DEVELOPMENT OF A GRAIN CIRCULATING TYPE NATURAL AIR IN-BIN DRYER

H. S. YUN, H. CHUNG, Y. G. CHO, W. K. PARK

National Agricultural Mechanization Research Institute
249 Seodun-dong, Suwon, Kyunggi-Do, 441-100, Korea
E-mail : hsyoon@rda.go.kr

ABSTRACT

A natural air in-bin grain dryer with a grain circulator was developed for on farm use. Natural air drying test for rough rice was carried out to evaluate drying rate, uniformity of moisture content distribution in grain bed and energy consumption.

It took 10 days to dry 8 ton of paddy rice from 21.9%(w.b) to 16.7%(w.b) moisture contents using the prototype dryer. The average drying rate was 0.52%/day. The uniformity of moisture content after drying was superior to the conventional natural air dryer where is grains were not circulated during drying periods. The dryer performance evaluation index was 738.3KJ/(kg.water), which was more effective than that of grain circulation type hot air dryer(3,500~5,000 KJ/kg.water).

Key Words : Natural Air Drying, In-bin Drying, Paddy Rice, Drying, Dryer

INTRODUCTION

In 1997, 98% of major farm operations (tillage, transplanting, pest control, harvesting, etc.) in rice production were mechanized in Korea. However, the mechanization rate of post-harvest operations is relatively on the primitive stage compared with that of major operations. The mechanization rate of drying is only 38% and so almost all of paddy rice are dried through sun drying, and 75% of the storage facilities are conventional types.

The Rice Processing Complex (RPC) was introduced to produce high quality rice and promote mechanization in post-harvest operations in the early 1990's. Since then more than 400 RPCs were established. However, the amount of paddy rice that could be dried at RPC was only 15% of total production and so most of paddy rice were still dried and stored in the farm household. In addition, on the aspect of the usage of the RPC, efficient drying was impossible because too much amount of paddy rice were brought into the RPC during harvesting periods and causing quality and quantity loss of paddy rice. Therefore, there is an urgent need to develop and manufacture a drying and storage machinery for farm use.

In Korea, drying by sun, natural air in-bin, and the hot air are used for paddy rice.

Among them, the natural air in-bin drying has advantages of reducing energy consumption and the cost of equipment, because the climate condition during harvesting periods of paddy rice is suitable for natural air drying. Also, the natural air dryer can be used both as dryer and storage facility. However, it can cause a great difference of moisture content in grain bed resulting to quality loss by over or under drying of grain. Also, it requires excessive labor because grain is charged and discharged by manpower. If these problems of the natural air in-bin dryer are solved, it is expected to reduce labor, cost and quality loss for drying and storage of paddy rice.

Therefore, the purposes of this study are as follows :

1. To develop a grain circulating type natural air in-bin dryer which is possible to dry grain uniformly and reduce required labor.

2. To carry out natural air drying test to evaluate drying rate, uniformity of moisture content distribution in grain bed and energy consumption of developed dryer for rough rice.

MATERIALS AND METHODS

Consideration for Developing Prototype Dryer

A grain-circulating type natural air in-bin dryer was developed considering the following :

ⓐ It provides multi-purpose use as a dryer and a storage facility.

ⓑ It has a grain circulating function for uniform drying of the grain.

ⓒ It adopts a hopper type bin for smooth discharge of the grain.

ⓓ It has a fan for natural air drying and aeration.

ⓔ It has a mechanical equipment to minimize the labor requirements for charging and discharging of the grain.

Performance indications were :

ⓐ Equilibrium Moisture content

When grain is left in the air of constant temperature and humidity for a sufficiently long time, an equilibrium state is reached in the system of the grain and the air. As a result, the moisture content of the grain settles at a certain level. This is called the equilibrium moisture content. For the natural air drying, the equilibrium moisture content of grain is the lowest that can be attained when dried. In Korea, the climate condition during harvesting periods of paddy rice has a great potential for natural air drying and the equilibrium moisture content of grain is 13.8~ 15.9% (w.b) (Keum, 1998).

