A REVIEW OF THE PROGRESS OF MODERN GRAIN STORAGE TECHNOLOGY THROUGH THE DEVELOPMENT OF GRAIN STORAGE TECHNOLOGY IN ANCIENT CHINA

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This report simply introduces the progress of modern grain storage technology, including : the determination of grain quality in China, analysis of the index of quality determination of grain and products, survey of stored-grain insects and microflora, probe into the grain storage techniques at low temperature and controlled atmosphere, research on pesticides used against the stored-grain insects and resistance. The report also introduces the development of grain storage in Ancient China, and using an old barley sample as an example, it has been proved that modern grain storage technology derives from Ancient China.

China is one of the earliest countries in the world to develop the technology for grain storage . The emergence and development of grain storage techniques in ancient times has made a great contribution to the existence, reproduction and propagation of the Chinese nation.

I . THE ORIGIN OF GRAIN STORAGE IN CHINA

According to archaeological investigation, primitive storage techniques came into use in China in the Late Old Stone Age and were developed in the New Stone Age, Historical remains which have been excavated show that China has a long history of about seven thousand years in the organized storage of grain. One of the earliest grain storehouses was discovered at the Hemudo ruin in Yuyao county, Zhejiang Province. The remains of underground storage pits were also found at the Banpo village in Xi'an, Shaanxi Province.

II . TYPES OF GRAIN STORAGE IN ANCIENT CHINA

For many years, archaeological excavation has unearthed many grains storage facilities ans containers. Most of them were found in ancient tombs or carvings, for example, Figs. 1, 2, 3, 4, and 5.

Fig. 1, Han Dynasty (206 B.C. - 220 A.D.), the multi-floor grain storehouse, Jiaozou City, Henan Province.

Fig. 2, Han Dynasty (206 B.C. - 220 A.D.), the flat grain storehouse, Chengdu City, Sichuan Province

Fig. 3, Han Dynasty (206 B.C. - 220 A.D.), the round bin, Guangzhou City , Guangdong Province,

Fig. 4, Han Dynasty (206 B.C. - 220 A.D.), the flat grain storehouse; Dalong County, Qinghai province

Fig. 5, Han Dynasty (206 B.C. -220 A.D.), the flat grain storehouse, Xianyang County, Shaanxi Province.

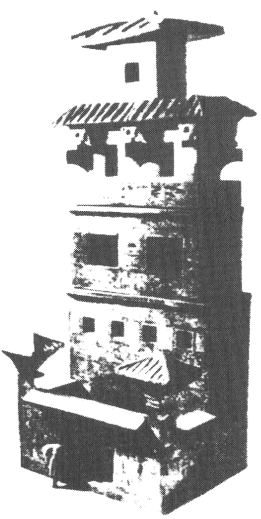


Fig. 1 Han Dynasty, the multi floor storehouse, in Maozu

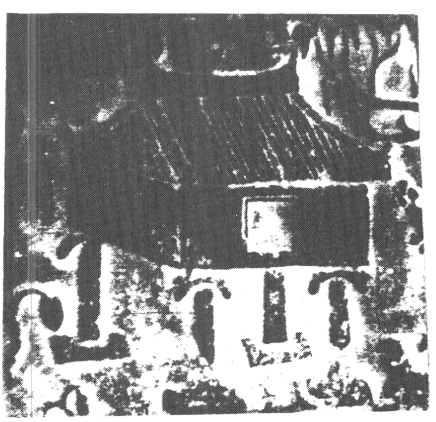


Fig. 2 Han Dynasty, the flat storehouse, in Chengdu

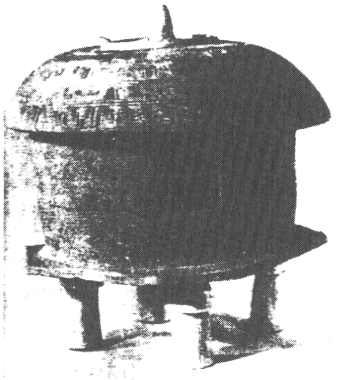


Fig. 3 Han Dynasty, the round bin, in Guangzhou

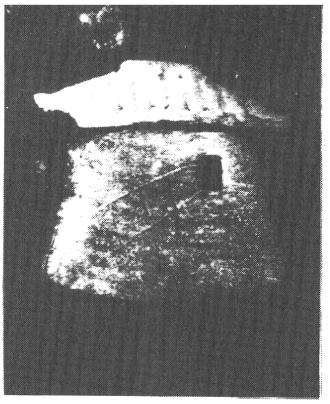


Fig. 4 Han Dynasty, the flat storehouse in Datong.

