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PRESENT AND PROSPECTIVE STATE OF THE "TRIPLE-LOW" GRAIN STORAGE TECHNIQUE

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ABSTRACT

In recent years, some new grain conservation techniques have been developed in China to redress the limitations of obsolete equipment in grain storages. These are aeration, and techniques termed "Temperature-Low", "Oxygen-Low", "Double-Low", and "Triple-Low". Among these techniques, aeration, "Double-Low", and "Triple-Low" are considered particularly effective. According to preliminary statistical data, 20 million tonnes of grain were stored successfully in China last year using "Double-Low" and "Triple-Low" conservation techniques. In this way, losses by insect pests and moulds were reduced and quality degradation of grain was effectively retarded. In consequence, the number of fumigations was reduced and expenditure was cut.

PRESENT STATE OF APPLICATIONS

Some Basic Concepts of the "Triple-Low" Grain Storage Technique

1. *"Temperature -Low":* The principle is to transform existing storehouses by equipping them with heat insulation and temperature control facilities in order to maximize the use of ambient weather conditions in winter as well as mechanical aeration to reduce grain temperatures. The grain should be covered tightly by plastic sheets before ambient temperatures rise in spring, thereby enabling the maintenance of average temperatures below 20°C over the summer. Where low temperature preservation relies on ambient cooling, this is regarded as a quasi- "Temperature-Low" technique, while grain storage at temperatures above 20°C is regarded as normal temperature preservation. Where mechanical coolers and window-type air-conditioners enable the maintenance of the grain temperature below 15°C the year-round, the method is called "Temperature-Low" preservation.

2. *"Oxygen-Low":* In order to reduce O_2 concentrations, plastic sheeting is used to cover the grain, asphalt is painted on the walls, and two layers of

asphalt, one layer of asphalt-felt and one layer of bricks are paved to form the floor, while in addition the floor may be lined with polythene sheeting. Plastic sheeting is used to provide a hermetic seal that enables a natural reduction in O_2 concentration as a result of aerobic respiration of organisms within the grain bulk. If the O_2 concentration is held at 4% - 12%, the grain is said to be in "Oxygen-Low" preservation; if it is higher than 12%, the grain is in "Sealed" preservation; if it is below 4%, the grain is "oxygen-deficient". For some types of grain, if the O_2 concentration is still above 12% using only the single plastic sheet sealing method, then an oxidation retarder should be used.

3. *"Fumigant-Low :"* By covering the grain with plastic sheeting, the amount of aluminum phosphide (AlP) used to fumigate the grain may be reduced to as low as 0.5-1.0 g/m^3 or 1.0-2.0 g/tonne. This method is called "low aluminum phosphide fumigant storage".

Principles of "Triple-Low" Grain Storage Technique

In accordance with local and overseas research findings, when grain temperatures are below 15°C, insect development is retarded; when they are below 8°C, most insects are inactive; and when they decrease below -4°C, the insects die within a short time. If the temperature is kept below 15°C, the respiration of grain at safe moisture contents (m.c.) can be restrained so as to keep the grain in the state of dormancy, thereby effectively reducing weight loss resulting from catabolism and respiration as well as maintaining organoleptic and germinative qualities of the grain. Therefore, 15°C is considered the critical temperature for low-temperature grain preservation. As a result of the recent development of the "Triple-Low" grain storage technique, even if the grain temperature is above 15°C, the rate of deterioration of grain can still be retarded and satisfactory quality maintained, provided that the temperature is kept at about 20°C and a storage environment of "Oxygen-Low" is provided together with low hydrogen phosphide treatments.

Low-oxygen grain storage is achieved using plastic sheet sealing to isolate the grain from the ambient air. Through the respiration of the grains, insects, and microorganisms, the O_2 concentration can be reduced gradually, to attain the objective of preventing insect and mould development, thereby ensuring safe storage. "Oxygen-Low" is not equivalent to "oxygen-free". It restrains aerobic respiration, reduces energy consumption, and helps maintain dormancy of the grain, as well as preserving the grain from the harmful by-products of anaerobic respiration.

Hydrogen phosphide is one of the most effective fumigants in grain storage, being capable of restraining the respiration and development of microorganisms, maintaining the state of grain dormancy, and thereby enhancing the stability of the grain in store. Compared with storage using

high hydrogen phosphide concentrations, "low-hydrogen phosphide" has several advantages. Findings of an experiment at the Agriculture Department of Jiangsu province and the Biology Department of Nanjing Normal Institute in 1983 indicated some of the benefits:

1) "Low-hydrogen phosphide" (0.2 mg/litre) has as much an effect as "high-hydrogen phosphide" (1.5 mg/litre) in restraining the normal respiration of grains.
2) "Low-hydrogen phosphide" can inhibit the activation of cytochrome oxidase by 21.9 - 31.6% and ascorbic acid oxidase by 25.4 - 29.1%.