ⓑ Minimum Specific Airflow Rate

The minimum specific airflow rate(MSAR) is one that will dry the grain to a safe storage moisture content before the grain goes out of condition. In Korea, it is recommended MSAR levels are 4, 3, 2.5, and 1.5 cmm/㎥ under 24, 22, 20 and 18%(w.b) of initial grain moisture contents respectively(Go, et al. 1990).

ⓒ Airflow Resistance

When air is forced through a layer of grain and air duct, resistance to the flow, so-called pressure drop, is developed. For effective natural air drying, the resistance must be overcome by providing a pressure build up on the air entrance side.

The resistance of rough rice(640kg/㎥ of fill density) to airflow is calculated by the following equation (Go, et al.1990).

$$\Delta P_g = 468.506V^{1.1485}$$

Where, ΔP_g = airflow resistance of rough rice(mm.Aq/m)

V = airflow rate(㎥/s.㎡)

The airflow resistance of perforated metal which has 10% or more hole area of the total surface area, is small compared with that of grain and can be neglected (Henderson, 1943).

ⓓ Dryer Performance Evaluation Index

The dryer performance evaluation index(DPEI) is the ratio of consumed energy for drying to the amount of water removed from grain. The DPEI of the grain circulating type hot air dryer is 3,500~5,000kJ/kg.water(Go et al. 1990).

$$DPEI = 3{,}600 \times P/\Delta M$$

Where, P = total consumed energy(kW)

ΔM = amount of water removed from grain(kg)

Performance Test

The performance of the prototype dryer was examined using Suwon 334 variety of rough rice in the Youngin county from 16th Oct. 1998. The weight of rough rice was 8ton, and the initial average moisture content was 21.9%(w.b).

The fan was operated from 10a.m to 5p.m every day. The grain was circulated from 2p.m to 5p.m every day except on the first, 3rd, and 8th day. On the first, 3rd, and 8th day, the grain was circulated from 5 p.m. to 6 p.m.

The grain sample was collected every day at 14 positions in the grain bed before grain circulation. Fig.1. shows the grain sampling positions.

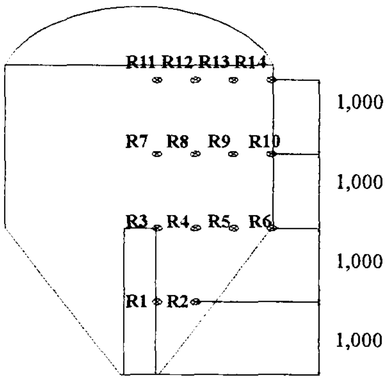

Fig. 1. Grain sampling position.

The moisture content of grain was measured by the single kernel moisture meter(SHIZUOKA, GTR-800E) which was calibrated comparing with the air oven method.

RESULTS AND DISCUSSION

Development of Prototype Dryer

The developed dryer is composed of a grain bin, a screw conveyor, a bucket elevator, a fan and frame. The schematic diagram and photo of the prototype is shown in Fig.2 and Fig.3 respectively, and Table 1 shows the specification of prototype.

Grain bin was made of F.R.P for increasing durability and decreasing price. The type of grain bin was hopper type and hopper inclination was 60° .

The discharged grain from the grain bin are returned to the upper part of the bin by screw conveyor, bucket elevator and 2-way gate which is attached at the end of discharge gate of bucket elevator. It is possible to control by 2-way gate, whether the grain are discharged or circulated.

A perforated round duct was installed perpendicularly in the grain bin, and the duct was connected with a centrifugal fan for natural air drying.

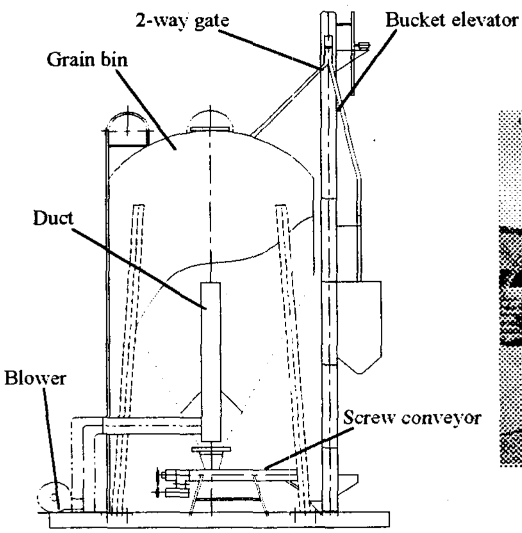

Fig. 2. Schematic diagram of prototype dryer.

