The great achievement of grain storage scientific research in China

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The 7th IWCSPP will be held in China This is a great event for scientists of grain storage in China at the end of this century Not only will we warmly welcome our friends from all over the world, but also we want to take advantage of the chance to introduce the achievement of scientific research of grain storage in China We believe it is useful for each of our guests to know about the current development in China

As you may have already seen, we published an English book named '*Chinese Grain Storage*' which was written by more than ten experts Jin Zuxun's paper '*A Retrospect of the Development of China's Grain Storage Scientific Research*,' published at 'Journal of the Chinese Cereals and Oils Association' special 1997, was also sent to each of you At present, the general condition is China has an extremely long history of grain storage technique, During the past fifty years, China has made delightful achievements in the grain storage scientific research The great progress in grain storage technique and facilities is due to scientific research achievements I would like to give you a brief introduction on three topics as follows

1. **A Retrospect of History of China's Grain Storage**

Chinese ancestors began to store grains and other seeds at least 7000 to 10000 years ago

1.1 **Grain**

1 1 1 The paddy which was first excavated is 10000 years ago in Dao County, Hunan Province

1 1 2 The millet which was first excavated is 8000 to 7500 years ago in Ci-shan County, Hebei Province

1 1 3 The wheat which was first excavated is 5000 years ago in Min-le County, Gansu Province

1 1 4 The sorghum which was first excavated 5600 years ago in Zhengzhou, Henan Province

1 1 5 The soybean which was first excavated 2300 years ago in Hou-ma County, Shanxi Province

1 1 6 The maize which was first excavated 2000 years ago in Xing-yang County, Henan Province

1 2 **Grain Storage Facilities (real object)**

1 2 1 The 'frame-style' grain storage facilities (house made of wooden bars for the purpose of good ventilation and moisture control), which came into use 7000 years ago in Yu-yao County, Zhejiang Province

1 2 2 Underground cellars for grain storage, beginning 6000 to 7500 years ago (excavated in Xi'an, Shanxi Province)

1 2 3 Underground brick-up grain depots, originating 2000 years ago (excavated in Luoyang, Henan Province)

1 2 4 House-style earthen wall grain depots with holes on the walls for natural ventilation, beginning 2000 years ago (remains in Dunhuang, Gansu Province, Ming Dynasty horizontal depots in Zhangye, Gansu Province, Qing Dynasty horizontal depots in Dunhuang, Gansu Province,)

1.3 **Grain Storage Implements (Funerary Objects)**

1 3 1 Horizontal warehouse with windows on the top for ventilation and frame at the bottom for easy air circulation, beginning Han Dynasty, 221B C – 206B C

1 3 2 Multi-storied grain warehouse, beginning Han Dynasty 206B C – 220A D (four-storied house, excavated from Jiaozuo, Henan Province Three-storied house, excavated from Yiyang County, Henan Province Two-storied house, excavated from Pinggu County, Beijing City)

1 3 3 Dumpy grain bin, excavated from Henan Province originating in 206B C – 220A D

1 3 4 Dome style grain warehouse , excavated from Henan, Hunan, Hubei, Anhui, Guangdong, Beijing, Jiangsu, Gansu Provinces originating in 206B C – 220A D

1 4 **Experience of Management**

In China's Xia and Shang Dynasties, grain production was already advanced By the Qin and Han Dynasties, much experience had been accumulated concerning the grain storage management

1 4 1 Each Chinese dynasty paid attention to the grain accumulation

1 4 2 Each Chinese dynasty paid great attention to management and adjustment functions of the storage system

1 4 3 Each Chinese dynasty paid great attention to implementation of grain storage techniques and policies

· On the safety norm of grain supply and sales The

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ancient China proposed one year storage for three years cultivation

- On the minimum norm of grain preservation loss
- On the disposal of old grain and change for the new
- On the storage of paddy instead of rice

1 4 4 Each Chinese dynasty paid great attention to the development and improvement of grain storage technique

- The grain depot facilities for draft which came into use 7000 years ago
- Application of natural plant as protectants in stored grain (for the former, see book of Fan-sheng, for the latter, see the Rites of Zhou), the former starting in 206B C －220A D , the latter starting in 1100B C － 771B C
- Technique of rodents control, beginning 2 6B C, － 220A D (Sichuan Province, Han Dynasty grain storage depots with pictures on the bricks)
- Design and construction of warehouse, see Agriculture Book of Wang-zhen in Ming Dynasty

