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# Effect of Paddy Drying by Solar Energy Concentration Blast-Grain Circulation Dryer

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# 太陽熱集熱送風, 穀物循環式 乾燥機의 벼 乾燥効果

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## 초 록

米穀의 安全乾燥와 乾燥時間을 短縮시킬 수 있는 乾燥機를 開發하기 위하여 2.5ton 規模의 太陽熱集熱送風, 穀物循環式 乾燥機를 製作하여 常溫送風式과 比較 試驗을 實施한 結果는 다음과 같다.

1. 太陽熱集熱送風, 穀物循環式 乾燥機에 送風되는 空氣의 溫度는 外氣溫度 및 常溫送風式 乾燥機에 送風되는 空氣의 溫度 보다 4～5°C 높았다.

2. 벼 乾燥期間中 乾燥機內의 部位別 水分含量은 常溫送風式 乾燥機內에서는 差가 극심하였으나 太陽熱集熱送風, 穀物循環式 乾燥機內에서는 差가 거의 없었다.

3. 水分含量 24%의 벼를 15%까지 乾燥시키는데 常溫送風 乾燥로는 14日 程度 所要되었으나 太陽熱集熱送風, 穀物循環式 乾燥機로는 3日 程度 所要되었다.

4. 常溫送風 乾燥機로 乾燥한 벼의 胴割粒率은 上部, 中部, 下部가 각각 6, 6 및 12%로 乾燥機內의 部位別로 差가 있었으나 太陽熱集熱送風, 穀物循環式 乾燥機로 乾燥한 벼는 모든 部位가 7%로 部位別로 差가 없었다.

5. 벼 乾燥期間 中 에너지 (energy) 所要量은 常溫送風式 乾燥機는 108Kw/2.5ton인데 比하여 太陽熱集熱送風, 穀物循環式 乾燥機는 28.8Kw/2.5ton이었다.

## Introduction

The moisture content of rice at harvest reaches 21～25%. It is essential to bring it down to 15% by drying, conditioning rough rice for storage and milling[1], in order that qualitative and quantitative bio-losses of rice during storage and milling be prevented. But in Korea, shortage of drying facilities and rural labors at the harvest time tends to impose farmers too heavy a labor work to operate drying properly and sufficiently. Earlier they used to utilize rice-straw mats, but these days concrete-plates, synthetic cloth-tent materials or asphalt-plates have been increasing use because of their readiness and lower cost. Efficient seed drying with a hot wind dryer, supplied by the number of the facilities is very limited at the current situation. Some farmers who tried the drying at high temperature for shorter time found more cracked kernels and rice quality in general to become inferior. Pressing need for the improvement and development of the drying method,

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which should be short-time, and yet free of deterioration in rice quality has been stressed in the recent years.

Goh[2] remarked that the good drying temperature is 30~40°C for seed, 46°C for general consumption, and that the drying speed greatly depends on temperature, relative humidity and aeration speed passing grains. And Keum et al.[3] reported that the average temperature, relative humidity of October in Korea are 13.0~16.8°C and 67~76%, respectively, and it depends on the equilibrium moisture content at 14.9°C, 69.0% relative humidity, and that it is therefore feasible to bring down to 15% of moisture content by drying. Chun et al.[4] reported that it takes 4~5 days to dry rice to 15% moisture content with the spread of rice at a depth of 6cm, the ratio of cracked kernels is found the lowest in the autumn in Korea. According to the report by Chung,[5] under the sun drying of paddy exposed to change of weather, tend to produce fissures to rice kernels resulting in low yield of polished rice in the milling and biological losses during storage. The high potential of paddy drying under the autumn weather in Korea was reported by Cheigh[6] and Kim et al.[7] These results indicated the most important factors that influence in-bin grain drying at outside air are the initial moisture content of the rice grain; amount and depth of spread of rice grains, air flow ratio and weather conditions. It was generally agreed by Han[8], Calderwood[9] and Roberts and Brooker.[10] that the major disadvantage of in-bin grain drying at outside environment is difference of moisture content according to parts of grain layer in-bin during drying. To solve the problems, overturning(Lee and Chung.[11] and Kim[12]), stirring (Calderwood[9],) or recirculation (Roberts and Brooker[10]) of the grain during operation have been recommended and put into general practices.

