개량곳간을 이용한 벼의 상온통풍건조

Ambient-Air In-Bin Drying of Paddy with the Modified Flat-type Store for Small Scale Korean Farmer

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적 요

중규모 벼농가에서의 벼건조 및 저장을 위하여, 한국형 개량곳간(크기: 1.8×2.4m, 높이 : 3.2m, 규모 : 2-4 M/T)을 개발하였다. 송풍기(0.5마력) 및 공기유도닥트를 부착하여 건조 및 aeration이 가능하도록 하였으며, 저장중 양곡손실을 최소한 줄이기 위해 방서용철망, 환풍창 및 구판들을 설치하였다. 그리고 양곡의 입출고가 용이하도록 내리닫이쪽문을 설치하였다. 개발된 개량곳간을 이용하여 1981년, 1982년, 1983년 가을에 각각 수확한 물벼를 수확즉시 건조하였을 때, 기후조건, 수확시기, 수확시의 수분함량, 풍량, 송풍시간, 곳간내에서의 벼의 높이 등에 따라서 차이는 있으나 상온 통풍에 의하여 벼를 잘 건조할 수 있었다. 그리고 건조조건에 따라서 건조양상은 달랐으나 180~352시간의 건조시간이 소요되었으며, 연속 상온통풍에 의하여 건조된 벼의 품질은 비교적 양호하였다.

Introduction

The traditional paddy-drying methods in Korea require a high input of labour and condiderable losses of mass have also been reported.[1] The previous studies have shown that the low-cost small scale dryers for on-farm use must be urgently developed to solve the present drying problem and that in-bin low-temperature drying seems to be one of the most feasible drying methods considering the requirements of the Korean farmers.[2-4]

Realizing the fact mentioned above, the in-bin drying and storage (IBDS) system by the modification of the conventional flat-type paddy store was developed. For the development and designing of this IBDS system at farm level, the following basic concepts were considered: capacity according to harvesting size (2-4 M/T of paddy), maximum natural ventilation, mechanical aeration, rodent proofing and prevention of water permeation from the floor as well as the wells.

The advantages of this system includes a lower investment cost, less attention and handling requirement for drying and storage, no need of petroleum fuel, more uniform drying, and good grain quality.

The objective of this study was to evaluate the in-bin low-temperature drying of paddy

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with the developed IBDS system under the Korean climatic and farming conditions.

Materials and Methods

Experimental system

The IBDS system (rectangular type: 2.4 m x 1.8 m and 3.2 m height) located in Seoul was used (see Fig. 1 and 2). This system was fitted with the air duct which had a main rectangular wooden duct (20 cm x 20 cm and

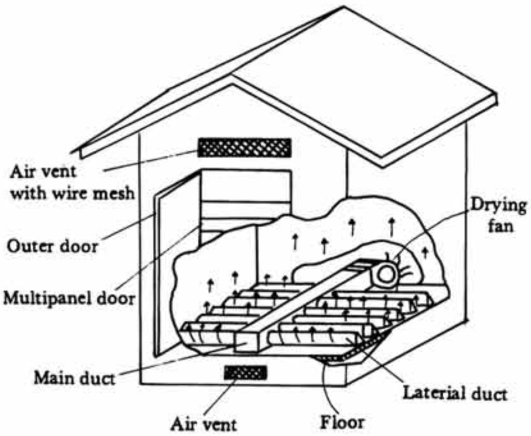

Fig. 1. Conceptual drawing of modified flat-type store (IBDS system).

about 235 cm long) and twelve inverted V-shaped lateral ducts (bottom: 17 cm, height: 18 cm, length: 79 cm) on the floor. A centrifugal fan driven by an electric motor of 0.4kw was attached to the system. Air vents on the wall were placed at 15 cm high from the ground (just below floor) and 30 cm below the roof. The construction material of the IBDS system was mainly cement (or cement block), except for the roof which consisted of corrugated slate. The wall and inside roof of the system were painted with water proofing material and/or were lined with styrofoam sheet. And the floor was also spaced to prevent the permeation of heat and moisture from the ground. Outer

