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In-Bin Drying of High-Moisture Paddy with Continuous Blowing of Ambient Air

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연속상온 통풍에 의한 고수분 벼의 In-Bin 건조에 관한 연구

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Abstract

Low-temperature in-bin drying with high-moisture paddy were demonstrated and studied under local autumn weather condition. Paddy with the initial moisture content of about 24.5 percent in the steel storage bin(diameter: 3 *m*, height: 3.17 *m*) was uniformly dried to about 15 percent by continuous blowing of ambient air (average temperature: 10.5°C, RH: 58 percent) in the middle part of October. The amount of grain and grain height were 4.19 M/T and 90 *cm*, respectively. Total fan operation time was 288 hours and airflow rate was 4.81 m^3/min/m^3 of paddy. Mean drying rate was 0.03 percent per hour and enery requirement for fan operation was 0.38 KWh per *kg* water removed.

Introduction

In-bin drying involves the drying of a relatively large batch of grain and then the dried grain is usually stored at the same bin during the certain period. In-bin grain drying system with a natural ambient air convection during the harvesting season has advantages of low initial equipment costs, reduced energy requirements, simplicity of management, and improved grain quality[1~3]. This is also widely used as an on-farm process and/or as an offfarm finish-drying step[4~8]. However, the capability of in-bin grain drying with ambient air is mainly dependent on uncontrollable weather conditions. Accordingly, optimization of in-bin grain drying with ambient air is very complicated since various parameters affect the drying behavior and grain quality during drying[2~6].

The high potentiality of the autumn weather in Korea on paddy drying was reported by several workers[9~13]. These results indicated that the most important factors which influence in-bin grain drying with ambient air are the initial moisture content of the grain, amount and depth of grain, air flow rate, and weather condition[9~13]. It is generally agreed that the major disadvantage of in-bin grain drying with ambient air is the less uniform moisture content of the grain after drying[11~16]. To overcome such problems, overturning[11~12], stirring[15], or recirculation[16] of the grain during drying operation is commonly practiced. However, it was reported that uniform drying of paddy in a steel bin could be achieved by controlled air flow and grain depth without any other operations during drying[19].

On the other hand, increasing the operational efficiency of the post-harvest system to overcome rural labor shortage and post-production loss of grain is one of the problems to be solved in the near future in Korea. And also it is known that field harvesting would be changed from the conventional system of dry-material threshing to the system of wet-material threshing for the saving of labor and for the reduction of field losses of grain. From this point of view, in-bin drying with high-moisture paddy from wet-paddy threshing is considered as a highly recommended farm innovation[19,20]. However, there are few successful results on the high-moisture paddy (21~25 percent, w.b.) drying with in-bin drying system under the local weather condition.

This study was undertaken to evaluate the in-bin paddy drying by empolying a larger amount of paddy (4.19 M/T) with high moisture content(24~25 percent) and the continuous blowing of ambient air with higher air flow rate.

Materials and Methods

Low-temperature (ambient air) in-bin paddy drying experiments were carried out at Noryangjin of Seoul area in October 15~28, 1980. Steel bin for this study had 3.0 *m* in diameter and 3.17 *m* in height. The bin was equipped with perforated false floors (open area, 25 percent) and a centrifugal fan (0.375 Kw, 0.5hp)as shown in Fig. 1 and Table 1.

The paddy of *Indica* type variety *Milyang* 30 was combine-harvested, pre-cleaned, transported to the experimental site and loaded in the steel bin. Loading amount and depth of paddy were 4.19 M/T and 0.9 *m*, respectively. The average initial moisture content of loaded paddy was 24.3~24.7 percent as wet basis. Continuous fan operation started immediately

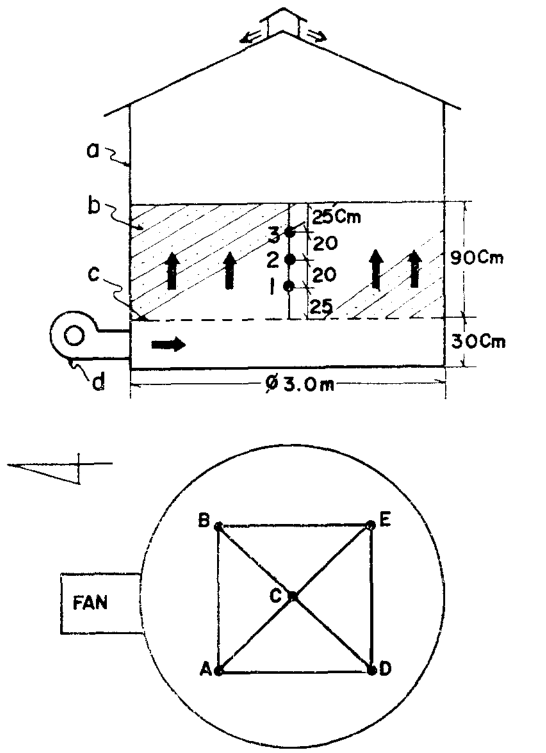

Fig. 1. Experimental steel bin and sampling position
a: Steel bin; b: Paddy; c: Perforated false floor (25% open area); d: Fan
A,B,C,D,E: Sampling point at 1, 2, and 3 grain depth