Grain quality and quality control, beginning 206B C － 220A D

2. The Progress in the Scientific Research of Grain Storage

Although our country has an extremely long history of grain storage technique, the scientific research of grain storage started at the beginning of this century, more thorough and systematic studies were conducted fifty years ago In the middle of the 1950's, institutions for grain science and research were set up In the middle of the 1960's the Research Institute of Grain Storage was established (the grain bureaus of various provinces, cites, and autonomous regions also began to set up grain research organizations) Since the 1970's, the research has been made more thorough, especially the 'Modern Grain Storage Technique', which was listed in the key science and technique programs for the sixth, seventh and eighth 'five-year plans', and gained nearly 200 principal achievements, ten of them approached the international level A few of important research aspects are presented here

2.1 The applied basic and theoretical research work

2 1 1 Regional fauna investigation of the Chinese stored pests and relevant biological and ecological studies

2 1 1 1 Regional fauna investigation of stored pests

Table 1 Regional Fauna Investigation of Stored Pests

Order	Researchers	Species	Investigation time	Publishing year
1	Bureau of Grain Storage and Transport of the Food Ministry	43	1955	1957
2	Bureau of Grain Storage and Transport of the Food Ministry	59	1957	1959
3	The food Ministry and Research Institute of Entomology of the China Academy of Science	63	1956－1958	1959
4	The National Investigation Group of Stored Pests Distribution under the Food Ministry	174	1974－1975	1976
5	The Food Ministry and the Ministry of Forestry and Agriculture	194	1980－1982	1983

By the end of 1995, 242 species of stored product insects had been found in whole China The insects belong to the following 10 Orders, 52 Families and 143 Genes Among these insects, 140 species are stored grain insects, in which 128 species are pests and 12 species are natural enemy insects

2 1 1 2 Research on biology of stored grain pests

From the 1950's to present, many Chinese entomologists have been researching the insect biology, which includes insect life cycle, life span, generation number per year, feeding habits, place of living through winter, methods and behaviors of reproduction, etc The following species' biology have been studied by Chinese specialists

Sitophilus zeamais (Motschulsky)
Sitophilus oryzae (L)
Sitophilus granarius (L)

2 1 1 3 Research on ecology of stored grain pests

From the 1930's, our entomologists had studied the influence of different entomological condition on growth and reproduction of stored grain pests Since the 1970's, the research has been made more thorough, including

- Entomological system of stored grain
- Physics entomology of stored-grain pests
- Community entomology of stored-grain pests
- Math entomology of stored-grain pests
- Economic entomology of stored-grain pests

2 1 2 The classification and identification of stored-grain pests

Chinese specialists have made lots of classification and identification for stored-product pests investigation and the related research

- 1931－1973, classification and identification according

to morphological observation

- 1974-present, applying comparative anatomy along with morphology observation
- Observing chromatin of pests and their hybrids
- Classification and identification by gas chromatography, scanning electron microscope
- Identification by enzyme chemistry

2 1 3 Research on stored-grain pests resistance

- Research on resistance of primary stored-grain pests to phosphine(PH_3)
- Studies on resistance of primary stored-grain pests to common pesticides in China
- Studies on cross-resistance of *Sitophilus zeamais* (Motschulsky) to a few organic phosphine protectants
- Studies on counter-measure of stored-grain pests resistance

2 1 4 Research on stored-grain mites

2 1 4 1 Investigation and classification of stored-grain mites

From 1957, some specialists have investigated stored-grain mites, and recorded principle stored-grain mites in China, which including

Tyrophagus putrescentine (Schrank)
Aleuroglyphus oratus (Troupeau)
Suidasia nesbitti Hughes
Carpoglyphus lactis (L)
Lepidoglyphus destructor (Schrank)
Cheyletus malaccensis Oudemans

More than 100 species stored-grain mites have been recorded in China, which belong to Acaridida, Oribatida, Actinedida and Gamasida In these mites there are 60 species of acarid mites and 10 species of cheyletida mites

2 1 4 2 Biology of stored-grain mites

Chinese scholars have researched biology of *Aleuroglyphus oratus* (Troupeau), *Carpoglyphus lactis* (L), *Suidasia nesbitti* Hughes and *Cheyletus malaccensis* Oudemans, and recorded their life cycle, generation, overwintering, habit of laying egg, behavior and feeding habits

