In-store Drying of High Moisture Rice

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Abstract

This paper describes the fundamentals of the drying mechanism in high-moisture japonica rice by sucking in hot air as the drying medium based on the variation of moisture in grain, principle of drying high-moisture rice and quality maintenance of rice in low temperature and thus raising temperature of grain to about 28℃. As temperature rises in grain stocks, the moisture inside the grain particles moves towards the surface to evaporate and the blowers drives away the moisture from the intervals and surface of the grain. After 2 days, cool air is sucked into the grain stocks causing interaction between the grain surface with hot and cool air. This process results in the transfer and evaporation of moisture, reduces moisture in grain and keeps the temperature of grain below 30℃ These undertakings attempt to maintain quality and freshness of grain, reduce labor intensity and grain losses and maintenance cost in handling so as to achieve better social and economic benefit.

Introduction

Grain drying process by sucking in air through aeration boxes can not only delay the temperature rise in grain stocks, equilibrate moisture and temperature of grain, reduce pest-insects and microbial activity, increase stability of grain preservation, but also lower moisture content and dry the product. When the moisture in the air is higher than the equilibrium moisture of the product, the grain will absorb the moisture and moisture content increases; conversely, it decreases. As temperature and pressure of water vapor vary in different layers of grain, in which air is forced to convect, the vapor moves from the higher-temperature layers to lower temperature ones through intervals of the grain, and thus increasing the moisture content in lower-temperature grain. Based on the principle of rice drying, the movement of the hot and cool air will cause changes of temperature in grain and moisture inside the grain particles to move to the surface and evapourate. At this stage, blowerss in operation will suck the humid air out of the grain layers so as to reduce the moisture. This type of drying technique is of practical significance for processing high-moisture grain (about 16.5%) in local grain depots possessing low level of mechanization.

At present, moisture content of grain, when delivered into the local depots by farmers, varies greatly from batch to batch. This is extremely true for late season japonica rice. And to some extent, the grain is mixed with frard and foreign matters. Our city is the main production base of japonica rice. Depots purchase a lot of rice every year. As delivery is limited in a short period of time, much work should be done and it is always rainy at that season. Taking last year's situation for example, it rained almost one month at the harvesting season, making it difficult to thresh the rice. The moisture content in part of the rice was as high as 25%. For making delivery convenient for farmers, local depots had to relax the requirements of purchase. As a result, 50 milliom kgs of japonica rice was of high moisture, accounting for 80% of the total and creating great difficulties for safe preservation of grain. If the conventonal means of drying or sreading out to dry in the sun are adopted, a lot of factores, such as expenses, labour cost, weather, electrical power and time, will bring about problems of high operational cost and low efficiency. Compared to that, the drying process by sucking in drying air through aeration boxes to dehydrate the rice is a simple and safe grain preservation way. It is practical to solve drying problem caused by too much high-moisture grain in depots and save operational cost, losses and labor in handling and maintain food quality.

The fundamentals of the dry experiment are as follows: the blowers suck in air through aeration boxes to create interaction between the grain surface with hot and cool air. Based on the variation of moisture in grain and principle of drying high-moisture rice, hot air is sucked in as the drying medium continuously or intermittently and thus raising temperature of grain. As temperature rises in grain, the moiture inside the grain particles moves towards the surface to evapourate. When the pressure of the vapor outside the grain stock is higher than that in the interval of grain stock, the moisture of grain is released and at the very moment, blowers drives away the moisture and keep the grain dry After 2 days (the period is same with the curing during conventional drying process), cool air is sucked in to lower the moisture again so as to keep the grain in low temperature and maintain its freshness.

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Experimental Conditions and Methods

1. Aeration Process

Ambient air – surface of grain layers-(inlets of the aeration boxes opposite the blowers) – grain stocks(aeration boxes) – blowers – ambient air.