Table 1. Experimental conditions of paddy drying using steel bin

Variety of paddy	*Milyang* 30
Total amount of paddy (M/T)	4.19
Grain depth (m)	0.9
Harvesting date	Oct. 13, 1980
Bottom area of bin (m^2)	7.1 (ϕ=3 m)
Height of bin (m)	3.17
Material of bin	Galvanized iron
Type of bin	Lipp silo
Fan	Centrifugal type (0.5 Hp)
Volumetric air flow rate (m^3/min/m^3)	4.81
Drying period	Oct. 15-Oct. 28, 1980
Ave. temp. during drying period (°C)	10.5
Ave. RH during drying period (%)	58
Fan operation time (hr)	288

after loading of paddy into the bin. Volumetric airflow with ambient air was kept at 4.81 m^3/min/m^3 paddy throughout the drying period. Dry-bulb temperatures and relative humidity of inlet and exhaust air were recorded by hygrothermometer, and grain temperatures were monitored using a network of thermocouples. The moisture content of the paddy samples (for the sampling points, see Fig. 1) taken at every 24 hrs by sampling trier was determined by a standard oven method[14]. Overall experimental conditions are summarized in Table 1.

Results and Discussion

The weather data of experimental site during the drying period are shown in Fig. 2. Ambient air temperature and relative humidity were 0.8~22.1°C and 30~93 percent, the average being 10.5°C and 58 percent, respectively. The time period without drying potential of ambient air, that is, the time of which relative humidity was 75 percent or higher was about 30 hrs. It could be said that local weather during paddy harvest season has a high drying potential for low-temperature in-bin paddy drying as shown in other reports[9,12].

The drying curve of paddy grain at each layer during the in-bin drying with the continuous blowing of ambient air was shown in Fig. 3. This figure indicates that the drying rate of bottom layer was

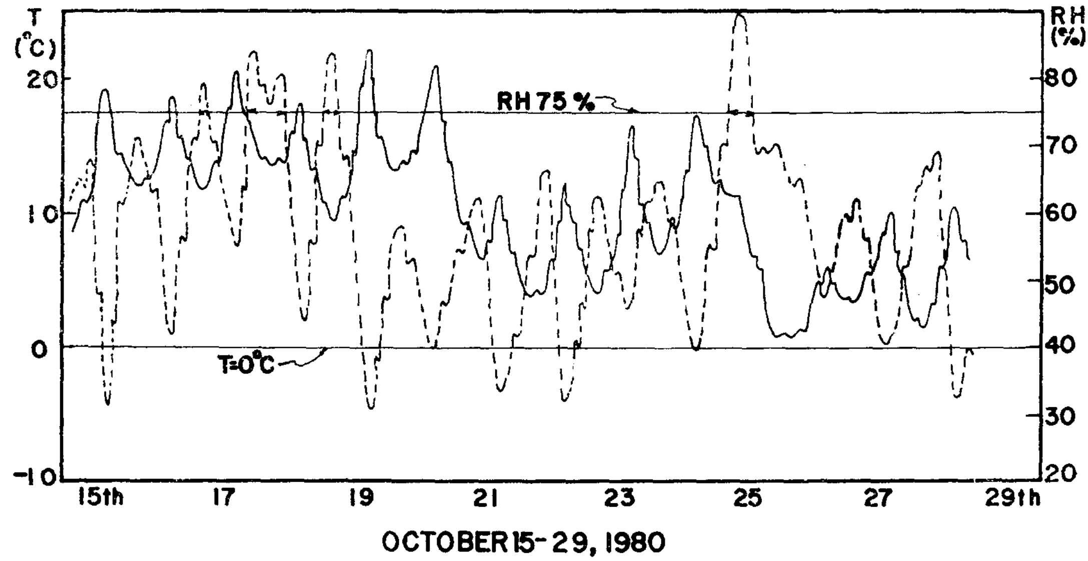

Fig. 2. Change of ambient air temperature and relative humidity of experimental site during drying period

Experimental site: Noryangjin, Seoul

——— Temp, ············RH

←——→ Period without drying potential

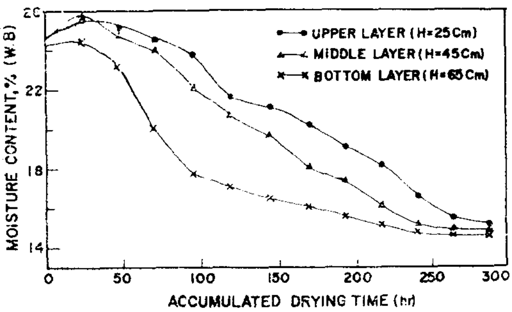

Fig. 3. Drying curves of paddy at different layers in steel bin with blowing of ambient air

much higher than that of upper layer. However, it was decreased apparently after the fan operation of about 100 hrs. These results were somewhat different from those of previous study[19], which reported the similar drying rates for the middle and bottom layers. This may be due to the differences in the initial moisture content of grain, air-flow rate and/or grain depth employed between two studies.