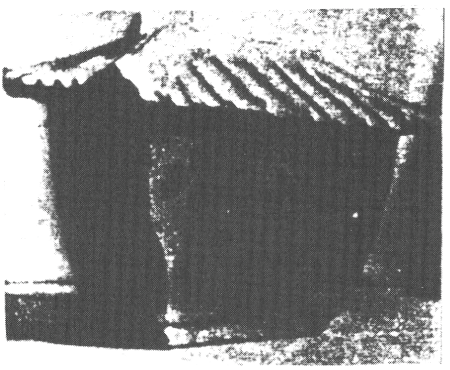


Fig. 5 Han Dynasty, the flat storehouse, in Xianyang.

III . THE STRUCTURE OF BARLEY OF ANCIENT CHINA AND ITS CONDITION OF STORAGE.

The barley sample of Ancient China was discovered at the Maquanwan ruin in Dunhuang County, Gansu province. The sample, according to archaeological investigation, is believed to have existed for about two thousand years, (71 B.C. - 21 A.D.). However, the barley sample is as good as fresh barley seeds, juged by the morphology and its structure through the electron microscope, and its cotour is still yellow.

Fig. 6, micrograph of portion of a cross-section of the barley sample x75 GC : grain coat, AL : aleurone Layer, SE : starchy endosperm.

Fig. 7 surface view of the epidermis of the grain x350.

Fig. 8 Cross-section of the grain coat x350. VB : vascular bundle.

Fig. 9 longitudinal section of the outer portion of the grain showing the grain coat x280.

Fig. 10 longitudinal section of the outer portion of the grain showing the vessel elements with annular and helical thickening x100.

Fig. 11 the aleurone cell of the grain x350. SC : seed coat, W : cell wall N : cell nucleus Ag : aleurone grain.
Fig. 12 starchy endosperm showing starch grain x75.
Fig. 13 Showing the type of the starch grain x350. S1 ; first starch grain, S2 second starch grain.
The barley sample was discovered in a small hole under a storehouse. Above the seeds was a layer of sands. It was important that the conditions were as follows : A) low temperature B) low relative humidity and low moisture content of seeds C) closed container and low oxygen content.