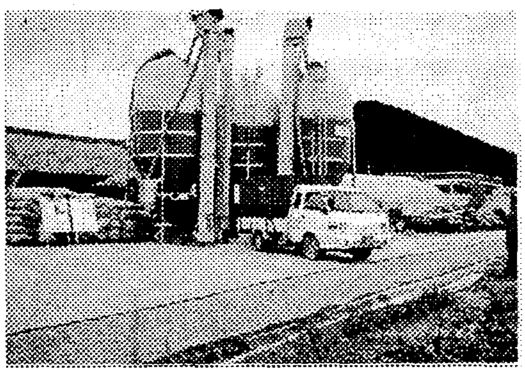

Fig. 3. Photo of prototype dryer.

Table. 1. Specifications of prototype dryer

Items	Specifications	
Grain Bin	Dimension Capacity Material	2,100(Φ)×4,650(H) mm 8 ton F.R.P
Bucket Elevator	Dimension Motor Power Capacity	7,400(H)×200(W) mm 1.5 Hp 2 ton/h
Screw Conveyor	Dimension Motor Power Capacity	1,550(L)×100(Φ) mm 0.75 Hp 2 ton/h
Fan	Airflow Rate Static Pressure Motor Power	45 cmm 74 mm.Aq 1 Hp
Air Duct	Dimension	250(Φ)×1,500(L) mm

Performance Testing

a. Ambient Air Condition

Fig.4 shows change of the ambient air temperature and the relative humidity during drying periods. The average air temperature and relative humidity from 9a.m to 6p.m during drying periods were 17.2℃ and 67.2% respectively, and there was no rainy day. It was considered a very nice condition for natural air drying.

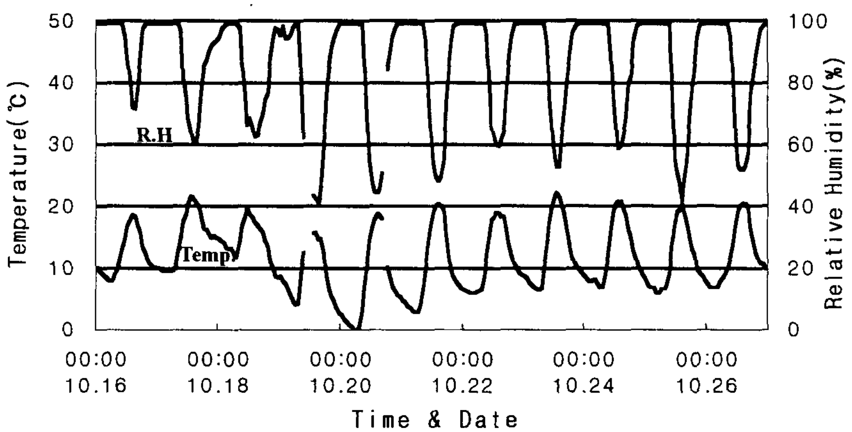

Fig. 4. Change of ambient air condition during drying periods.

b. Drying Rate

Fig.5 shows change of grain moisture content during drying periods. It took 10 days to dry rough rice from 21.9%(w.b) to 16.7%(w.b) moisture content. The average drying rate was 0.52%/day, and the final moisture content was distributed within

16.3~17.0%(w.b). In this experiment, the grain depth was 4.4m which is equivalent to 2.2m of depth for the flat type round bin of the same diameter.

According to Kim's research(1987) on natural air drying with flat type square bin at 1m depth of rough rice, when the moisture content of top bed grain was dried to 15%(w.b), that of the bottom layer has reached 12~13%(w.b).