Kunze and Calderwood[13], Morey et al.[14] and Morrison[15] reported that in-bin grain drying system at outside air convection during the harvesting season equipped with low-cost facility helped to reduce energy requirements, simplify management and improve grain quality. Lee et al.[16] made cereal bin which had the bottom area 2.25m$^2$, height 1.9m, where he conducted experimental drying. It reported that it took 130hr for drying to 13.7% moisture content with solar energy concentration dryer: 325hr for drying to 15.1% with the amount of wind at normal temperature by ventilation drying.

Prasad et al.[17] reported that 1% change in moisture content will produce stresses in the grain that are 100 times the magnitude produced by 1°C temperature change. Kunze and Choudhury.[18] hypothesized stresses that might develop in the rice grain during and that moisture removal from the grain would cause tensile stresses at the grain surface. The grain being a free body, equal and opposite compressive stressed would be produced in the interior portions of the grain. Stahlel[19] pointed out that the term "sun crack" is a moisture since fissures (sun cracks) at a critical moisture content of 14% or lower. Kunze[20] reported an experiment in which rice harvested at 29.8% moisture content before being dried to 9.1% in a single 12-hour pass with 59°C air. The dried rice produced a milled head rice yield above 70% shortly after drying.

With these investigation as the base, this study was carried out to develop of solar energy concentration blast-grain circulating dryer to be able to shorten drying time and prevent the losses quality and quantity during drying of paddy.

## Materials and Methods

The test paddy was consisted of several rice varieties of Tongil type that were cultured in Hwaseong, Gyeonggi, Korea in 1985. The initial moisture content was 24%. The amount tested was 2.5 ton per treatment. The in-bin drying and storage (IBDS) method which has been extensively popularized in Korea farm houses is tested as the control. The method is that rice grain are subjected to dry with continual blow-

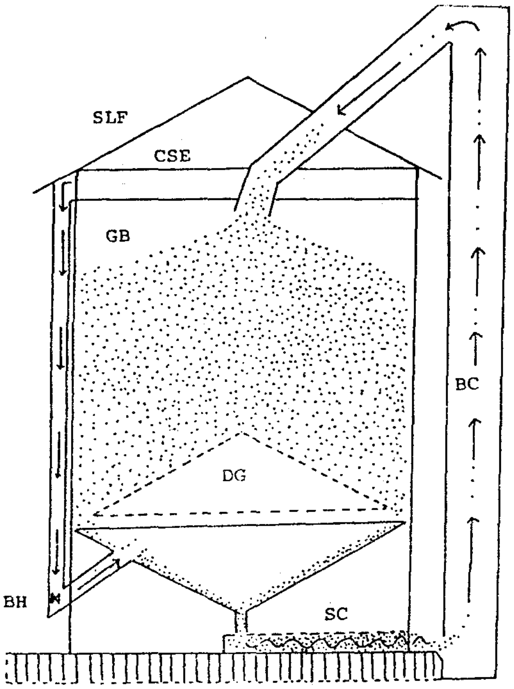


Fig. 1. Dryer of grain by solar energy concentration blast-grain circulation

C S E : Collector of solar energy
S C : Screw conveyer
B C : Basket conveyer
B H : Blower of heated air into grain
G B : Grain bin
D G : Divider of grain
S L F : Sun light flat

ing of ambient air during storage in a warehouse. The solar energy concentration blast-grain circulation dryer (SECD)(Fig. 1), a newly developed dryer, is being introduced in this experiment, where the scale is set at 2.5 ton-paddy per circulation.