2. Experimental conditions

a) Depot: No. 9 Storehouse of Yuqiao Grain Depot in our city with designed capacity of 500,000kgs. It is composed of 5 reinforced-structured rooms with 7 aeration boxes on walls (5 on the rear wall,1 on the left front wall and 1 on the right front wall).

b) Grain: 440,000 kgs of high-moisture late japonica rice delivered in Dec. 1996. The mean moisture content in the whole storehouse was 16.5%, moisture content in partial area 18% and discolored grain 0.3% (data monitored by Central Monitoring Lab under the grain administrative bureau after aeration in winter), 4.3m in grain depth The temperature ranged from 5 to 9℃ after being aerated in cool air in winter and in a point temperature reached 12℃ as the highest.

c) Apparatus: 2 sets of Type 4-72-4.5A centrifugal blowers (power:7.5kW),7 aeration boxes (L×W×H=1m×1m ×0.6m), plastic film, tubes of temperature monitoring, thermometer and humidometer.

d) Three prevention facilities: Three-prevention doors, pest-insects prevention line and curtains were installed to reduce insects growth and attack, regulate the temperature in the storehouse and keep it in low temperature and delay the rise of temperature.

3. Experimental Methods

Reasonable temperature and relative humidity must be determined for aeration based on the variation of moisture in grain and temperature and humidity in different seasons Then the grain was aerated with dry cool air in winter to reduce the temperature below 10℃ for the purpose of controlling and delaying temperature rise in grain. After this process, the grain, with mean moisture content of 16.5% when delivered, was kept in the storehouse safely until the proper weather for drying. In mid of June, air temperature reached 20 – 32℃ (more than 10℃ of temperature difference), the grain was aerated with hot and cool air to dehydrate. Attention had to be paid to enhance the cool air suction in night time after having been aerated by hot air in day time so as to maintain grain in low temperature and good quality.

On April 20, the temperature in some points of the bed layer reached 34℃ so blowers were run to suck in cool air in proper time to reduce the temperature to 24℃. On June 16 – 17, air temperature was 20 – 33℃ with great temperature difference and low relative humidity, which was good for grain dehydration, hot air was sucked in to raise the grain temperarure to about 28℃ in two days As the temperature in grain rose, moisture inside the grain particles moved towards the surface quickly to evaporate and blowers took away the moisture. Two days later, cool air was sucked in to create interaction between the grain with cool air and moisture evaporated from inside was drove away again and temperature of grain was decreased in which grain could be maintained safely Monitoring and sampling data up to July 22 showed that the temperature was 25 – 26℃ in upper layer, 27 – 28℃ in middle layer and 27 – 28℃ in bed layer and on one point in bed layer high temperature (33℃) was found. Data monitored up to Sept. 5 showed that temperature was 24 – 25℃ in upper layer, 26 – 27℃ in middle layer and 26 – 28℃ in bed layer And also on one point we found temperature was 32℃ We monitored the grain in this point and result showed the grain quality was good and temperature could be controlled under 30℃. All data on aeration, dehydration and monitoring are listed in the appendix table.

High moisture content in the grain will lay foundation for growth and reproduction of pest-insects and mite. In order to prevent temperature rise in grain as storehouse closed for fumigation in July, aeration by cool air was conducted on June 28 – 29 when air temperature was low. The storehouse was fumigated on June 30-July 7 with good efficiency. After the fumigation, temperature of the grain did not rise too much. For preventing grain heating, cool air was sucked in to lower the temperature. During mid. and late June, the temperature difference was not great, causing it difficult to process high-moisture grain in this situation. We had to increase the number of aeration times, producing higher cost but the quality of grain was well maintained. On August 15, Sitophilus oryzae was found and we aerated the storehouse for several hours and fumigated by low chemical concentration with storehouse fully sealed to keep the grain safe in storage

Experimental Results

Through several times of aeration in the whole storehouse and partial points, grain was interacted with hot and cool air and its temperature increased or decreased so that the mean moisture content in the storehouse was lowered from 16.5% to 15.5%. Monitoring showed that the moisture and temperature in upper, middle and bed layers remained almost even. Since no dogdays occured last year, the rice was kept in the storehouse without degradation in quality throughout the summer.