Fig 6 - Micrograph of portion of cross section of the barley sample

Fig 7 - Surface view of the epidermis of the grain x350

Fig 8 - Cross section of the grain coat x350 of the grain

Fig 9 - longitudinal section of the cuter portion

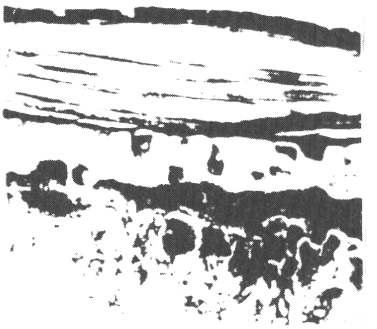


Fig 10 Longitudinal section of the water portion of the grain

Fig 11 - The aleurone cell of the grain

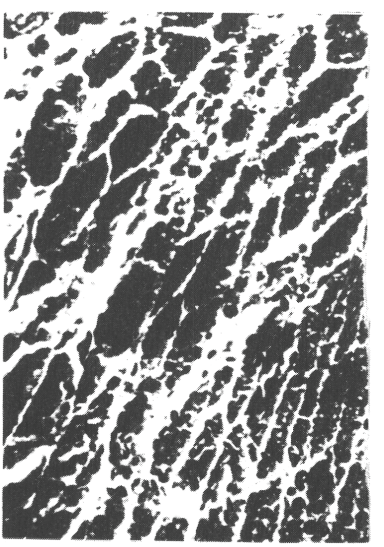


Fig 12 Starchy endosperm showing starch grain x75

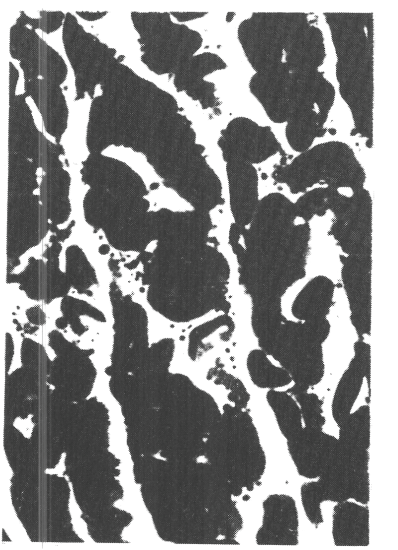


Fig 13 - Showing the type of starch grainx350

IV THE DEVELOPMENT OF THE MODERN GRAIN STORAGE TECHNOLOGY IN CHINA.

Modern grain storage technology is a continuation and advancement of the ancient grain storage technology from Ancient China. In China, many research institutes have been doing a large quantity of research work and have made quite a lot of progress.

1. The Three-Year Quality Determination of Paddy, Wheat and Maize in China.

Through an extensive sampling study, the basic data about grain quality in the country have been accumulated, which give a relative reference value to the determination of grain quality and the genetic breeding of new varieties. Mr Yang HAORAN and others have already made some reports on it in the light of the research outcome from the institutions concerned, such as the Sichuan Institute of Grain Storage Science of the Ministry of Commerce.

2. Research into the Index of Quality Determination of Rice, Wheat, Maize, Soybean and Flour. Discovering the Law of Determination and a Mathematic Model.

For example, on the basis of much research work done by the Sichuan Institute of Grain Storage Science of the Ministry of Commerce and others research institutes of grain science such as Zhejiang, Shanghaï, Guangdong and Liaoning etc., various determinations have been made on rice under the conditions of different areas, different years and different storage means. It proves that there exists a remarkable interrelation between the germination, the number of the fatty acid, the viscisity number and the mark of rice tasting.

$Y= 65x(73+0{,}07X1-0{,}25X2+1{,}70X3)$; X1 as a germination, X2 as a value of fatty acid, X3 as a viscosity, Y as a regression score.

If Y is less than 65 points, it is not suitable for continuous storage.

3. The Investigation of Stored Grain Insects

Trough the extensive sampling study, the basic data about the stored grain insects in the country have been accumulated. According to Professor Zhao Yangchang's record, there are ten orders, thirty-four families and two hundred and thirteen species.

4. The Investigation of Microflora in the Stored grain and Oil Seeds.

Reference is made to Associate Professor Xiang QI's record,

Table 1

The important Genus of Grain Cephosporium in China

Ecotype	Name of fungus	Rice	Wheat	Maïze	Peanut	Oilseed
	Alternaria	1	1	3	4	1
	Fusarium	2	3	1	1	1
	Phoma	3	+		3	+
	Cladopsorium	6	2	4	5	3
Field	Halminthosporium	5	4	+	+	+
	Nigrospora	4	+	+	+	+
Fungus	Epicoccus	+	6			
	Chatomium	+	+	5	+	+
	Cepholisporium	+	+	2	+	2
	Tricothecium	+	5	+	+	+
	Tricoderma	+	+	6	+	+
	Rhizoctonia	+	+		2	+
	Aspergillus	1	1	2	1	1
Stored	Penicillium	2	2	1	2	2
Fungus	Rhizopus	4	4	+	3	
	Mucor	3	3	+	4	.3

1,2,... are the important ordinal numbers as the dominant musticerae.
+ is common mycoaceae.

5. Research on the Grain Storage Techniques at the Low Temperature.

A) natural draft
B) Mechanical ventilation and aeration system under the control of a computer
C) Improvement of storehouses and use of refrigeration equipment in order to store rice and flour
D) Underground storage of grain, utilization of low temperature.