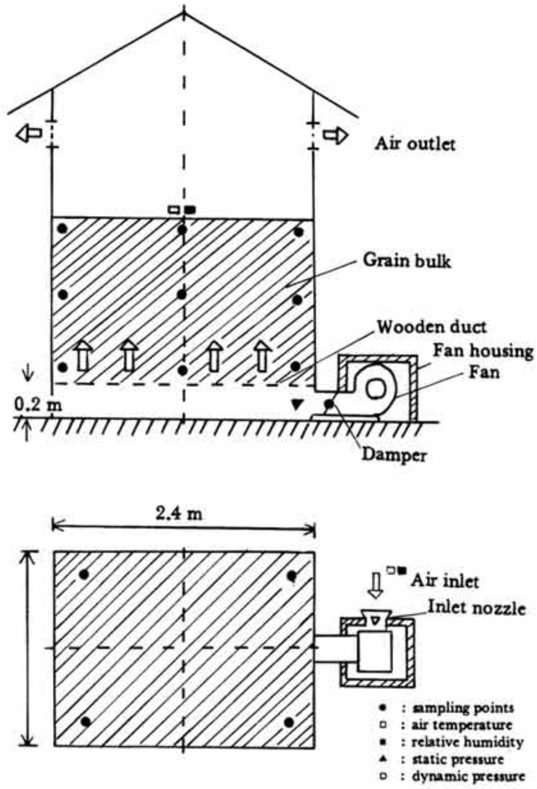

Fig. 2. Schematic diagram of an experimental system with the points for moisture content and other determination.

and inner multipanel doors were installed for grain handling.

Instruments and methods of analysis

Temperature and relative humidity of ambient and at the head space of the store were recorded continuously on hygrothermometer (Sato Co., Japan). Airflow rate was calculated from the manometer reading of dynamic pressure through the inlet nozzle and static pressure was measured from pitot-tube in the main duct. Samples were taken by a double concentric tube type trier for the determination of moisture content and the quality evaluation at the various points in grain bulk. The samples taken prior to drying were dried under the shade on a single layer and served as the control. The moisture content of grain was determined by dry oven method (24 hrs at 105°C. Acid value was determined by the method of AACC.[5] Milling properties were ascertained by the methods outlined in the Agricultural Product Inspection Manual[6] as follows; About 300 gm of paddy rice was dehulled in a Satake testing mill and 165 gm of brown rice was milled for 175 seconds in a mill. Theoretical drying potential of air is defined as the capacity of air to absorb water, which is a difference in water content between the ambient air and the adiabatically saturated air.[7] It was calculated by the iterative approximation on a HP-86B personal computer using ASHRAE data.[8]

Paddy rice

Paddy rice were harvested by a combine harvested in Suweon area. They were the high yield variety (Milyang 30) in 1981 and 1982 and traditional variety (Akibare) in 1983. Moisture contents of paddy were 21.0, 21.4, 24.0% in 1982, 1982 and 1983 respectively. The paddy were loaded manually after precleaning, however, in 1983 precleaning was not performed completely.

Drying procedure

Harvested paddy of 2,500 kg were loaded in an IBDS system to 0.9 m in 1981 and airflow was fixed at 6.0 m^3/m^3 paddy/min. Air was blown continuously, except on rainy days, from the loading time to the day when the moisture content at the top surface was lower than 15%. Sampling was carried out every day at 5 points at each layer as shown in Fig. 2. In 1982, an IBDS system was filled to 1.1 m with 3,000 kg of paddy rice and air flow was kept at 5.0 m^3/m^3 paddy/min. On the other hand, the paddy rice of 2,900 kg were harvested and loaded up to 1.2 m in the IBDS system in 1983. And airflow was 3.9 m^3/m^3 paddy/min. In this case, bulk volume increased because of the incomplete precleaning of paddy. Other general procedures were almost the same as in 1981.