2 1 4 3 Ecology of stored-grain mites

The grain pile is a complicated ecosystem Chinese specialists have mainly studied

- Stored-grain mites in grain bulks
- Dynamic of population
- The influence of temperature, moisture and seasons on growth and decline of stored mites

2 1 5 Stored-grain microbiology

2 1 5 1 Investigation of cereals and oils microflora in China

Some specialists investigated microfloras of paddy and wheat in China during the 1950's Some specialists investigated microfloras of main cereals and oils in China during the early 1980's

- Microflora of paddy (1981 – 1983)
- Microflora of wheat (1981 – 1983)
- Microflora of maize (1980 – 1983)
- Microflora of peanut (1986)
- Microflora of rapeseed (1982)

There are 182 species of molds belonging to 50 genera identified in Chinese microflora investigations of that is mentioned above (three species of grains and two species of oil materials), the important mold genera of Chinese grain microflora are (table 2)

Table 2. The important mold of Chinese grain microflora

Ecological type	Mold name	Paddy	Wheat	Maize	Peanut	Rape seed
Filed fungi	*Alternaria*	1	1	3	4	1
	Fusarium	2	3	1	1	4
	Phoma	3	+		3	+
	Cladosporium	6	2	4	5	3
	Halminthosporium	5	4	+	+	+
	Nigrospora	4	+	+	+	+
	Epicoccus	+	6			
	Chaetomium	+	+	5	+	+
	Cephalosporium	+	+	2	+	2
	Trichothecium	+	5	+	+	+
	Trichoderma	+	+	6	+	+
	Rhizoctonia	+	+		2	+
Stored fungi	*Aspergillus*	1	1	2	1	1
	Penicillium	2	2	1	2	2
	Rhizopus	4	4	+	3	
	Mucor	3	3	+	4	3

* * 1、2 Dominant genera and their order of importance
\+ Common genera

2 1 5 2 Studies on factors of rice yellowing and reddening

2 1 5 3 Studies on the influence of various stored techniques on succession patterns of grain microbe

- Relation between stored-product fungi and grain quality
- Succession patterns of stored-grain microorganism in controlled atmosphere storage

The influence of fumigants on stored-grain microbe

- The influence of protectants on stored-grain microbe
- The influence of draft, cooling and drying on stored-grain microbe

2 1 6 Mycotoxins of stored grain

Mycotoxins found in grain in China are mainly aflatoxins and fusarium toxins, sterigmatocystin (ST) and Ochratoxin A (OA) are found at intermediate frequencies

Research works on wheat scab has been developed in China since the 1950's Since the 1970's, the main research works on grain mycotoxins are

2 1 6 1 Studies on aflatoxins forming, damage degree, detective methods, and mechanism and methods of detoxification

2 1 6 2 Isolation, purification and identification Don from gillerella damage wheat, setting up thin layer chromatography (TCL) for determination of Don, establishing enzyme-linked immunity-sorbent assay (ELISA) for determination of T-2 in wheat, establishing monoclonal antibody and an immunological assay of wheat F-2 toxins

2 1 6 3 Isolation, purification and identification of sterigmatocystin (ST) and establishing ST thin layer chromatography

2 1 6 4 Establishing determination and methods of Ochratoxin A (OA)

2 1 7 Studies on grain quality

Much research work has been done on quality of main grains since the 1950's, Since the 80's, comprehensive and system research has been done

2 1 7 1 Comprehensive investigation on grain quality in China

Table 3. Comprehensive investigation on grain quality in China

Kind of cereals	Investigation time	Investigation scopes	sample		result
			Commodity samples	Species samples	
Paddy	1982～1984	14 provinces and regions	3223	920	Determination report
Wheat	1982～1984	11 provinces and regions	2523	314	Determination report
Maize	1985～1987	14 provinces and regions	615	113	Determination report
Bean	1983～1985	13 provinces and regions	1335	195	Determination report

2 1 7 2 Studies on quality characteristic of Chinese grain

- Paddy Major research on relation of amylose content and physical character between technological quality and edible quality

Wheat Main research on relation of wheat unit between flour yield, relation of wheat sedimentation value between edible technological quality, bringing forward regression equation for appraising quality