Storage of grain by the ventilation system in China means the two aspects of reducing moisture and lowering temperature and much research work has been done before.
A brief introduction of storage of grain under low temperature in China given by Mr. Zhou Jinxing is as follows:

TABLE 2 : A SURVEY OF STORAGE OF GRAIN UNDER LOW TEMPERATURE IN CHINA

1. Type	2.Utilization of materials and equipments	3. Performance
Natural low Temp.	1) Bin with multiple-tube natural ventilation consisting of bin mudsill, bin base, air inlet and air outlet. 2) Ventilation device : conical tube and horn tube.	
Lowering temperature ventilation	Aerator (axial flow centrifugal) ventilating duct and automatic ventilate form a ventilation system.	Type 4-72 aerator often used is centrifugal with medium/volt. Axial flow aerator often used is T 30 and T 40, with low voltage.
Lowering temperature by mechanical ventilation	Type of refrigerator : KD-10, KD-20, 2FV10, L3,5 etc... Type of air conditionor :CKT-3, CKT-1,etc.	Type 4F10 compressor is often use output is 28 000Kcal/hr; while tk=+40°C to =-15°C, its refrigerating output is 56 000Kcal/hr; Type CKT-3 airconditionor, its refrigerating output is 3 000Kcal/hr; refrigerant : F-22, controlled temp. range : 20-28 + / - 2°C
Undergr. low temp.	Sort of bin : flat-bed horn bin, conical-bed horn bin and cave bin. In summer grain in bin with high-temp. of 35-40°C can be stored by the means of cold storage while filling bin and with help of mechanic draft.	

4. Sort of Aeration Syst.	5. Adaptative range	6. Effect of lowering Temp.
	Area with low temp., low humi. and low moisture.	In Jan. and Feb. moist. reduction is less than 1% In March moist. reduction gets to 2-4% as climbing temp. but it keeps the temp. of grain in low condition for a longer time.
Sort of air conduct : 1) Through channels in ground, 2) through air-piping on ground, monotube or mutiple-tube bellow-type aeration. Ventilating way : pressing and drawing.	Adopted broadly in all parts of the country, the unit ventila. output for the axial flow is 5-8 m^3/hr ; the centrifugal aerator is 15-20 m^3/hr. In South China the ventilating quantity can be increased with discretion.	If the temp. of grain can be lowered to 0-2°C in winter and sequencing survise is adopted; in summer requirement of quasi-microtherm (belo w 20°C) can be fulfilled.
	Used for storage of such finished grain as rice, flour etc., in big and medium cities.	Refrigerating temperatu -re of bin by refrigerator can reach to below 15°C, rice with moisture of 15,5% below can be stired in safety. Refrigerating temperatu-re of bin by air conditioner can reach to 18°C or so and relative humidity 75% or so.
	Constant temp. number for underground bin in 27'16"-34'61" latitude is 16-20°C; Constant temp. number for underground bin in 37'53"-43'35" is 10-15°C.	Bin cap layer with thickness of insulation course can meet the requirement of quasi -microtherm.

6. The storage of grain with a controled atmosphere

In the country there are three kinds of methods to be used:

A- The biological method.

Using microflora, tree leaves, grain, etc. The natural anoxia means that the grain in bulks covered with plastic film relies on its own respiration to inhibit mould and pest . Therefore, it is a biological method. The natural anoxia method effects the quality of grain. It has been proved that, with the exception of low germination which results from high moisture, quality is higher than that of the control group; the experiment group for fatty acid is lower than the control group; the experiment group is completely free from mould and pest.