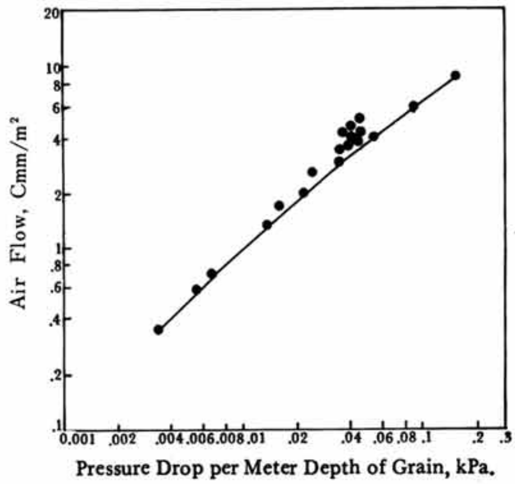

Fig. 3. Air resistance in the IBDS system.

. : IBDS system

— : Shedd's data

Results and Discussion

Static pressures in the IBDS system were compared with the Shedd's data as shown in Fig.3.[9] A summary of the low temperature in-bin paddy drying is given in Table 1 and the quality changes after drying are also given in Table 2. Weather conditions and the changes of moisture content of paddy with the drying time are shown from Fig. 4 to Fig. 6.

Static pressure in the IBDS system

Static pressure was measured at 1.1 m depth in IBDS system filled with 14% moisture content of paddy. With the variation of airflow

Table 1. Summary of the results of low-temperature in-bin paddy drying in IBDS system.

	1981	1982	1983
Initial moisture content (% w.b.)	21.9	21.6	24.0
Final moisture content (% w.b.)			
maximum	15.1	13.9	15.2
minimum	13.8	12.6	12.5
average	14.6	13.2	13.6
Drying period	Oct. 3-12	Sept. 27-Oct. 9	Oct. 13-28
Air temperature average (°C)	15.8	18.6	12.6
Relative himidity average (%)	69.9	63.3	64.0
Drying potential (kg H_2O/kg air)	0.00135	0.00187	0.00143
Airflow rate (m^3 air/m^3 paddy/min)	6.0	5.0	3.9
Grain depth (m)	0.9	1.1	1.2
Mass of wet grain (kg)	2,500	3,000	2,900
Mass of dried grain (kg)	2,286	2,710	2,551
Water removed (kg)	214	290	349
Drying time (hr)	185.5	211	351.5
Drying rate (kg H2O/hr)	1.15	1.37	0.99

Table 2. Paddy quality after the low-temperature drying in IBDS system.

	1981	1982	1983
Milling yield (%)	92.0	91.5	90.1
Cracking ratio (%)	5.0	4.0	6.0
Acid value (mg KOH/gm crude oil)	6.5	8.5	7.2

rate, static pressure changed along to the line of Shedd's value with minor differences. It was considered that the differences were caused by the different conditions such as bulk depth, variety of paddy and air distribution mechanism between two systems. However, it could be inferred that air distribution duct in IBDS system hardly had influence on the static pressure and Shedd's data would be adapted for the design of low-temperature paddy drying by IBDS system.

Weather conditions

Average ambient temperatures during the drying period were 15.8, 18.6 and 12.8°C in 1981, 1982 and 1983, respectively. While, average relative huminities were recorded as 69.9, 63.3 and 64.5% in the respective years. Drying potentials were from 0.00135) to 0.00187 kg H_2O/kg air and higher drying potential period was longer in 1982 than in the other years. In 1983, drying potential was low but lower range in this period was shorter than in the others.