2 1 7 3 Research on Chinese grain nutrition

Few experts engaged in nutrition research in the 1930's The nutrition quality of cereals and oils and their processing products were systematically analyzed by medical and grain research departments in the 1950's The body nutrition by different edible ways of few varieties had been tested in the early 1960's Protein quality of Chinese main cereals had been roundly appraised for nutrition in the 1980's

2 1 8 Research on the index of deterioration

Chinese experts had done lots of research works on deterioration index of grain quality in the 1980's, and researched the possibility of valuing and controlling storage quality of cereals and their processing products by regression equation Researchers had determined great deal of species samplers from different areas, different number of storage years and different storage conditions, got related data, and obtained regression equation based on edible quality, of which the best precision is

- Paddy

Long-grain nonglutinous paddy $Y_L = 65\ 7 + 0\ 07X_{germination} - 6\ 25X_{fatty\ acid\ value} + 1\ 70X_{viscosity}$

Short-grain nonglutinous paddy $Y_s = 80\ 63 + 0\ 005X_{germination} - 0\ 61X_{fatty\ acid\ value}$

It is proved that 65 marks can be regarded as the standard for grain being out of granary in rotation, but if the fatty acid value > 25mgKOH/100g (dry sample) or viscosity value > 3 0CST, it also can be regarded to be out of granary in rotation

- Maize $Y_{corn} = 75\ 5 + 0\ 10X_{germination} - 0\ 34X_{fatty\ acid\ value}$ If the score over 80 marks is suitable for long storage, the score of 65 is the basic standard for corn being out of granary in rotation
- Soybean It is proved that PST (total of soluble phosphatide /total phosphatide)can be used as staleness

index of soybean

$Y_{PST} = A_0 - (B_0 + K_T)X_0$

(A_0, B_0, K are constants, T is storage temperature, X is storage time)

It is known that PST has a positive relativity with NSI (water-soluble nitrogen index) and germination, but has a negative relativity with acid value, the relative coefficients were 0 89, 0 64 and −0 86

Table 4. Lethal concentration and time of PH_3 to several stored-product insects

Name	Temperature (℃)	Action time (h)	Lethal concentration (mg/l)	Researcher
Sitophilus oryzae (L)	30	72	0 029	Shanghai grain research institute
Sitophilus zeamais (Motschulsky)	26 − 29	72	0 018 − 0 020	Zhengzhou grain college
Rhizopertha dominica Fab	25 − 30	48	0 038	Shanghai grain research institute
Lasioderma serricorne (F)	20 − 29	72	0 020	Zhengzhou grain college
Tribolium castaneum (Herbst)	20 − 29	72	0 027	Zhengzhou grain college
Oryzaephilus surinamensis L	20 − 29	72	0 022 − 0 025	Zhengzhou grain college
Trogoderma granarium Everts	25 − 30	48	0 040	Shanghai grain research institute

Table 5. Adsorption of various cereals to PH_3 (%)

Sorghum	89 0	Millet in husk	65 1	Flour	28 6
Peanut	86 1	Maize	50 1	Rapeseeds	25 8
Long-grain nonglutinous paddy	82 8	Wheat	41 4	Red bean	19 2
Kidney bean	80 7	Millet	33 8	Yellow bean	13 8
Glutinous paddy	79 3	Pea	31 2	Green bean	12 1
Sesame	68 4	Rice	28 8	Broad bean	11 0

* 30℃ , 21 days, and 0 5g/m^3(PH_3)