Table 3

Moisture content	Sampling time	Fatty acid		Reducing sugar		Irredu. Sugar		Germination		Mould & Pest Situation			
		Anox.	Contr.	Anox.	Contr.	Anox.	Contr.	Anox.	Contr.	Anoxia Pest	Anoxia Mould	Contrast Pest	Contrast Mould
13	Jul. 1978	16.87	16.26	0.48	0.50	2.35	2.42	75	80	No	No	No	No
	Mar.1979	27.08	33.66	0.57	0.38	2.06	2.07	85	69	No	No	Yes	Yes
11.5	Jul. 1978	14.73	15.04	0.47	0.52	2.42	2.40	83	85	No	No	Yes	No
	Mar.1979	17.79	23.46	0.41	0.26	2.49	2.17	93	84	No	No	Yes	No
12.3	Jul. 1978	17.11	17.17	0.40	0.45	2.37	2.52	89	85	No	No	No	no
	Mar.1979	20.39	24.15	0.27	0.32	1.80	1.99	91	73	No	No	Yes	No

Anox. = Anoxia Contr. = Contrast

(The Sichuan Research Institute of Grain Storage Science of the Ministry of Commerce)

Table 4

Variety of Grain	New Wheat	New Wheat	New Wheat	New Wheat
Quan. (00,000 jin)	20	47	50	52
Moisture (%)	11.5	11.4	11.4	11.0
Temperature (°C)	38	35	37	32
Thickness (mm)	0.14	0.32	0.20	0.12
Sealing Time (days)	12	108	66	38
Minimum Oxygen Content (%)	3.4	0.8	0.8	3.5
Duration for Preservation Under 5% Oxygen Content (days)	12	58	53	10
Duration for preservation Under 8% Oxygen Content (%)	43	108	76	38

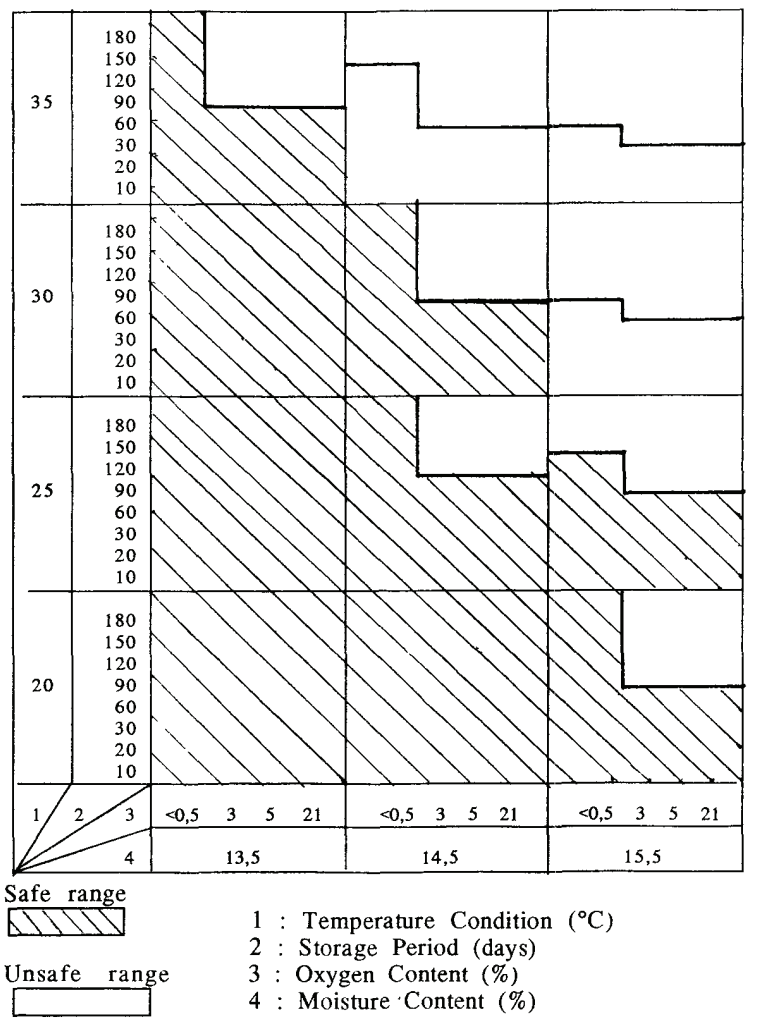
Source : (grain Storage by Anoxian Method) by Mr. Zhao Zhiming

The different thickness of plastic film has a notable effect on the natural anoxia and the reduction of oxygen. The different thickness of polyvinyl chloride plastic film effects the efficiency of the oxygen reduction.