Briefly, the "Triple-Low" grain storage technique is a synthesis of preventive measures, that can obviate the shortcomings of a single-item preventive measure, and conforms with the demands for safe, hygienic, economical, and effective conservation principles. In "Triple-Low" technique, the seeds remain dormant. Under such conditions, their metabolic rate is very low. By means of uncoupling resulting from "low-hydrogen phosphide" and "Temperature-Low", energy metabolism is lowered to a minimum level. Furthermore, in the dormant stage, the circulation intensity of its cellular protein is several times higher than that in the germinating stage. However, the protein catabolism is very low. As a result, the slow-down of protein catabolism and isomerization may further reduce the harm from metabolites (e.g., aldehyde, ketone, and non-protein nitrogen), retaining the desirable qualities of the grain.

Main Requirements for the "Triple-Low" Grain Storage Technique

Storehouses should be modified properly to provide the required facilities, such as heat insulation, temperature control, and hermetic sealing to obtain natural O_2 reduction. The modification should include painting asphalt on the inner walls; installing fixed plastic troughs along grain stacks, around walls, and at the storehouse door, paving the floor with two layers of asphalt, one layer of asphalt-felt and one layer of bricks or polythene sheeting; and using plastic sheets to seal the grain-stack. For storage of end-products or some of the more valuable commodities, suspended ceilings formed from sections of polystyrene-foam boards are useful for heat insulation.

The grain in storage should be of fair quality. The grain is required to be at safe m.c.s (e.g., hybrid rice - 13.5%; early rice - 14%; mid-season rice - 15%; late-season rice - 15.5%; wheat - 12.5%; rapeseed - 8%; and soybeans - 13%). Impurity levels of the above grains should be kept to within 1% maximum.

"Triple-low" grain storage requires a complete set of equipment and monitoring facilities. Plastic sheets are installed to seal the grain and should be connected to throttle valve plates. Plastic troughs and rubber pipes are

positioned to interconnect the sheets. Other monitoring equipment must be installed within the store for measurement of air temperature, grain temperature, air humidity, O_2 concentrations, and fumigant residues in the grain bulk. In addition, ventilation apparatus is required.

Management of "Triple-Low" Grain Storage

According to the grain stored, m.c., and the storage season, the procedures of plastic-sheet sealing, mechanical aeration and fumigation are employed according to a sequence. At present, there are four situations suitable for application of "Triple-Low":

1) The grain is placed in storage during the "low-temperature" season, as in the case of late-harvested rice. The sequence of the preservation procedure is: "Temperature-Low" (cooling with aeration systems), "Oxygen-Low" (use of plastic sheets for sealing until the next spring), "Fumigant-Low" (use of low dosages of PH_3 to kill the insects).
2) The grain is placed in storage during the "high-temperature" season, as in the case of rapeseed. Preservation should be handled in the following order: "Oxygen-Low" (plastic sheet sealing), "Fumigant-Low" (use of low dosage of hydrogen phosphide) and "Temperature-Low" (use of machinery to aerate the storehouse from the autumn and thereafter).
3) Newly-harvested wheat is generally stored in the order of "Oxygen-Low" and "Fumigant-Low". This is because the after-ripening effect of new wheat can help accelerate O_2 reduction under plastic-sheet sealing. After one month, the O_2 concentration can be reduced to about 10%, while the carbon dioxide (CO_2) concentration can increase to 5%. This may be followed by the "low-aluminum phosphide" procedure.
4) For early indica rice and rice processed in winter, the sequence of "Temperature-Low" and "low-PH_3" should be followed. Because of the relatively high temperature of early indica rice when placed in storage, yellowing may occur unless proper measures are taken. It is unsuitable to cover the grain immediately with plastic sheets. Instead, the correct order is first to use ventilators to lower the temperature, and to subsequently seal the grain retain for low temperature retention. To prevent the development of insect pests, "low-PH_3" should also be used. This method has the same effect as the "Triple-Low" technique, but because this rice is stored at a low m.c. the O_2 concentration may remain at about 18% and not reach the "Oxygen-Low" standard. Thus, strictly speaking, this measure still falls into the category of the "Double-Low" storage technique. However, in practice, there may be some flexibility. For example, by flushing the grain-stack with CO_2 or N_2 and introducing an iron-powder

oxidation retarder, the O_2 concentration can be reduced to the standard of "Oxygen-Low". In view of this, the method is also within the scope of the "Triple-Low" storage technique.

More ventilation should be employed to dissipate heat within the storehouse so as to control temperature. For this reason, ventilators and axial-flow fans must be installed. On cool summer nights, this equipment is operated to prevent heat accumulation. In storehouses with suspended ceilings, ventilators and fans should be installed between the suspended ceiling and the roof to control the grain temperature even more effectively.