Monitoring Record During Aeration in No 9 Storehouse of Yuqiao Depot

Aeration 1997	Temp ℃		Relat humidity %	Air	Time (hour)	Grain temperature ℃			Moisture %			Discolored Grain			Remarks
	Max	Min				Upper layer	Middle layer	Bed layer	Whole storehouse	Partial area	Partial area	Whole storehouse	Partial area	Partial	
Apr 20	12	20	65	cool	5	17－18	19－20	21－24	16 5	18 1	17 5	No	0 2	0 3	
Apr 21	11	20	62	cool	10	17－18	20－21	20－25	16 5	17 5	17 1	No	0 1	0.2	
Jun 17	20	32	65	Hot	10	20－21	22－23	23－25	16 0	17 0	16 2	No	0 2	0 2	33 ℃ at a point in bed layer
Jun 18	22	33	65	Hot	6	25－26	26－27	27－28	15 6	16 2	16 0	No	0 2	0 3	
Jun 20	20	32	68	Cool	7	23－24	25－24	26－27	15.6	15 9	15 9	No	0 2	0 2	
Jun 22	20	32	70	Cool	8	23－24	24－25	25－26	15.5	15 8	15 8	No	0.2	0 2	
Jun 28	23	31	75	Cool	7	25－26	25－26	26－27	15 5	15 8	15 7	No	0 2	0.2	32 ℃ at a point in bed layer
Jun 29	23	31	75	Cool	8	23－24	25－26	25－26	15 5	15 7	15 6	No	0 2	0 2	30 ℃ at a point in bed layer
July 8	20	30	75	Cool	7	24－25	26－27	27－28	15 5	15 5	15 5	No	0 2	0 2	34 ℃ at a point in bed layer
July 9	23	30	78	Cool	8	25－26	26－27	27－28	15 4	15 5	15 5	No	0 2	0 2	32 ℃ at a point in bed layer
July 16	24	33	82	Cool	4	24－26	26－27	26－27	15 4	15 5	15 5	No	0 3	0 3	32 ℃ at a point in bed layer
July 17	25	33	80	Cool	3	24－26	26－28	26－28	15 4	15 5	15 5	No	0 3	0 3	
July 22	27	35	80	Cool		25－26	27－28	27－28	15 4	15 5	15.3	No	0 3	0 3	33 ℃ at a point in bed layer
July26	25	33	81	Cool	3	25－26	27－28	27－28	15 3	15 4	15 3	No	0.3	0.3	33 ℃ at a point in bed layer
Aug 2	26	34	82	Cool	3	26－27	27－28	27－28	15 3	15.4	15 3	No	0 3	0.4	33 ℃ at a point in bed layer
Aug 15	23	31	82	Cool	3	25－26	26－27	27－28	15 2	15.4	15 3	No	0.3	0 4	33 ℃ at a point in bed layer
Sept 5	19	27	80	Cool	3	24－25	26－27	26－28	15 1	15 3	15 2	No	0 3	0 4	32 ℃ at a point in bed layer

From the table we can see that there are two points with moisture content of 17.5% and 18.5% respectively at delivery. We aerated these points seperately and lowered the moisture to 15.2% and 15.3%, resulting in no obvious quality degradation afterwards (samplings of partial points are not included in the sampling of the whole storehouse)