Therefore, it was considered that the natural air drying by prototype was very effective for uniform distribution of moisture content in grain bed.

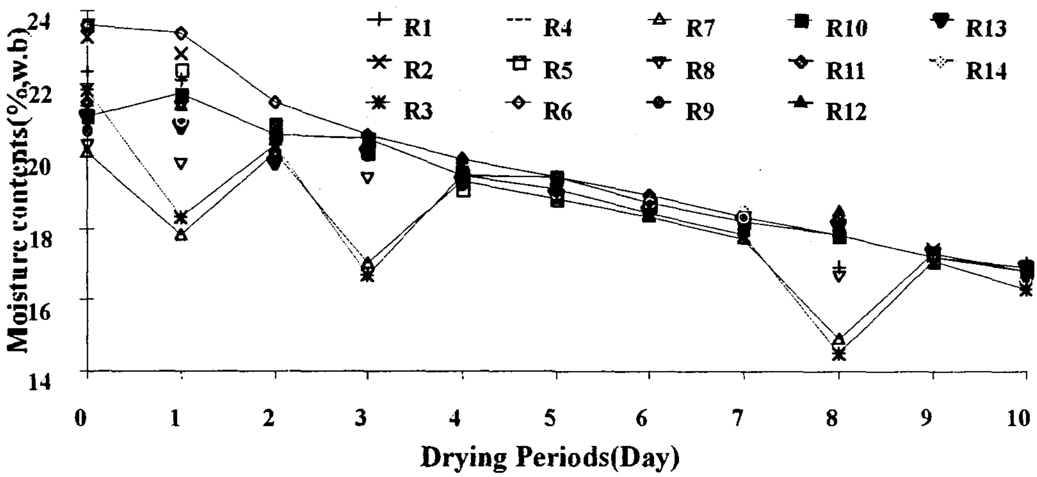

Fig. 5. Change of average moisture content.

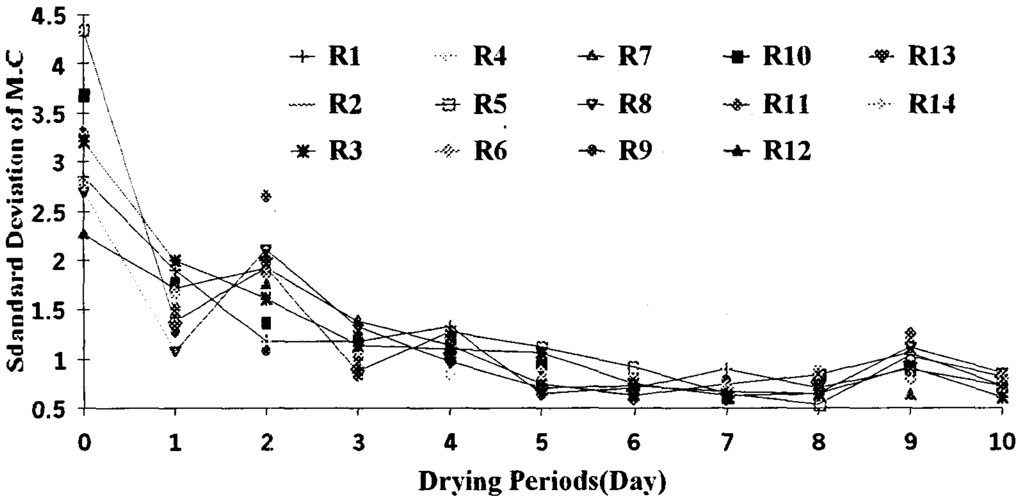

Fig. 6. Change of standard deviation of moisture content among grain kernels.