The equilibrium moisture content of paddy rice requires drying potential above 0.0006 kg H_2O/kg air for the reduction of the moisture content below 17% during the harvesting season in Korea. The period which had a drying potential below 0.0006 kg H_2O/kg air rather increased the moisture content of grains as shown in

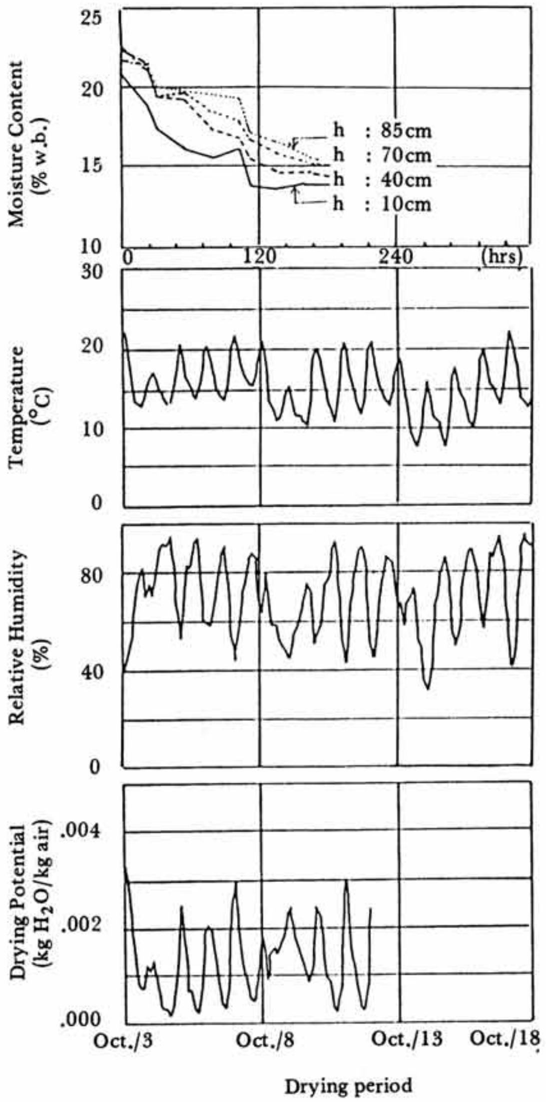

Fig. 4. Changes of moisture content of paddy and weather conditions during the drying period in 1981.

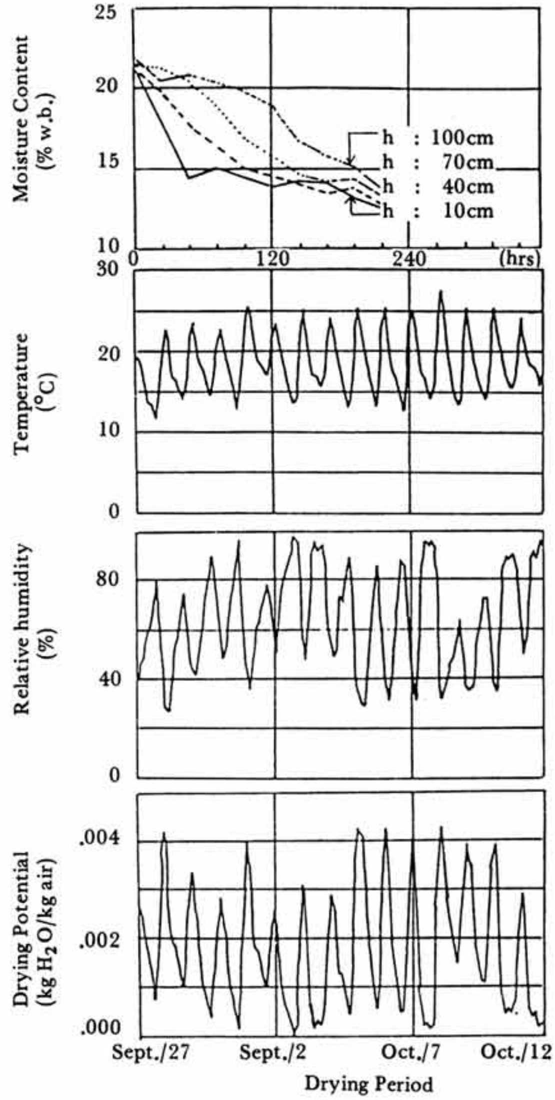

Fig. 5. Changes of moisture content of paddy and weather conditions during the drying period in 1982.

the period after initial drying time. In 1983, only 12% of period was below this value of 0.0006, but in 1981 and 1982, about 20% of period was below the indicative value. After all, when the moisture content of the paddy rice at the top surface is lower than 17%, the operation period of fan would be determined according to the weather conditions.

