Aspects of grain storage at low temperature in China

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Abstract

This paper has made an analysis over the feasibility and favourable conditions to realize the grain storage at low temperature, fully in consideration of the actual conditions or realities of grass-root grain depots in China. For which it has proposed to have an appropriate transformation of the present storage facilities by way of the step-by-step implementation of '6-doubles' project, aiming to enhance the heat insulation and cool preservation of grain depots and to minimize the negative effects of 'external heat source' With a full play of the coordinate functions among the three major ventilating technique and the massive adoption of the ventilating method, such as 'double radiation, triple drops in temperature plus an adjustment', the temperature of grain piles is expected to be further lowered and a good storage environment will be created, and then as a result of the continuous study on the grain storage technique of '3-lows' and the extensive application of comprehensive new technique like '6 in 1 to 3-lows', the 'internal heat source' will be effectively controlled and the stability of grain storage would be promoted. This paper has also put forward a series of comprehensive technical measures, such as, to intensify the practice of the regulations for technical operations and to exercise the management through the 'systematic engineering', all in an attempt to ensure the healthy development of grain storage at low temperature. Moreover, it has described the operating procedures and methods in details available for the productive operations in most of the grain depots.

Introduction

China is one of the major grain-producing countries in the world, and along with the improvement of national grain storage system and its unceasing development in China, it will gradually become one of the major countries worldwide in grain storage, and the duration of grain storage will be prolonged accordingly. Under these circumstances, the grain storage technique in China shall not be oriented only to the assurance of quality and quantity, instead, it's required to have a massive development of the new technique concerning the grain storage at low temperature and fresh preservation so as to cope with the trends of building up and developing the grain storage system in China.

A New Route of Grain Storage at Low Temperature Based on China's Actual Conditions and with Chinese Peculiars

Now, China is still a developing country with a vast territory, a large population, but a weak economic foundation, and the grain storage in China is thus of the characteristics different from those in the developed countries like the European countries, USA and Japan. It features a large storage volume, wide distribution, complex grain quality, simple and crude equipment, less storage expenses and poor quality of storemen, moreover the grain is itself a kind of commodity occupying a large storage space, but cheap in price. In such a case, the above features shall be considered in the development of grain storage at low temperature in China, that is to say, to proceed in all cases from the realities in China and to open up a new route which coincides with Chinese peculiarities and is of universal significance for an extensive application of grain storage at low temperature This new route must be designed with reference to the current storage means, preserving conditions and facilities, level of expenditure and personal quality in China, and it must be in accordance with the principle of safety, convenience, strict economy and efficiency, and acceptable to the great majority of grass-root grain storage units and storemen. While in the process of specific implementation and understanding of the concept for low temperature, it is important to make a full use of present storehouses, equipment and other grain storage facilities, and just undertake an appropriate simple reconstruction and comprehensive application of various techniques so that the storing temperature remains all the year round at low or quasi-low temperature, i. e. 15℃ or below at mesothermal or microthermal season, but average 20℃ or below at megathermal season.

The Feasibility and Favourable Conditions to Realize the Grain Storage at Low Temperature in the Light of Chinese Peculiarities

The most effective way to maintain at temperatures below

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15℃ all the year round is to adopt mechanical refrigeration or the necessary air conditionings and to construct or reconstruct the low-temperature or air conditioning barns. But in fact, it is difficult to achieve a widespread implementation when the realities of most grain depots presently in China are taken into account, instead, it's required to start from the actual and present facts, and to realize the grain storage at low temperature only in the light of Chinese peculiarities, for which the grain temperature could be relaxed adequately to the limit of quasi-low temperature, because the temperature of grain remains mostly at 15℃ or below throughout a year and only around 20℃ within a short period of time, which will not cause impact on grain quality to a great extent and the low temperature is still available. Since the storage of cereals and oils sees a rapid development in every aspect starting from the later period of 1970s in China, it has prepared sound conditions for an extensive practice of grain storage at low or quasi-low temperature

Tremendous development of grain storage technique

Favoured by a nationwide campaign to utilize the grain storage technique starting from the end of 1970s to 1980s, such as the '2-lows', '3-lows', 'mechanical ventilation' and the methods of slow release, intermittent fumigation, aspiration and circulation, the major harms resulting from the heat source incurred in the reproduction of microbes and insects in grain storage have been effectively controlled, and the stability of grain storage thus shows a magnificent improvement and the grain storage has shifted nationwide from the relatively high temperature in 1950s and 1960s to the relatively low temperature in 1980s and 1990s. It is said that in quite a few barns of China, the grain temperature of upper layers can be controlled approximately at 25℃, and that of mid and lower layers can be controlled mostly at 20℃ or below. It has laid a solid technical foundation on the current extensive application of grain storage at low or quasi-low temperature.