Effect and Analysis

1. Effect

July and August are the hottest season in our city with

temperature over than 36℃ as usual, which produces great difficulty for preserving grain. Although special doors, windows and fans are installed to regulate the air, temperature in upper layers in the ordinery depots can be as high as 35℃ and is 38℃ in part of the layers. But aeration system is enhanced in this depot to control the temperature of grain under 30℃ generally and 35℃ in part of the points. Through aeration and dehumidification in storehouse, grain is dried and quality is well maintained and cost on power consumption lowered as well. As estimated, two blowers had worked for 95 hours with total expenses of RMB 1,222 yuan. But in the conventional drying system, cost on electric power, coal and labour (depreciation on machinery is not included) would be RMB 14088 yuan, and grain loss in handling is another problem, which is about 1 kg per 100 kgs. If calculated by this rate of loss, the total loss would amount to 4400 kgs, equaling to RMB 7040 yuan So compared with the conventional drying process, which would cost RMB 21128 yuan to dry the same quantity of grain, the new technique saves RMB 19906 yuan and quality of rice and color is better, which produces more economic benefit.

2. Conclusions

a) When grain was delivered into the depot by farmers, most of it was packed in bag Storehouse workers just cut bags open when they were sent into the storehouse, producing uneven moisture content of grain (some is about 18%) In addition to that, japonica rice produced in 1996 was of inferior quality with much microbia and easy to get heat, so numbers of aeration times was increased for safe preservation. If the grain temperature in some part of the bed layer is 33 – 34℃ and it remain stable, regular aeration is enough to control the temperature under 30℃ for saving cost (the point with highest temperature doesn't mean the same point all the time in the table).

b) Compared with previous experiments, this drying process, based on the variation of moisture in grain, principle of drying high-moisture rice, temperature difference and low relative humidity in different seasons, dried the high-moisture japonica rice positively by sucking in hot and cool air alternatively through aeration boxes and grain is dehydrated effectively.

c) This process is simple and economic, and it not only reduces the moisture content of grian, but also enhance the shelf life of the product and helps to maintain its quality and get maximum economic benefit by minimum power consumption

3. Suggestions

a) This process should be conducted in proper seasons based on variation of moisture in grain, principle of drying rice and method of grain maintenance in low temperature. Careful routine checks to the grain and storehouse should be done by experienced storehouse keepers. Grain should be kept in a certain range of temperature and grain heating must be avoided During the whole process, monitoring, chemical analysis and comparison should be undertaken often. Experiments suggest that the best time for aeration with hot air is between mid of May and mid. of June in which difference of temperature is great and relative humidity low

b) During aeration, attention must be paid to sucking in air thoroughly and evenly to avoid occuring of dead-corners. In points close to the walls and room corners, suction of air for longer time is suggested(1 – 2 hours more) to take away the humid hot air thoroughly. Sealing along the walls must be good enough during aeration to prevent dewting and mildewing on walls and floors. In winter, drying cool air should be sucked into the grain completely to prevent grain heating in certain points (during this experiment, no phenomenon of dewting and wildewing have been found by tests with electrical sampling sticks to the ground, the color and odor of grain are good). When abnormal rise of temperature occurs in future, proper measures must be taken to solve the problem separately.

c) It's better to cut the grain bags open beforehand and send the grain into the storehouse by bamboo baskets or conveyers so as to avoid problems such as uneven moisture distribution, quality degradation and increase of aeration times

d) This drying process is suitable to storehouse with capacity of less than 500,000 kgs and mean moisture content of some 16.5%

e) If the storehouse is aerated again by sucking in drying cold air in winter to decrease the temperature below 15℃ and moisture below 15%, the grain can be kept throughout the summer safely

f) In order to raise the efficiency of aeration and lower cost, it is suggested to install aeration boxes (dimension changed to 2m×0.2m×1.5m(L W.H)) in the front and rear walls of each room and bamboo ducting at the four corners of the walls. In this way the aerated area will be increased and dead-corners reduced and at the same, it will increase the efficiency of air suction and save electricity consumption. The best time to suck in cool air is between 0 – 6 o'clock during the night

In-store drying process in japonica rice, which can save much manpower and energy, is a new means to preserve grain It is suitable for local depots with small capacity Since strict monitoring and management to the grain are required for safe operation during the whole process, every depot should try to draw their own experience and operational rules practical for their own depots.