B - Machinery method, charging with N2, CO2 and vacuum-pumping, etc.

Mr Lu Qianyun and others have made research on the textural changes of rice under controlled atmosphere. Among the different mixture of gases investigated 30% CO2, 5% O2, 65% N2 (artificial C.A.) and 15% CO2, 2% O2, 83% N2 (imitated hermetic storage) can maintain rice quality better. Mr ren Xihong and the others from research institutes under the control of Ministry of Commerce as Sichuan, Shangaï and Guangdong, have made some research on it and demonstrated that the safe period for storage of rice with different moisture content changes at the various temperatures and oxygen contents. The experimental results of the mould infection rate, fatty acid number, acid value of aqueous solution as well as tasting mark, can be used to construct a diagram :

The safe period for storage of rice under different Oxygen Content, Moisture Content and temperature.



In this field, the effect of different oxygen concentrations, temperatures or moisture contents on rice quality has been investigated. The findings of research have been used as reference and put into application throughout the country.

C - chemical method, using dioxdizer, such as free-oxygen absorber $Na_2S_2O_4$ or Fe etc.

Mr Zhao Zimin has made research on free oxygen remover Fe on the soybean, wheat and flour, it has been proved the effect of different sealing material and its rate.

Table 5

			TESTING TIME (day)/ OXYGEN CONTENT (%)												
	MOIST (%)	INPUT (g/t)	2	4	6	8	10	12	14	16	18	20	22	24	26
SOY	13,5	160	18,2	14,6	8,8	10	0,2	0,2	0,2	0,8	0,8	0,8	0,8	1,0	1,2
		320	17,6	16,4	0	0	0	0	0	0	0	0	0	0	0
WHEAT	12,5	160	16,2	8,64	1,4	1,2	0,6	0,4	1,0	1,0	1,0	1,0	1,0	1,5	1,9
		320	15,8	8,2	1,0	0,6	0,6	0,4	1,0	1,0	1,0	1,0	1,0	1,0	1,0
FLOUR	13,0	160	19,2	19,0	19,0	19,0	18,0	11,4	11	11	11	11	10	9,0	9,0
		320	19,0	19,0	19,0	18,0	15	10	9,9	8,5	8,5	8,5	8,0	7,5	7,2

Mr Wang Xiaoyong and others have made research on the application of free oxygen remover on grain (oilseeds) and edible oil storage.

7 - Research on the protectant against the stored grain insects

Many years ago, we have researched the applied techniques of lindane, malathion and pyrethrum. In the recent years, pirimiphos-methyl, bromophos, chlorpyrifos-methyl fenitrothion, etc...; have been screened in the laboratory. Their effects have already been demonstrated in the field trial.

8 - Research on the pesticide against the stored grain insects

A lot of experiments on the effects of phosphine, applied techniques and law of diffusion have been made. The investigation has been made into the stored grain insects resistance to pesticides in China. The outcome of this work is of great reference value to improving the contolled techniques of the stored grain insects.

9 - Research on the physical method for preventing insects

A - Freezing

Research proves that the effective lethal temperature, for killing pests by cryogenic

methods, changes with different pests. Mr Jiang Rong and others testify that the cold-resistance of the Trogoderma granarium Everts is the strongest, i.e. 0-3°C, they are not dead untill sixty-four days;
the cold-resistance of the Rhizoperta dominica Linnacus, moved from 34°C indoors to minus 8°C outdoors, is the weakest.It would be numb with cold in a few minutes and dead completely in twelve hours. Some other scientific research has proved that a good insecticidal effect can be achieved, striking it repeatedly by strong cold current.

B - Electromagnetic Wave Energy

a) Solar energy

Mr Ge Hao and others have demonstrated that the death rate of insects is 100% as grain is heated to 53°C

b) Infrared Ray

It has been borne out that within a certain distance the insecticidal effect can be heightened by prolonging the exposure and raising the temperature. In fifteen minutes the death rate is 4.7% while the temperature inside the container comes to 39,5°C; at the temperature 53°C, the death rate can reach to 100% in forty-five minutes.