Prominent improvement of storage facilities

Since 1980s, a large amount of investment from the central government or local government has been input specially into the massive establishment of barns so as to suit the needs of increasingly large storing volume. As a result, many medium or large-sized barns have been set up, and the original barns in civil houses or ancestral temples or in the forms of short and stout houses have been dismantled and reconstructed, presenting a prominent improvement of storage facilities in China. Generally speaking, these newly-constructed or reconstructed barns are provided necessarily with the primary functions like airtight, ventilation, insect-prevention, moisture-proof, heat-insulation and rat-prevention, etc.. They are available for the grain storage at low or quasi-low temperature only subject to simple reconstruction.

Better quality of storemen

Since 1990s, many aged or illiterate storemen have retired one after another, and many graduates from grain schools or the young people who are well-educated have been recruited in succession They can satisfy the requirements of scientific grain storage only after the necessary professional technical training and examination Moreover, the professional storage system, which was set up as early as in the very beginning of 1950 at each level from the central to grass-root units in China, has been insisted on and reserved up till now, it has turned out a group of professional storemen who will be able to better serve the step-by-step development of storage technique in China.

Progressive improvement of the quality of storehouse-in grain

The system of drop-in quality inspection to the villages or production teams and inspection over the quality of storehouse-in grain has been exercised all along in China Particularly in the recent years that the state has reasonably increased the price of grain and has strengthened the implementation of the policies for timely purchase and the special protective pricing to the grain at negotiated price, the farmers' enthusiasm to sell quality grain has been stimulated and most of the storehouse-in grain conforms with the safe storage standard. Therefore it has provided good conditions for the storage at low temperature.

Technical measures for grain storage at low temperature with Chinese peculiarities

The heat in grain piles is different in source, but the 'internal heat source' and 'external heat source' in general. The internal heat is mainly from a combination of the heat accumulated in storage at megathermal season, the heat produced by microbes and insects in the storehouse-in grain and the heat from grain itself, while the external heat mainly includes the radiant heat from outside barns and the heat generated in the process of conduction and convection of hot air, among which the most important is the radiant heat on barn roof, and then the radiant heat on the wall exposed to sun. As shown in the materials concerned, the heat transferred from the roof is 16 times the heat from the wall. Provided that effective measures are adopted and the relevant technique with complementary properties are sufficiently utilized to control or eliminate these heat sources, the grain storage at low temperature is indeed achievable.

1. Adequate reconstruction of present storage facilities and step-by-step implementation of '6-doubles' programme to improve the heat-insulation and cool preservation

inside barns and to minimize the effects of external heat source The barns presently in China are mostly imperfect in heat insulation and cool preservation due to the unreasonable design of roofs, walls, doors and windows Therefore it is necessary to put into practice the '6-doubles' programme over the barns in a progressive and a planned way

