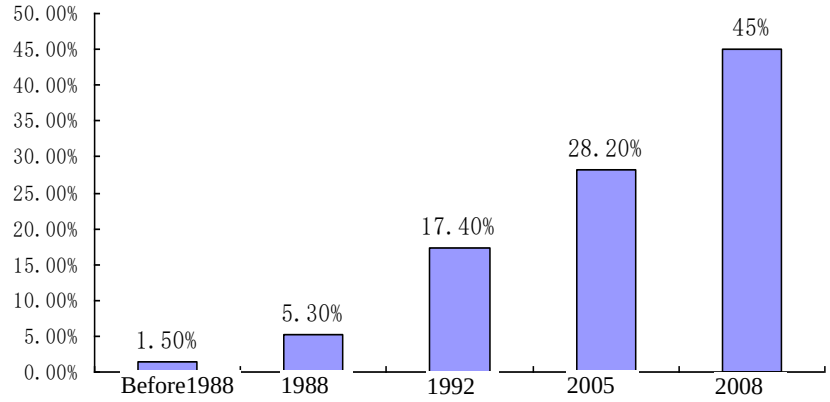

Figure 1 The Highly-resistant strains in the proportion of survey.

Scientists at the Chengdu Grain Storage Research Institute have done laboratory tests. Conditions were: two nitrogen concentration ranges (96 to 98% and 98% to100%), temperature at 25 ± 1°C, with different test insects and life stages (Table 1).

Table 1 Different nitrogen concentrations lethal time of stored-grain pests (day).

	Control of adult ($LT_{99.9}$)		Inhibition of eggs, pupae and larvae ($LT_{99.9}$)	
	98%~100%	96%~98%	98%~100%	96%~98%
Sitophilus zeamais Motschulsky	5.57	6.55	18.95	14.22
Rhizopertha dominica (Fab.)	10.94	68.40	19.04	37.97
Tribolium ferrugineum Fab.	4.48	21.16	4.33	15.03
Oryzaephilus surinamensis (L.)	4.48	16.51	4.15	10.34

3.1.3. Low oxygen control stored-grain pests at 30°C

Researchers at the Academy of State Administration of Grain have done relevant experiments in the laboratory at 30 ± 1°C, 75 ± 5%R.H. and 100% high-purity nitrogen conditions with different stored product species as test insects. LT values were determined for different exposure times.

3.1.4. Nitrogen concentrations at different temperatures

Previous studies have shown [5] that the lethal effects of nitrogen were related to temperature. At a moisture content below 12% and a nitrogen concentration of 98 to 100%, 28 days were need for complete kill but at 18°C 105 days was need to achieve the same insecticidal effect. When the O_2 content was less than 1.0% and was maintained for at least 20 days, satisfactory control was achieved. Other data are summarized in Table 2.

Table 2 The maintain time of N_2-CA at different temperatures, different concentrations to control stored pests (Day).

Nitrogen Concentrations	The maintain time of N_2-CA at different temperatures to control stored pests.		
	17ºC	25ºC	30ºC
≥95%	-	-	60
96%~98%	-	70	21
≥98%	105	28	14

3.1.5. The practical application of nitrogen

The practical application of N_2-CA in stored grain shows that the effect of N_2-CA control pests are closely related to the nitrogen concentration and processing time. The efficacy of N_2-CA is closely related to the pest species, nitrogen concentration, grain temperature and exposure time.

3.2. The inhibition of grain fungi

Oxygen has a significant effect on the metabolic activity of fungi. When the oxygen concentration is < 2% most fungi cannot reproduce. However, some species can tolerate a low oxygen environment, and only pure nitrogen will eliminate those fungi. Reducing grain moisture content is necessary for complete elimination of fungi.

3.3. Delaying the deterioration of grain quality

3.3.1. Preservation of grain and oil quality

Grain quality deteriorates more at high temperatures compared to low temperatures. Nitrogen control is more effective at high temperatures compared to low temperatures because there is more quality loss at high temperatures. Nitrogen can also help in maintaining quality parameters such as germination rate, fatty acid value, crude fat content, soluble protein and nitrogen solubility indexes.

4. Construction and operating costs

The main two cost components of N_2-CA are depreciation of fixed assets investment and operating costs. Costs and scenarios are compared in Table 4.

5. Prospects

With the gradual improvement of living standards, people have higher demands on food quality, nutrition, and taste. N_2-CA grain storage technology as an advanced green technology, and construction and application in China is feasible. In recent years, the success of application in some depots illustrates the technology has a solid foundation. N_2-CA technology will be applied and developed more to improve the grain market system.

Table 4 The additional cost of different green storage technology.

Storage Technology		Effects	Additional Cost（yuan/ton）
Refrigeration	Mechanical refrigeration	average temperature below 18ºC, local max. 22ºC	20.34
	Air-condition	average temperature below 18ºC, upper average max. 22ºC	4.17
Insulation	Five-sided cover, polystyrene board gland	upper average max.25ºC, other average max.20ºC	2.87
	Five-sided insulated by rice husk bag	upper average max.20ºC, other average below15ºC	2.19
	Bubble-type composite insulation blanket gland	upper average max.25ºC, other average below20ºC	2.24
N_2-CA	nitrogen controlled atmosphere	Pest control, preservation, inhibit mold	2.90
	Combine temperature control and nitrogen controlled atmosphere	Pest control, preservation, inhibit mold, average temperature below 25ºC； Cold season, the maximum temperature below 22ºC, the hot season temperatures higher than 28 ºC point does not exceed the grain pile surface 20% of the total number of test points, no more than 60 days	5.40
Carbon Dioxide Controlled Atmosphere	Fixed carbon dioxide controlled atmosphere	Pest control, preservation, inhibit mold	4.77
	Mobile carbon dioxide controlled atmosphere	Pest control, preservation, inhibit mold	4.12