Fig. 6 shows change of the standard deviation of moisture content among grains at every sampling position during drying periods. At the start of the drying period, the standard deviation of moisture content was within 2.3~3.7%. However, as drying process progressed, the S.D was also diminished; it was lower than 1% from the 6th day of drying, and it was within 0.58~0.87% at the end of the drying period.

c. Uniformity of M.C Distribution in Grain Bed by Grain Circulation

As shown in fig.5, when grain was circulated for 3 hours per day, the grain moisture distribution was almost uniform. However, when grain was not circulated on the 1st, 3rd, 8th day, grain which was close from the duct was dried faster than others and so the difference of moisture content was increased. Especially, when the moisture content of grain was low(8th day), some grain was dried to 14.5%(w.b) of moisture content and so it contained a risk of over drying. Therefore, it was considered that grain circulation was very effective for uniform distribution of grain moisture content in grain bed.

As shown in fig.6, when grain was not circulated on the 1st, 3rd, 8th day, the standard deviation of moisture content among grain kernels on the next day was increased remarkably. The reason was considered because the grain was mixed with each other what was not dried uniformly. Therefore, it can be concluded that grain circulation was effective to diminish the moisture difference among grain kernels.

d. Energy Consumption and Dryer Performance Evaluation Index

Table 2 shows the electric energy consumption and the DPEI of prototype dryer. It was consumed 102.54 kWh of electric energy to evaporate 500kg of water from grain, and calculated DPEI was 738.3 kJ/kg.water. This was lesser than that of the grain circulation type hot air dryer(3,500~5,000 kJ/kg.water). Therefore, the prototype dryer was very effective to reduce energy consumption for drying.

Table.2. Energy consumption and dryer performance evaluation index

Electric energy consumption(kWh)			Total evaporated water(kg)	Dryer performance evaluation index (kJ/kg.water)
Fan	Grain circulating	Total	500.0	738.3
52.5	50.04	102.5		

CONCLUSIONS

A natural air in-bin grain dryer with a grain circulator was developed for on farm use. Natural air drying test for rough rice was carried out to evaluate drying rate, uniformity of moisture content distribution in grain bed and energy consumption. The obtained results can be summarized and concluded as follows.

1. The average air temperature and relative humidity from 9a.m to 6p.m during drying periods were 17.2℃ and 67.2%, respectively. These conditions were considered as most appropriate for natural air drying.

2. It took 10 days to dry rough rice from 21.9%(w.b) of moisture content to 16.7%(w.b), the average drying rate was 0.52%/day, and the final moisture content was distributed within 16.3~17.0%(w.b). It was considered that the natural air drying by prototype was very effective for uniform distribution of moisture content in grain bed.

3. The standard deviation of moisture content among grain at the start of the drying period was within 2.3~3.7%. However, as drying progressed, the S.D was diminished to 0.58~0.87% at the end of drying period. It can be concluded that the natural air drying by prototype was effective to diminish the moisture difference among grain kernels.

4. Circulated drying was better than non-circulated drying for uniform distribution of the grain moisture content in grain bed and to diminish the moisture difference among grain kernels.

5. The natural air in-bin dryer consumed 102.54 kWh of electric energy to evaporate 500kg of water from grain, and calculated DPEI was 738.3 kJ/kg.water. That was lesser than that of the grain circulation type hot air dryer(3,500~5,000 kJ/kg.water). Therefore, the prototype dryer was very effective in reducing energy consumption for drying.

REFERENCES

1. H. G. Go et al. 1990. Agricultural Processing Machinery. pp377. Hiyangmun Co(In Korean).
2. D. H. Keum. 1998. Paddy Rice Drying ang Storasge Handbook by Circular Flat Type Steel Bin. pp.84. Sung Gyun Gwan University(In Korean).
3. Chung, C.J. 1980. Post-production Rice Systems in Korea. College of Agriculture, Seoul National University.
4. D.B. Brooker. 1992. Drying and Storage of Grains and Oilseeds. pp.450.
5. D.H.Keum and S.T.Park. 1996. Minimum Specific Airflow Rate Requirements for Natural Air Drying of Rough Rice in Korea. J. of the Korean Society for Agricultural Machinery 21(1) : 60～71(In Korean).
6. K.S.Kim and M.G.Shin. 1987. Ambient-air In-Bin Drying of Paddy with the Modified Flat-type Store for Small Scale Korean Farmer. J. of the Korean Society for Agricultural Machinery 12(3) : 50～56(In Korean).