- 'Double-roofs'. It is to install a steel mesh ceiling under the roof to form a roofing insulation ceiling. The constructional process top to bottom is: Installation of wood framework – fixing of steel mesh – evenly plastering of mixed mortar – plastering of lime paste This kind of ceiling is durable in use and with great resistance to negative pressure, featuring the advantages of leak-proof, airtight, heat insulation and rat prevention. It may be horizontal, saddle-like, herringbone and curved in shapes. The first two are reliable in heat insulation, but slightly higher at construction price, the other two are less at construction price, but not so good as the first two in heat insulation. The optional use must be based on local conditions However the distance between roof and ceiling shall not be less than 60 cm, and if possible, a layer of rice husk or other heat-insulating materials may be arranged over the ceiling for a better heat insulation. If the ceiling is horizontal or saddle-like, it would be best to mount exhaust fans or ventilating shutters on the acute arches of gables at both ends of the ceiling so as to enable the exchange of hot and cool air and to lower the temperature inside barns. As shown in the practical work in Yihuang, Jiangxi Province and Weifang, Shangdong Province, the temperature inside the 'double-roof barn' is 4℃ or 6℃ lower than that of non-double-roof barn. In addition, it's required to whitewash the roof tile with white cement mortar to lower the temperature by reflection
- 'Double-walls'. the dual heat insulating wall It is usual to construct, on the economical or practical basis, another wall made of steel mesh outside barn, attempting to cut the construction price. Because the exterior wall is constructed on buttress, a 40 to 50 cm gap thus forms between the two walls, available for the fill-in of rice husk or other similar heat insulating materials. The constructional process is: Barn wall and buttress – fixing of big square stock – fixing of small square stock – fixing of steel mesh – plastering of waterproof mixed mortar – whitewash with lime paste The wall shall be whitewashed to lower the temperature by reflection. A moisture-proof layer with two asphalt coatings and one asphalt felt shall also be arranged on the surface of interior barn wall, and the surface must be flat, smooth and free of cracks
- 'Double-doors'. It is to mount a movable frame-structured plastic door between barn door and grain retaining board and to embed a plastic film into the grain retaining board so as to achieve the 'double-doors and four successive heat insulation'
- 'Double-windows' It's to properly broaden the windows, mount additional outward windows, and mount exhaust fan between inward and outward windows, then to embed plastic film into fillisters around the inward window so as to achieve the 'double-windows three successive heat insulation'
- 'Airtight by double-films' It's to cover the grain with two quality polyvinyl chloride film of an appropriate thickness, then to embed film into fillisters of interior walls nearby so as to create an air layer between the two films and achieve heat insulation with the help of minor coefficient of heat conductivity According to the fact of practical application in Jinxi County of Jiangxi Province and Shouguang County of Shandong Province, the temperature of grain after the treatment of 'airtight by double-films' is 7℃ to 11℃ lower than that of the contrast grain to be stored as usual
- 'Double-faced airtight' It is to carry out the 'embedment of plastic film into fillisters' of all doors, windows and interior barn walls to ensure a complete hermetic sealing of barn and grain surface and to enhance the airtight and heat insulation of grain piles. Meanwhile it's required to avoid the presence of moisture on the ground of barn and to plant shadowy woods around barn and set up a proper water drainage system so that the storage environment could satisfy the requirements of '3-preparations, 4-protections, 6-doubles and 8-accomplishments', briefly as: to prepare ground ventilating channel, exhaust fan and ground fumigation pipeline; to exercise the insect prevention, moisture-proof, rat-prevention and heat insulation; to construct double roofs, double walls, double windows, double films and double-faced airtight; and to install overhead steel mesh, prevent the presence of fissures in column, ceiling and wall, ensure the airtight of door and window, embed plastic film into fillisters of interior wall, whitewash the exterior wall, prevent the presence of moisture on the ground, to green and reinforce the barn all around, and to dredge the drainage system.

2. To give a full play of coordinate functions of the three major ventilating techniques, with an emphasis on massive implementation of ventilating method of 'double radiation and triple drops in temperature plus an adjustment' so as to steadily cool the grain piles and create a satisfactory environment of grain storage. In order to lower the grain temperature for fresh preservation, it's important to start from the storehouse-in process and apply the new technique of 'double radiation and triple drops in temperature plus an adjustment' and 'exhaust ventilation under the film covering the grain piles', apart from the proceedings of

natural ventilation, exhaust ventilation and mechanical actuated ventilation in a proper order.

- 'Double radiation' It's to turn the grain upside down for a natural ventilation in the storehouse-in process, and then when the barn is full, to proceed the exhaust ventilation in the morning and evening just in an attempt to release the original heat from grain.
- 'Triple drops in temperature' It's to proceed after the storehouse-in process the radiating ventilation, low-temperature ventilation and cooling ventilation in three stages respectively in the middle ten days or last ten days of September, the first ten days or middle ten days of November and then in the next January, so that the grain could be cooled down to about 5℃. It would be best to carry out the exhaust ventilation under the film and without uncovering of film.
- 'An adjustment'. It's to proceed the regular adjustment of temperature inside the barn. To turn on the exhaust fans regularly early in the morning or in the nighttime period to ventilate and clear away the heat so as to cool down the barn and maintain a lower temperature inside barn and within grain piles Because the grain piles are of poor thermal conductivity and thermal transfer, the temperature-rise of grain is only approximately half of the barn in speed. The grain temperature in the middle or lower layer may be controlled at about 15℃, and that of upper layer may be controlled at about 20℃ at megathermal season, in case of a simple reconstruction of barn for heat insulation and a proper employment of the above measures.
- As to the design of ventilating ground channel, it is recommended to design in the principle of one channel for several purposes, to arrange the channels horizontally with a reasonable distance of only 3 metres, and to open holes on the northward wall and arrange exhaust fans on the southward wall, because it will be good to the ventilation and fumigation.