Drying time

Drying time is dependent upon weather conditions, air flow rate, grain depth and initial moisture content of paddy. With the decrease of airflow rate, drying rate was reduced accordingly. In 1983, the late harvested paddy was dried for the drying period extended up to near November with the airflow rate of 3.9 m3/

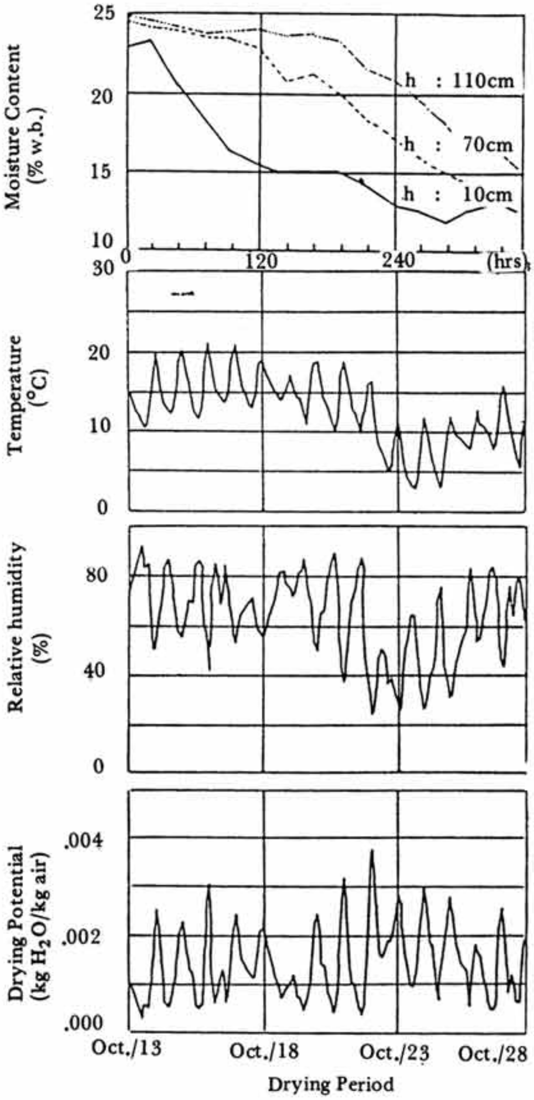

Fig. 6. Changes of moisture content of paddy and weather conditions during the drying period in 1983.

m^3 paddy/min. Even at high airflow rate, drying time was extended considerably because of the bad weather conditions. Drying potential was relatively high but temperature was low, thus mass transfer was limited, which, in turn, resulted in low drying rate. In 1982, weather conditions accelerated drying rate and thereby shorten the drying period relatively. Therefore, drying conditions should be adjusted according to the harvesting date and weather conditions. Low airflow, high grain depth and/or high moisture content will extend the drying period and invite spoilage of paddy. On the other hand excessively high airflow will require high operating cost.

Conclusion

Ambient-air in-bin paddy drying with the modified flat-type store (IBDS system) under the Korean climatic and farming conditions could be adapted for the small scale Korean farmer. In general, success of drying depended upon the uniformity of moisture distribution and milling yields. After drying the paddy had relatively uniform moisture content and extended fan operation produced better results. Moreover, paddy dried in IBDS system had a relatively good quality as shown in Table 2.

Acknowledgements

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