Table 6. Synergism of lowering O_2 and increasing CO_2 in atmosphere to PH_3

Insect species	Common atmosphere LC_{50}	O_2 12%, CO_2 4% in atmosphere		O_2 4%, CO_2 8% in atmosphere	
		LC_{50}	Synergism coefficient	LC_{50}	Synergism coefficient
Sitophilus oryzae (Chuan F22)	0 0115 (0 0105 − 0 0125)	0 0089 (0 0078 − 0 0099)	1 29	0 0039 (0 0028 − 0 0051)	2 95
Sitophilus oryzae (Guang S12)	0 8638 (0 8321 − 0 8342)	0 5224 (0 5110 − 0 5338)	1 65	-	-
Sitophilus zeamais (Chuan F9)	0 0079 (0 0068 − 0 0089)	0 0063 (0 0053 − 0 0074)	1 25	0 0048 (0 0037 − 0 0059)	1 64
Rhizopertha dominica (RRd4)	0 0058 (0 0048 − 0 0068)	0 0045 (0 0030 − 0 0060)	1 29	0 0030 (0 0020 − 0 0041)	1 93
Rhizopertha dominica (RRd7)	0 0077 (0 0067 − 0 0086)	0 0054 (0 0037 − 0 0070)	1 42	0 0035 (0 0024 − 0 0045)	2 20
Oryzaephilus serricorne (ROs1)	0 0057 (0 0046 − 0 0068)	0 0043 (0 0032 − 0 0054)	1 32	-	-
Oryzaephilus serricorne (Ros2)	0 0059 (0 0048 − 0 0070)	0 0041 (0 0031 − 0 0052)	1 44	-	-
Tribolium castaneum (RTc4)	0 0082 (0 0072 − 0 0093)	0 0071 (0 0061 − 0 0080)	1 15	0 0052 (0.0042 − 0 0062)	1 58
Tribolium castaneum (RTc6)	0 0089 (0 0079 − 0 0099)	0 0065 (0 0055 − 0 0075)	1 37	0 0040 (0 0030 − 0 0051)	2 22

1 Synergism coefficient $= \frac{\text{Common atmosphere } LC_{50}}{\text{Control atmosphere } LC_{50}}$ 2 Intense resistance strain

Table 7. Dosage, tightness time, releasing time and the lowest grain temperature of PH_3 fumigation

Medicine name	Purity (%)	Dosage (g/m³)				The least time of freeing gas (days)	The lowest temperature of fumigation
		Space	Grain bulks	Factory and apparatus	Tightness time after dispensing		
Aluminium phosphide(table)	56	3-6	6-9	4-7	3-15	2-10	over 10
			1 5-2*		over 45	1-2	over 10
Aluminium phosphide(powder)	85-90	2-4	4-6	3-5	3-15	2-10	over 10
			1-1 5*		over 45	1-2	over 10
Zink phosphide	90	3-6	8-13	5-10	3-15	3	over 10

* low dosage fumigation, which uses low O_2, slow releasing, airflow and intermittent fumigation at long tightness time

2.2 **Research on applied technique**

2 2 1 Technique of stored-grain control

2 2 1 1 Technique of chemical control

A Fumigants

Our country usually used phosphine (PH_3) as fumigants, and have done great deal of research work since the 1960's Chloropicrin had been used in the 1950's, it is seldom used at present Mathyle is mainly used in quarantine fumigation Research on PH_3 including

- Efficient (dosage, tightness time, control result)
- Factors of effecting efficient (different species, various stage, different temperature, absorbability of grains to PH_3, granary of different sealed condition and performance, airflow in grain bulks)
- Gas diffusion law of horizontal warehouse and silos
- Toxicity of PH_3 to human being
- The synergism of lowering O_2 content and increasing CO_2 content to common pests
- Operational methods of different PH_3 fumigation techniques (controlled atmosphere fumigation, airflow fumigation, circulation fumigation, intermittent fumigation and slow releasing fumigation)
- Dispensing apparatus
- Combustion condition and preventing

B Protectants

The thorough research on protectants began from the 1950's Protectants which we had researched in the 1970's and the 1980's were malathion, fenitrothion, pirimifos-methyl, deltamethrin and mixture of organophorous with deltamethrin About the cereal protectants being used in China at present, please see table 8

2 2 1 2 Techniques of non-chemical control

2 2 1 2 1 Research on technique of physical control

A Low temperature control by refrigeration At −5℃ ~ −6℃ and keeping the temperature about a week, pests in grain can be effectively killed

B Pests control by electromagnetic wave

- Applying solar energy
- Applying infrared ray
- Applying microwave
- Applying γ-ray

Lethal dose 40000R can kill eggs of *Callosobruchus chinensis* L , 20000R can inhibit its damage, the lethal dose for killing *Tribolium castaneum* Herbst and *T confusum* Duval is 80000R

Sterile dose 60000R can cause the sterilization of adult of *Sitophilus zeamais* Motschulsky

Incomplete sterile dose 2500R can breed the incomplete sterile adult of Plodia interpunctella Hubner

Control by laser Control insects by YAG laser is proved that 5w/cm² or 8w/cm² have better lethality to *Sitophilus zeamais*, radiation time is 10 or 20 seconds