3. To continue the research on grain storage technique of '3-lows' and have an extensive use of the new comprehensive technique '6 in 1 to 3-lows' in the process of grain storage, attempting for an effective control of 'internal heat source' within grain piles and to promote the stability of grain storage. The immanent cause of temperature-rise, molds, insect pest within grain piles is the breathing of microorganism, insects and grain itself To eliminate the molds and insect pest and achieve the better grain storage, it's necessary to take into account the national realities and continue to base ourselves on comprehensive utilization of various techniques like biological, physical and chemical or other preventive measures. The comprehensive technique of '6 in 1 to 3-lows' as developed by us in recent years is just on the premise of the vigorous performance at low temperature, low oxygen and lower amount of fumigant and is to have an intimately combinative use of the 6 major techniques applicable widely at grass-root units (i. e grain storage at '2-lows', mechanical ventilation, applying fumigant on the bottom of barn, intermittent fumigation, spreading of protective agent and electronic inspection) according to the 6 stages (radiation, hermetic sealing, fumigation, cooling-down, cool preservation and supervision) and the 12 operative steps in a proper order, striving to complement and coordinate each other and to achieve a favourable grain storage in a comprehensive manner. It represents a new developing trend to store grain at '3-lows' under the current circumstances, and as a matter of fact, it has shown its strategic importance for its integration of the processes like drying, cooling-down, air adjustment, ventilating, cleaning and chemical prevention.

4 To ensure a healthy development of grain storage at low temperature, it is essential to intensify the standard technical operations, to exercise the administration by 'systematic engineering' and to keep up with the latest development of up-to-date technique. The grain storage at low temperature maintains a close link with the technique and administration. It not only involves in the administration of staffs, ideological work, expenses, chemical reagent, devices, storage facilities, environment, hygiene, quality control, technique and system, but also the processes of storehouse-in, radiation, airtight, fumigation, cooling, covering, cool preservation and inspection, in which they have an inseparable association with each other and will complement each other Therefore it's required to exercise the administration by 'systematic engineering' and to formulate the relevant administrative methods and standard operating steps, aiming at quality rather than quantity whilst in the process of grain storage at low temperature Now, the administrative work must be stressed on in the following three aspects:

a To formulate strict rules and regulations for heat insulation, cool preservation, insect prevention, moisture proof and rat prevention, and to insist on the principle of 'enclosing in spring, separating in summer, ventilating in autumn and freezing in winter'. Generally it is to carry out a complete airtight storage inside barn and pay particular attention to the blocking of air passage with clean and insect-free rice husk in bags so as to prevent the entrance of humid heat and harmful insects from outside.

b. To improve the checking system or methods over the grain conditions, cut down on inspections inside barns, wear the regular work clothes and slippers and carry the special-purposive inspection instruments to inspect the low-temperature barn before other kinds of barns just

early in the morning at 6 or 7 o'clock when the temperature is lower

c To have a good command of ventilation, airtight and adjustment of temperature inside barn To close the barn in the daytime of mesothermal or megathermal season, and turn on exhaust fans in the evening to adjust the temperature inside barn While at the microthermal season, it is required to ventilate for temperature-drop and cool preservation, but to close the barn and adjust the temperature when the ambient temperature goes up again. Anyway it is required to repeat the above steps again and again for a proper adjustment of temperature so as to assure a lower temperature inside barn or within grain piles.

The above-mentioned measures are generally defined as: The grain storage at low temperature with Chinese peculiarities = The comprehensive grain storage technique of '6 in 1 to 3-lows' + The ventilating technique of 'double radiation, triple drops in temperature plus an adjustment' + Reconstruction of barn based on '3-preparations, 4-protections, 6-doubles and 8-accomplishments' + Storage administration by 'systematic engineering'.

The Operating Procedures and Methods for Grain Storage at Low Temperature with Chinese Peculiarities

Subject to an adequate reconstruction of storage facilities and a proper control of 'external heat source', the following operating procedures may be adopted in order for the grain storage at low or quasi-low temperature.

1 To check in the storehouse-in process and to guarantee the grain quality. As indicated in the practical work, the airtight preservation of dry and clean grain at an appropriately lower temperature is the best storage method. In such a case, it's important to have a careful check on the quality of the grain to be preserved so that the moisture and impurities within the grain could be controlled to the extent that the safe preservation standard permits. The lower content of moisture and impurities, the better.

2. To put in storage the grain separately for a timely and sufficient radiation When the early rice is to be put in storage, it is high in temperature It's important to pile up the grain in a proper way and put in storage the grain separately, or turn over the grain in the storehouse-in process for natural ventilation and exhaust ventilation so as to give off the heat within the grain. It's of particular importance to have a full play of exhaust fan's advantages, such as, the exhaust ventilation respectively in the morning and evening to lower the grain temperature and minimize the moisture.