C) Microwave

Research has been made on it proved that insects mortality results from the heat effect and the lethal temperature is above 50°C.

D) Laser

Mr Jiang Xinglian has put his point of view recently that it is suitable to kill insects by the means of the (YAG Laser) radiation dose as 5 w/cm2 or 8w/cm2 and radiation duration as ten or fifteen seconds.

E) Gamma ray

In China it was reported as early in 1962 that Sitophilus zeamais (Motschulsky) can be killed within 15 to 20 days by a radiation dose of fifteen thousand roetgen. Mr Sun Baogen has ascertained in recent years that different kinds of pests have different sensitivities to radiation effects; the sensitivity of Tribolium castaneum (Hbst.) is the weakest, Tribolium confusum jacq du val is the second and S. zeamais (Motschulsky) is the strongest. Fifty-four thousand roentgen can be considered as a effective dose for the prevention and treatment of the common pests in the stored grain pests. A high efficiency of prevention and treatment can be achieved by use of radiation duration as fourteen minutes and high radiation dose as two hundred thousand roentgen/per hour. Madam Chen Lizhen and others have made research on the Plodia interpunctella Huebner through the technique of prevention and treatment for imcomplete sterility of radiation heredity.

10 - Research on the biological means for preventing against the insect

A) Research on the technique of prevention and treatment for the stored grain pest has been made with predatory insects. Mr. Zhen Xiangxing has made known that Xylocoris sp. can inhibit stored grain pests. Mr. Yao Kang and Mr. Deng Wangxi have also reported that Perigrinator bioannulips Montrpzier and Xylocoris flovipes

(Reuter) do the same to the stored grain pest.

B) Research on the Prevention and Control of Stored Grain Pests by Ectohormone.

Mr. Wu Guixing reports that an experiment on Callosobruchus chinensis Linnacus has been made with ectohormone. Mrs. Gao Jintang; Huang Yuanda and LI Zhenfan respectively report their own experiments that gyplure is used to prevent and control Sitotraga cerealella (oliv).

C) Research on the prevention and control of Stored Grain Pests by Endohormone.

Mr. Sheng Zhaopeng has made an experiment on the prevention and control of S. zeamais (Motschulsky), T. confusum Jacquelin du Val and Oryzaephilaes surinamensis Linnaeus with a larva hormone. Mr. Zan Jiwa reports the experimental result that larva-killing urea N°1 can prevent and control Callosobruchus chinensis Linnaeus.

11 - Research on the plant insecticides, such as meliaceus, cellastrceus

Mr. Zhao Shanhuan made some reports in 1960 on this. After that it has been reported in Zhejiang, Fujian, Hunan, SDichuan and Jiangsu in China, that some plants can be used to kill stored grain pest. In recent years, some important research work is as follows : Mr. Zhang Xing has reported his research on melliaceus and celastrceus. Mr. Huang Fuhui has reported his research on the litsea cubeba. Mr. Li Guangchan and others have by perfume oil. Mr. Gao Jiqi and others have report on preventing C. chinensis Linnaeus by vegetable oil protectant.

12 - Study and manufacture of igh speed grain moisture meters; temperature meters; insect monitors and special computers etc..

UNE REVISION DES PROGRES DE LA TECHNOLOGIE MODERNE DU STOCKAGE DU GRAIN EN PASSANT EN REVUE LE DEVELOPPEMENT DE LA TECHNOLOGIE DU STOCKAGE DANS LA CHINE ANCIENNE

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Résumé

Ce mémoire présente simplement les progrès accomplis par la technologie moderne dans le stockage du grain : l'évaluation de sa qualité en Chine, l'analyse de l'échelle de mesure de cette qualité et celle des produits, l'étude des insectes des stocks et la microflore, le sondage, les techniques basses températures et en atmosphère modifiée, la recherche sur les pesticides contre les ravageurs et leur résistance. Il présente également l'histoire du stockage du grain dans la Chine ancienne. En prenant l'orge comme exemple, il est prouvé que le stockage moderne dérive de celui de la Chine ancienne, les deux technologies étant très proches.