2 2 1 2 2 Research on biological control techniques

A Research on stored-product control by predatory insects (*Xylocoris flavipes*, *Xylocoris sp*, *Montrouzier etsignatet*)

B Research on trapping and killing stored-product pests by pheromones

- Research on space-time dynamic law and utilizing behavior technique of stored-grain pests
- Research on various kinds of trap inspection techniques of stored-grain pests

C Research on stored − product pests control by hormones (juvenile hormone)

2 2 1 2 3 Research on plant insecticides

A Study the stored-product pests control effect (including lethal, attractive killing repelling) of seeds, leaves and roots of Melliaceus plants and other wild plants

B Study stored-product pests control effect of natural volatile plant oil and edible plant oils (Litsea cubeba, perfume plant oil)

C Study stored-product pests control effect of perfume and acrid plants

2 2 2 Techniques of molds control

Since the 1950's Chinese experts have done lots of research work on molds control On the one hand, experts deeply studied the relation of mold ecology between various ecological factors, on the other hand, mainly studied emergency control molds measure of high moisture grains

Table 8. Several species of protectants by practices and experiments in China

Agency name	Common dose	Application method	Pests kind by control	efficiency	Comparison
Malathion	State granary 10 – 20ppm, Rural granary 15 – 30ppm	Spraying or mixing with powder, mixing insecticide with husk	Wide spectrum insecticide, there are better effect on *Sitophilus*, *Oryzaephilus* and *cucujidae*, but worse effect on *Rhizopertha dominica* and *Ptinidae*	1 year, but primary density of pests is below 4 /kg	
Fenitrothion	10ppm	Spraying or mixing	Wide spectrum insecticide, good effect on *Sitophilus zeamais* and *Tribolium castaneum*, better effect on *Rhizopertha dominica* at high dose	Over one year	The effect is better than malathion, the dose can be declined 1/2～1/3
Chlorpyrifos-methyl	10 – 20ppm, 5 – 10ppm	Spraying or mixing	Can effectively control stored beetles, moths and mites, 20ppm can effectively control *Rhizopertha dominica*	Over one year	The effect is better than malathion, toxicity of mites control is higher than pirimifos-methyl
Pirimifos-methyl	5ppm, 10ppm, 20ppm	Spraying or mixing	Wide spectrum insecticide, can control various stored pests, especial *Rhizopertha dominica*	Half year or one year	The effect is better than malathion, the effect on Dermataphagoides farinae is better than other protectants, stability is the best standing
Deltamethrin	0 5 – 1 0ppm	Spraying or mixing	Wide spectrum insecticide, best effect on *Rhizopertha dominica*, unobviously effect on mites	One year	The effect is better than malathion
Piperonyl butoxide	0 5 – 1 0ppm	Spraying or mixing	Wide spectrum insecticide, obvious effect on *Rhizopertha dominica*, *Sitophilus zeamais*, *Tribolium castaneum*	One year	Synergism, and lowering dosage
Malathion + deltamethrin	20ppm, 0 2ppm	Spraying or mixing	Wide spectrum insecticide, obvious effect on *Rhizopertha dominica*, *Sitophilus zeamais*, *Tribolium castaneum*	One year	Synergism and reciprocal reinforce control spectrum, then lowering dosage
Fenitrothion + deltamethrin	10ppm, 0 2ppm	Spraying or mixing	Wide spectrum insecticide, can control various stored pests	One year	Reciprocal reinforce control spectrum
Chlorpyrifos-methyl + deltamethrin	10ppm, 0 2ppm	Spraying or mixing	Wide spectrum insecticide, can control various pests and mites	One year	Synergism and reciprocal reinforce control spectrum

2 2 2 1 Research on stored-grain fungus and ecological factors

According to biological character of grain microbes, some experts in China studied the effect of various ecological condition on fungus growth and development, to decrease fungus damage by controlling ecological environment Different moisture rice were stored at different temperature and O_2 concentration condition, succession law of stored-grain microbes is different Studies proved At the temperature of 30℃, rice with 14 5% moisture can prevent *Aspergillus candidus* growth, but can not inhabit *Aspergillus glaucus*, only by decreasing O_2 concentration to below 0 5% at the same time, growth of *A glaucus* can be completely prevented