3. Mechanical ventilation to lower the temperature and assure the quality. In order to assure the grain quality and shorten the storage period at high temperature, it is especially important to suit measures to local conditions apart from the timely giving-off of the heat in the storehouse-in period, and to proceed ventilation for the first time in the last ten days of September when the temperature declines, but the grain temperature is higher than the ambient temperature by 8℃ or more, so as to enable the grain temperature drop to about 25℃. Through which the grain temperature is expected to decline and the grain piles to be loose, being good to fumigation and killing of insect pests

4. To preserve the grain by '2-lows' and some other preventive measures The grain piles shall be covered and sealed by quality PVC film or PVC compound film as soon as the grain temperature is lowered, and it would be best to double the film for aerial airtight. Upon natural deoxygenation for about 20 days, it is necessary to spray insecticide in due time on the two films or apply by aspiration of exhaust fan, and then through the bottom ventilation channel, to enable an even distribution of PH_3. As soon as the application of insecticide is accomplished, to sterilize the doors, windows and the space within the barn, and to arrange some blockade lines for insect prevention.

5 Intermittent fumigation and gradual release. 8 or 10 days later after the two films are sprayed with insecticide, to apply for the second time an adequate amount of aluminum phosphide (if necessary, to spray the insecticide for the third time) so as to prolong the durative effect of poisonous gas, maintain an effective concentration for a longer period of time and to kill thoroughly the eggs or pupas tolerant towards the insecticide in their growth period.

6 Adequate ventilation and storage at low temperature. In order to further preserve the quality of grain and prevent the dewfalls due to the difference in temperature, it is required to proceed mechanical ventilation for the second time at the opportune moment of a sharp drop in temperature when autumn changes into winter, and if possible, try ventilating under the films and never expose the grain piles in the process of ventilation so that the grain temperature may decline to 15℃ or below, and the storage at low temperature is achievable.

7 To ventilate when it is cold and prepare the insecticide for insect prevention. When the grain piles have been preserved under the conditions of '2-lows' up to the month of next January, it is necessary to proceed mechanical ventilation for third time at the opportune moment of being cold and dry in local areas so that the grain temperature could drop to about 5℃ (the lower, the better in case it is in the northern parts of China,

because it will facilitate the killing of insects under the freezing climate) As for the grain piles not to be ventilated under films, it is possible to mix and distribute the protective agent like Kaianbao and Baoliangan evenly into the surface layer of grain after the grain cools down so as to prevent the pest-outbreak.

8. To cover the top in hermetic sealing and to make adequate adjustment Before the temperature rises again in February next year, to have a reliable enclosure of barn and a perfect airtight of grain piles at the opportune moment of being coldest in local areas It would be best to cover the grain piles with one or two layers of protective agent in bags, all in a compact form and one against another with the purpose to facilitate the moisture absorption, insect prevention, heat insulation and cool preservation as well, and then to seal with film. Besides, it is also necessary to pay much attention to the regular inspection over the low-temperature barn and to frequently adjust the temperature inside barn so as to maintain the barn and grain piles at low temperature

Suggestions

In order to do well in grain storage at low temperature with Chinese peculiarities, some suggestions are given:

1. According to China's actual conditions and the realities at grass-root units, it is proposed to take the 'quasi-low temperature' as the applicable standard of grain storage at low temperature now in China, because it has not so many restrictions to the building enclosure and it is accessible to simplify the heat insulation and the equipment, with less input and costs, but easy to be accepted by the grass-root units and accessible to an extensive application.

2 To increase the funds for barn reconstruction, adequately raise the construction price of new barns and transfer the original barns in China into the 'quasi-low temperature' The future new barns must be designed in accordance with the requirements of '3-preparations, 4-protections, 6-doubles and 8-accomplishments', and constructed towards the south, being long east to west, but narrow north to south, and on the basis of an adequate increase of construction price The 'quasi-low temperature' barns must be built up only in a single phase to avoid the disconnection of capital construction with the purpose of grain storage and to prevent the reconstruction of newly-built barns over again.

3 To intensify the technical training specially for grain storage at low temperature Any of good technique or methods may fail in application due to personal factors It is thus necessary to conduct a training on the special topic of grain storage, attempting to unify the operating methods, enhance the standard administration and promote the standard administration and enable the healthy development of grain storage at low temperature.