It required about 240 hrs for bottom layer, 270 hrs for middle layer and 288 hrs for upper layer to reduce the moisture content to 15 percent, which could be considered as safe level of moisture for paddy storage. After the continuous fan operation of total 288 hrs the difference in moisture content between the upper and bottom layers was about 0.5 percent. These results support the findings of previous study[13] which reported that the moisture gradient between the layers was less than 1 percent after 13 days of natural drying. In previous study fan was operated continuously for the first 7 days, and therafter intermittently from 9 : 00 AM to 9 : 00 PM for 6 days[19].

It was known that the disadvantages of in-bin grain drying with ambient air are the less uniform moisture content of the grain after drying, longer drying time and quality deterioration[11~16]. In order to overcome such problems it was suggested that the grain be mixed by overturning[11,12], stirring[15], or recirculation[16] during the drying process. However, in present study the paddy was dried to 15.0 percent level of moisture content with the good quality condition without any additional operation.

The results of the in-bin drying experiments were summerized in Table 2. The average moisture reduction and mean drying rate of paddy during the drying process was about 9.5 percent and 1.63 *kg* of water per hr, respectively. The mean drying rates expressed as percent of moisture content per hr were 0.032 at upper layer, 0.034 at middle layer and 0.033 at lower layer, the average being 0.033. These results were in a good agreement with those of previous study[19]. It should be noted that although the drying rates between the two studies were similar, the amount and the initial moisture content of paddy used in this experiment were much higher than those of previous study (2.0 M/T and 20.2 percent, respectively). On the other hand, grain depth was lower and air flow rate was higher comparing to those of previous study (1.1 *m* and 4.0 $m^3/min/m^3$ grain, respectively) The results thus imply that the predominant factors which influence the paddy drying are the grain depth and air flow rate.

The energy requirement for the in-bin paddy drying with ambient air is shown in Table 3. Comparing to high-temperature drying, fuel energy did not need in this experiment. However, electrical energy requirement for fan operation was observed as 0.38 KWh per *kg* water removed. This value was in a similar range of the previous work on the in-bin wheat drying[18].

Table 2. Summary of drying parameters and drying rate of the in-bin paddy drying with ambient air

Drying parameters	
Average initial moisture content(%, w.b.)	24.5
Average final moisture content(%, w.b.)	15.0
Mass of wet grain(*kg*)	4,190
Mass of dried grain(*kg*)	3,722
Water removed(*kg*)	468
Drying time(hrs)	288
Drying rate	
Mean drying rate(*kg* H_2O/hr)	1.63
Mean drying rate(%/hr)	
Upper layer	0.032
Middle layer	0.034
Lower layer	0.033

Table 3. Energy requirement during the in-bin paddy drying with ambient air

Thermal energy requirement (KWh/*kg* H_2O)	0
Mechanical energy requirement(KWh)	108
(KWh/*kg* H_2O)	0.38
(KWh/50*kg* paddy)	1.29
Electric energy cost* (won/*kg* H_2O)	7.73

*On the basis of farm use: 20.35 won/KWh

The results of this experiment are in a good agreement with those of the previous reports[9~13] in that the local October weather has higher potentiality for natural paddy drying. The low-temperature in-bin paddy drying is an alte rnative to the supplementary heat-air drying system[19,20]. A similar observation was reported for a wheat under Central European climatic condition[18]. This study also imply that a much larger quantity of high-moisture paddy(e.g., more than 4 ¥ and 24~25 percent of moisture content) from wet-paddy threshing may be dried by in-bin system with continuous blowing of ambient air under the careful conrol of grain depth and airflow rate.

요 약

철제 grain bin(지름 3미터, 높이 3.17미터)을 이용하여 수분함량이 높은 벼(밀양 30호)의 자연통풍건조시험을 우리나라 가을 기후조건하에서 행하였다. 이때의 시료벼의 초기수분함량은 평균 24.5%, 시료 벼의 량은 4.19¥, bin 내에서의 시료벼 높이는 0.9미터 그리고 풍량은 4.81m^3/min/m^3이었으며 그 결과는 다음과 같다.

건조시험기간중 외기의 온도는 평균 10.5°C, 상대습도는 평균 58%이었다. 연속자연통풍 288시간후의 시료벼의 수분함량은 15±0.3%로서, 상하층의 수분함량차이는 약 0.5%이었다. 그리고 평균 건조 속도는 시간당 0.03%이었으며 전기소요량은 1*kg*의 수분제거량당 0.38 KWh 이었다. 본시험결과, 상온자연통풍에 의한 in-bin 건조방법으로, 생탈곡된 고수분의 벼를 건조할 수 있는 것으로 분석되었다.

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