2 2 2 2 Research on emergency treatment measure of high moisture grains

We had studied and experimented some fungistats, which were

A Ammonium sulfite 0 4 – 0 8(w/w) ammonium sulfite treats paddy, rapeseeds and peanut 5 – 7 days

B N-butanol 0 3%, 0 5% (w/w) n-butanol treats wheat, corn, paddy and peanut 15 – 20 days

C Propionic acid and butyric acid 0 3% concentration has better effect of treating paddy

D Propionic acid and ammonia water mixture of proportion 2 1, which can effectively control corn molds

E Ozone (O_3) ozone concentration gets 0 80 – 1 07g/m^3, which can effectively control molds of rice, wheat and corn

2 2 3 Research on grain storage techniques

2 2 3 1 Research on grain storage by temperature control

A Low temperature and high temperature airtight storage

- Low temperature storage in covered airtight enclosures The proper time of putting on the covered material is at the end of winter when grain temperature is 0 – 5℃
- High temperature storage in covered airtight enclosures wheat and peas with moisture content of less than 12% may be put into sealed enclosure after exposed to sunshine, getting to the temperature of 46 – 50℃, then stored 3 – 4 weeks, pests can be killed

B Low temperature storage by refrigeration

- Cooling storage by air-conditioner
- Cooling storage refrigeration units The type of refrigeration units are 2FV10, L-3 5, KD-10, Kd-20

2 2 3 2 Ventilation of grain storage

Ventilation has been the major technique of grain storage in China for 40 years, it has been rapidly developed in the 1980's and applied in practice Main research work including

A Selection on the type of horizontal warehouse blower

B Selection on ventilation form (including single-pipe, multi-pipe, box-type, geosycline ventilation by under-floor air duct, cage duct on the ground) and experiment

C Electric simulation experiment and determination of the main parameters in mechanical draft room of grain bulks, and ventilation system design

D Experiment and design of granary ventilation control system

E Research and applied experiment of heat preservation and adiabatic materials

F Application of computers for ventilation management and control

G Research on mechanical draft parameters of silos

H Designed equipment which combine silo draft with pesticide application outside the silo, and full granary experiment

I Research and formulation of ventilation operation sheet

2 2 3 3 Research on controlled atmosphere storage

Controlled atmosphere storage has a long history in China, the thorough research has been carried out since the 1960's

A Research on natural oxygen-deficient atmosphere storage

- Species of cereals paddy, wheat, rice, peas, oil-bearing material (rapeseed, peanut)
- Sealed material polyvinyl chloride (PVC) or polyethylene (0 14 – 0 2mm)
- Degree of lowering oxygen O_2 below 12%, CO_2 over 14%
- Effect it can kill insects and control molds effectively, and has been spread and applied in our country

B Storage by filling N_2

Oxygen is displaced by nitrogen which is generated by nitrogen producing machine, and oxygen concentration is lowered to 5%, after a week, N_2 increases from 95% to 98 – 99%, the effect of killing insects is better

C Storage by filling with CO_2

- Study methods of filling CO_2
- Study the mechanism of rice absorbing CO_2 by filling CO_2 into small bags and applied effect
- Study airtight material and filling CO_2 methods, effect of control insects and rice keeping fresh in horizontal warehouses
- Study filling CO_2, seal material and fumigation effect
- Study effect of filling CO_2 on rice and paddy quality at different moisture and temperature
- Study stored-product insects and mites control effect by controlled atmosphere storage (special CO_2 and temperature) Physiology and biochemistry mechanism of some mites forming, recovering, heredity to controlled atmosphere resistance

- Study effect of filling CO_2 on rice texture and SH-base change

D Storage by artificial deoxidation

- Study applied techniques and effect of a set of deoxidation machine
- Study applied techniques and effect of deoxidation agents (FOA, FXA, FXB) used in wheat and paddy

E Storage in vacuum

Mainly study effect of storage in vacuum on pests and mites control and rice quality

2 2 4 Research on drying technique of post-harvest grain

Research on drying grain has been carried out in two respects one is the model of dryer, the other is drying technology 1949 – 1965 was a phase of learning and imitating, bricking-up tower dryer had been researched and used in China Experts developed new models of paddy drying to solve problem of rice drying, for example, fluidized-bed paddy dryer, spouted bed paddy dryer, double-cushion cylinder paddy dryer, paddy husk furnace, chain-pipe heat air furnace Grain dryer has been a great development in quantity, model, performance and quality during 1985 – 1995, and the widely spread new models are net column grain dryer, rotary drum grain dryer, concurrent grain dryer and new type cross-flow grain dryer