The ambient air temperature and blowing air temperature during drying period was measured with the stem-thermometer and the moisture content was measured with the grain moisture measurement meter (Kett SP-1). The ratio of cracked kernels was investigated with the grain perspective meter after removal of husk by hand. The milling recovery of dried paddy was measured with huller (T.H.U) and whitener (MCM-250, Satake Co.). The grade of milled rice was estimated by the standard inspection of agricultural production of Korea[21]. The energy requirement of each dryer for paddy drying was measured by a watt-meter for an hour, and calculated by multiplication the hours needed for drying to 15% moisture content of paddy.

## Results and Discussion

During drying period of paddy, the ambient relative humidity ranged 50~74% and the outside temperature was 13~18°C. The air used to blow through the in-bin drying and storage was same of the outside temperature, but that of the solar energy concentration blast-grain circulation dryer was 4~5°C higher than the ambient temperature(Fig. 2).

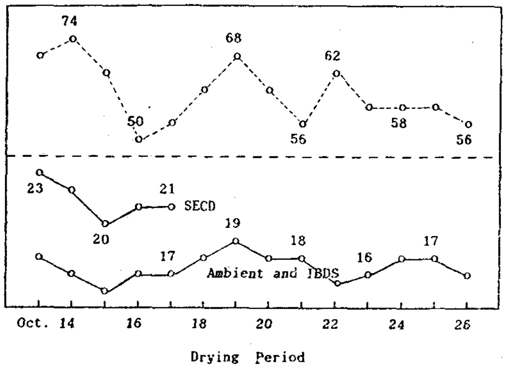


Fig. 2. Ambient air temperature and relative humidity of experiment site, and blowing air temperature during drying period

○--○ : Relative humidity(%)
○—○ : Temperature(°C)
SECD : Solar energy concentration blast-grain circulation dryer
IBDS : In-bin drying and storage

Considering the variation of moisture content affected by each dryer, the difference at that in-bin drying and storage was significantly depending on the sites (upper, middle, or bottom) of grain layer. The moisture content of upper site was 24% at initiation and rose to 25% after 3 days. And days needed for drying from 24% to 15% moisture content at all sites were about 14 days(Fig. 3). In the in-bin drying and storage, the humidity changed of air-tight though grain was higher according to passing from the upper site, and that the moisture content of the upper site of initial drying period

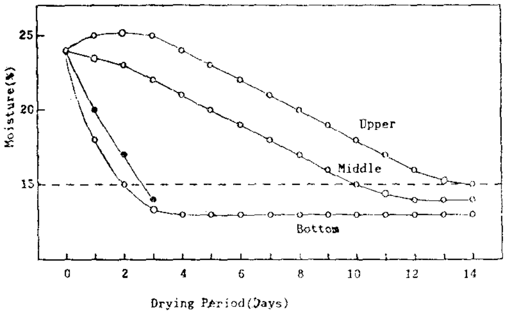


Fig. 3. Moisture content of paddy at different layers in dryers during drying period

○—○ : In bin dryer and storage

●—● : Solar energy concentration blast-grain circulation dryer (upper, middle and bottom)

incerased. On the contrary, the solar energy concentration blast-grain circulation dryer can perform uniform drying regardless of grain layer with that moisture content of all site was 15% after 3 days. These results agreed with the data reported by Lee et al.[16], Kim[12], Calderwood[9] and Roberts and Brooker[10].

The ratio of cracked kernels after drying of paddy varied depending on different types of dryers, and sites of grain layer in-bin drying and storage: 12% at the bottom, 6% at the upper and in the center with the solar energy concentration blast-grain circulation dryer, howe ver, the ratio was uniformly 7% in all sites. The reason why in-bin drying and storage method ended up with a high fissuring ratio of 12% at the bottom site seem to lie in the situation that by the time the moisture content of rice grain reach 15% in all sites, that of the bottom site is found to go over-dried and thus more fissures(Table 1).