Use is made of either polystyrene-foam boards (sections) with a rubberized fabric, or plastic air cushions to cover the grain surface in order to enhance heat insulation and minimize temperature change. This may help retain the mean annual temperature at below 20°C in grain stored in structures not equipped with heat insulation. Because the polystyrene-foam boards have a low thermal conductivity and good compressive strength when used as covering material, they are capable of reducing the heat transmission into the grain bulk. The rubberized fabric is used to seal the seams of the insulating boards so as to prevent the passage of air-currents thereby enhancing their effectiveness. Thus, the polystyrene-foam boards function as ideal covering material. Air cushions made of plastic sheets for covering the grain surface are capable of preventing direct air convection and conduction between cold air in the grain stacks and warm air in the storehouse. The two layers of plastic sheets form an independent environment separating the grain bulk from the exterior. This technique has the advantage of low expenditure, but its inconvenient operation and management require improvement.

Economic Benefits of the "Triple-Low" Grain Storage Technique

The plastic sheet sealing method has been proved to reduce both waste during storage and the losses by insect and rodent pests. In the rainy season, if leaks occur in the roof, this method protects the grain from losses due to water ingress. Investigations have shown that annual losses are only 0.1% by weight, or lower than the standard of 0.2% set by the government. Last year, grain stored in China under the "Double-Low" and "Triple-Low" techniques amounted to 20 million tonnes. These results shows that the techniques would save about 20 thousand tonnes of grain for the country each year.

The "Triple-Low" grain storage technique enhances the stability of the grain in store. By these procedures, grain can be stored and its good quality maintained in storehouses not equipped with heat insulation. Measurements indicate that germination, fatty acid levels, and viscosity, all conform with the quality indices set by the Ministry of Commerce.

This technique helps raise the level of utilization of storehouses. There are storehouses with a total capacity of 20 million tonnes equipped with throttle valve plates instead of the traditional means. By this method, bulk grain is surrounded by walls of bagged grain. Applying this technique, the gunny bags and straw sacks used normally for containing the grain are not required, and the storage capacity is increased by 4%, resulting in an increase in total capacity of 800,000 tonnes.

The amount of AlP fumigant used is reduced, thereby saving in fumigant expenditure. With normal fumigation methods, 14 g AlP are required per tonne of grain, whereas, using the new technique, 2 g/tonne AlP are sufficient. Therefore, by putting this technique into practice for 20 million tonnes of grain, more than 200 tons of fumigant can be saved each year resulting in a saving in expenditure of RMB 4.72 million yuan with the price at RMB 23,600 yuan per tonne. In several regions, namely, Wujiang, Jiangdu, and Guanyun, grain storage data show that by using the "Triple-Low" technique, the annual storage expenditure per tonne of grain is RMB 1.5 - 2.1 yuan, whereas by existing methods of air-conditioned storehouses, and refrigeration machinery, the storage expenditures are RMB 10.5-20.0 yuan/tonne, respectively. Clearly, the expanded use of this technique would produce great economic benefits.

POTENTIAL PROSPECT OF THE "TRIPLE-LOW" TECHNIQUE

Under the existing conditions of poor storage equipment in China, the "Triple-Low" technique holds more advantages than the individual "Temperature-Low" storage, "Oxygen-Low" storage, and "Fumigant-Low" storage techniques. A high degree of protection is achieved, the technique is economically beneficial, and it can be practiced in store houses where heat insulation is not installed. Therefore, it is an ideal way to store the grain and is appropriate to the present situation in China. It also shows great potential for most developing regions.

At present, the "Triple-Low" grain storage technique is still at the development stage. It lacks systematic research in theory and practice, and some problems still exist in management that need further exploration.

The objectives of future research are as follows:

1. Research to be carried out on basic theories of "Triple-Low" grain preservation, especially on the aspect of heat released by grain respiration.
2. Research on "Triple-Low" to understand the interrelationship between climate, O_2 concentration, fumigant requirements, and other factors.
3. Development of suitable plastic sheets and other plastic products for use in storing cereal grains, beans, and oil seeds.
4. Continuation of analysis of the synthesis of protective measures of

"Triple-Low" grain storage and effective ways of temperature reduction and grain quality maintenance.

5. Study of administrative aspects of "Triple-Low" techniques in grain storage, including the choice of covering materials, operation of fans, and techniques of interior ventilation.
6. Study and clarification of specific properties and dynamics of air currents in grain-stacks, the location of fumigants, and methodology of fumigation.
7. Research on different storage structures, sealing materials, and sealing techniques.
8. Studies on sealing with oxidation retarders and purging with N_2 or CO_2 as well as the use of plastic sheets.

After completion of the above studies, the consolidation of the grain storage technique may be improved further. This will result in more high-quality grain supplies to meet the needs of the people.