2 2 5 Application of electron computer in grain storage and pests and molds control

The period of the study on grain storage management and pests and molds control by applying computer in China is divided into four stages

- The first stage Researched grain presentation testing and overall detection by PC1500 computer during 1978 – 1984,
- The second stage From 1985 to 1989, studied applying PC1500 to control the production line of some grain depots Since PC, XT, AT, 286, 386 microcomputer came into grain depots in succession, computer auxiliary management system of grain depots came into being, there was an obvious improvement on automatic testing of grain conditions,
- The third stage From 1900 to 1994, studied matrix wiring technique of grain condition testing system, Applied technique of semi-transistor and thermo-couple in grain storage, Seri-transmission had been studied to increase speed and accurate of data transmission and overall detection By collaborating with some relevant department, an internet system in grain depot had been established, the applied system is a comparatively integrated one which organizes the management information system, grain detecting system and equipment controlling system into a whole
- The fourth stage After 1994, we mainly researched national grain information management system, computer stored grain management system, grain pests and molds management expert system, and got achievement which can be put into practice

3. **Technique progress**

Due to the great progress of grain storage research work in China in the past 50 years, especially the past 20 years, the Chinese grain storage facilities and techniques have made great improvement

3 1 Before the founding of the P R China, in the whole country, the capacity of grain depots was 7500 kilo-ton and the capacity of plant oil depots was 5 kilo-ton At the end of 1991, the capacity of grain depots in the country was more than 127000 kilo-ton, the capacity of vegetable oil depots got to 2600 kilo-ton Although grain and oil storage facilities is still inadequate, outstanding progress has indeed been made in the modernization of Chinese grain and oil storage depots

3 2 Our country has accumulated a complete set of effective grain storage management experience and technique, such as 'Four without' grain depots (when a depot and its stored grain can reach the standards of insects free, moldy grain free birds and rodents free, and accidents free, then it can be rewarded the title of 'Four without') have been spread nationwide 'Double Low'(low oxygen, low insecticide), 'Three Low' (low oxygen, low insecticide and low temperature) storage techniques have achieved satisfactory results

3 3 Grain storage technique by low temperature has been extended nationwide

3 4 Technique of stored-product pest control, especially protectants have made great progress in practice According to the law of fumigants gas diffusion in different types of grain depots, application technique of its has been improved

3 5 Improvement has been made in the design of silos and research on warehouse machine Because of various types of grain dryers coming forth, drying of high moisture corn has been solved in China

The application of electron computers in grain storage has pushed the grain depot management in our country a big stride forward to standardization, popularization, systematization, regularization and internalization

We believe that China's grain storage facilities and techniques will be sure to take a leap by the diligent work and using foreign advanced achievement for reference

The above is a brief introduction of research progress of grain storage and control of stored-grain pests Here in below, I would like to summarily introduce the work of the two authors

Li Lungshu, who has published nearly 200 treatises and monographs since 1946, has published more than 30 research papers in the recent ten years, which mainly includes

1 Description of several new species of mite;
2 Regional fauna investigation of food mites in whole China, several provinces and in Sichuan Province (putting forward name lists),
3 Lethality of temperature and controlled atmosphere against several species of stored-grain pests and mites, Influence of high carbon dioxide to resistance strain breeding of *Liposcelis entomophils* E
4 Biological and ecological research of *Zabrotes subfasciatus*, *Plodia interpunctella* and so on, glandularia morphology research of water mites
5 Research on control of grain-storage pests by fragrant oil of plant insecticide used with controlled atmosphere,
6 Research on ecology of grain bulk

Jin Zuxun, beginning engaged in the research work of potatoes since 1950's, has carried out the work of exploring and sorting out the legacy of Chinese ancient grain storage techniques in succession In 1965, he founded the Chinese Grain Storage Scientific Research Institute and presided over 'the Sixth Five-year Plan', 'the Seventh Five-year Plan' on tackling key problems of grain storage science and technique In recent years, he mainly engaged in research about science and technology policy and scientific conceive of grain storage in China in 21st century