As shown in Table 2, milling recovery of dried paddy and grade of milled rice among various types of dryers did not make any difference.

Energy requirement for drying paddy depending on various type of dryers was 108Kw/2.5ton for the in-bin drying and storage, and 28.8Kw/2.5ton for the solar energy concentration blast-grain circulation dryer (Table 3). It

Table 1. Cracked kernels(%) of dried paddy as affected by types of dryers and layer of grain

| Dryer | Layer of grain | NCEC 1 | NCEC 2 | NCEC 3 | Total |
|---|---|---|---|---|---|
| IBDS | Upper | 4 | 1 | 1 | 6 |
| | Middle | 4 | 1 | 1 | 6 |
| | Bottom | 9 | 2 | 1 | 12 |
| SECD | Upper | 5 | 1 | 1 | 7 |
| | Middle | 5 | 1 | 1 | 7 |
| | Bottom | 5 | 1 | 1 | 7 |

NCEG : Number of crack(s) on each grain
IBDS : In-bin drying and storage
SECD : Solar energy concentration blast-grain circulation dryer

Table 2. Recovery ratio of dried paddy and grade of milled rice after milling as affected by types of dryer

| Dryer | Recovery ratio of paddy(%) | | | | Milled rice grade (%) | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | Brower | HR | LB | SB |
| IBDS | 79.14 | 90.53 | 71.65 | 1.54 | 94.15 | 3.69 | 2.16 |
| SECD | 79.45 | 90.64 | 72.03 | 1.30 | 94.53 | 3.36 | 2.11 |

A : $\frac{\text{Weight of brown rice}}{\text{Weight of paddy}} \times 100$

B : $\frac{\text{Weight of milled rice}}{\text{Weight of brown rice}} \times 100$

C : $\frac{\text{Weight of milled rice}}{\text{Weight of paddy}} \times 100$

HR : Head rice
LB : Large broken rice
SB : Small broken rice

Table 3. Energy requirement(Kw) during drying as affected by types of dryer

| Dryer | Equipment: Blower | Screw | Conveyer | Total |
|---|---|---|---|---|
| IBDS | 108.0 | — | — | 108.0 |
| SECD | 7.2 | 14.1 | 7.5 | 28.8 |

* For explanation see Table 1

is evident from this result that the drying efficiency of the solar energy concentration blast-grain circulation was much higher than that of the in-bin drying and storage, major reasons being use of solar energy, circulating system of rice grains.

The drying method by solar energy concentration blast-grain circulation look only about 3 days for drying and bringing the moisture content from 24% to 15% and lowered the ratio of cracked kernels contributing positively to milling recovery of dried paddy and the grade of milled rice, while it proved to be highly energy-saving in the operation of the dryer.

## Abstract

A 2.5 ton scale of solar energy concentration blast-grain circulation dryer (SECD) was dev-eloped in order to shorten the drying time without damaged paddy. Comparative experiments were carried out on performance, drying efficiency, consistency in moisture content, milling recovery, grade of milled rice, and energy requirement and cost against all that of in-bin drying and storage (IBDS) method. The experiments were performed using mixture of several rice varieties of Tongil type(Japonica-Indica breeding type) under the autumn weather in Korea. The circulating air temperature inside SECD was 4~5°C higher than that of IBDS. The moisture content of the paddy during the drying period in SECD was uniform while substantially varied in upper, middle or bottom layer in IBDS. By SECD, 24% initial moisture content of paddy was reduced to 15% after only 3 days of drying as compared to 14 days at IBDS. The percentage of cracked kernels in upper, middle and bottom layers in IBDS was 6, 6 and 12%, respectively, whereas 7% in all layers in SECD. Both types of dryers did not significantly affect the milling recovery of dried paddy and grade of milled rice.

Energy requirement of SECD(28.8Kw/2.5ton) for paddy drying was much less than that of IBDS(108Kw/2.5ton).

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