

"A Study on the Drying Characteristics
and
Efficient Facilities for Rough Rice"

『벼의 乾燥特性 및 乾燥施設에 關한 試驗研究』

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<要 旨>

벼의 基礎乾燥試驗을 한것으로서 乾燥溫度는 40°, 50°, 60°C 를 택하였고 相對濕度는 30% 로 부터 70% 로 變更하여 乾燥時의 乾燥曲線 및 平衡水分含水率을 各 條件變化에 따라 찾아 내었다.

이 試驗은 다음 號에 계속될 乾燥施設의 基礎資料가 된다.

I. Introduction

It is known that the damage and loss during the storage of agricultural crops in Korea are large.

In order to minimize the losses during storage, it is desirable to select a dryer suitable for Korean farm conditions and easy to be used by farmers. In foreign countries the large scale dryers are now utilized but in Korea the primitive solar drying is taken as a common drying method of all harvested crops. Therefore, the simple small scale dryers must be studied as a first step in mechanized drying processing and eventually the use of large scale dryers under our larger farm situations. In the present research the development of suitable equipment for low cost farm drying was given first priority.

II. Fundamental Drying Experiment

1. Aim

In the past, rice, which is the main crop in our

country was dried by natural solar energy. However by solar drying it was difficult to dry rice to 13.5% moisture content which is the optimum moisture percentage for storage. Thus artificial drying is becoming necessary for the prevention of grain deterioration. In the present research the characteristics of the rice grain were studied in order to design a practical dryer.

2. Apparatus

1) Fundamental drying facility

(a) Structure

The dryer used had an air tight drying chamber in which the heated air was automatically circulated and the temperature and humidity controlled by an electric heater connected to a water tank. The switches for the control of the temperature and humidity are located on a panel board. (Reference "The existing drying plants for sliced sweet potatoes and a research facility to investigate the drying characteristics of them. published in the Journal of Korean Society of Agricultural Engineers, Vol 5, May 1967)

2) Sample

In the first experiment, 50 grains of rough rice from the College Farm were taken as one sample, and another portion of 50 grains were taken from each of new and old rough rice and rewetted for 20-24 hours. In the second experiment, 150 grains of new and rewetted old rough rice samples were taken and treated as in the first experiment.

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The sample for experiment of a large amount loading utilizing the fundamental drying facility were taken 2,000 grams respectively from new rough rice and rewetted new rough rice; latter samples were steeped for 10-12 hours and allowed to stand in the air for 3-4 hours.

3) Implements

(A) Balance

The samples were weighed with a balance weighing as small as 1/100 gr. at 30 minutes interval from the beginning. The intervals were extended as the the drying process continued

(B) Thermometer

The thermometers were installed at the upper and lower parts of the drying chamber for the measurement of temperature. Humidity was determined at the same locations in the chamber as the temperature.

4) Drying oven

To obtain bone-dry-weight for the calculation of moisture content (W. B.%, D. B.%), samples were dried in the temperature controlled drying oven. The temperature was controlled automatically at $105^{\circ}\text{C} \pm 5^{\circ}\text{C}$

3. Testing method

The experiment on small-sample drying and large-sample amount utilizing fundamental drying facilities were done as follows:

1) Measurement

After the temperature and humidity in drying chamber were controlled as desired samples were placed in the drying chamber.(The determination of wet bulb temperature was obtained from the psychrometric

chart.) Each sample was weighed at 30 minute intervals at the beginning and was extended to 60, 120, and 180 minutes. Total drying period was 48 hours basis. The large samples were weighed at 60 minutes intervals.

2) Temperature base and its change

The temperature and humidity are the most influential factors in the process of drying. They were changed as shown in the table 1 below. The air velocity was maintained at a constant flowing rate.

3) The determination of the bone-dry-weight and W. B.%, D. B.%

(A) After one drying, the samples were dried again in the drying oven at $100^{\circ}\text{C} \pm 5^{\circ}\text{C}$. The samples were recorded as bone-dry-weights.

(B) The decreasing rate of moisture content
The decreasing rate of moisture content was shown on W.B.(wet base) and D.B.(dry base).

$$\text{W.B.(\%)} = \frac{W}{W+w}$$

$$\text{D.B.(\%)} = \frac{W}{w}$$

W: Moisture weight in sample

w: Bone-dry-weight of sample

4. Results of experiment and their discussion

1) Results

The results of the small sample drying experiment are shown in Table 1 and 2, and the results of large amount samples drying experiment utilizing fundamental drying facilities are shown in Table 3 and 4.

Table-1 Experiment of Temperature and Humidity changes

| Temperature change | | | | Humidity changes | | | |
|--------------------|-------|-------|-------|------------------|------|-----|---|
| 40° C | 50° C | 60° C | 70° C | uncontrolled | | | |
| | 40° C | | 30 % | 50 % | 70 % | 90% | |
| | 50° C | | " | " | " | " | " |
| 40° C | 50° C | 60° C | | 50% | | | |

Table-2

Results of small Sample Drying(Temp. : 40°)

| New rough rice | | | | | |
|----------------|--------|------------|--------|-------------|--------|
| 50% | | 70% | | 90% | |
| Test No. 10 | Weight | Test No. 3 | Weight | Test No. 45 | Weight |
| Time | grams | Time | grams | Time | grams |
| 11.20 | 4.58 | 11.00 | 4.37 | 12.00 | 4.00 |
| 12.00 | 3.89 | 11.39 | 4.00 | 12.30 | 3.96 |
| 12.20 | 3.78 | 12.00 | 3.93 | 1.00 | 3.88 |
| 1.00 | 3.74 | 12.30 | 3.79 | 1.30 | 3.79 |
| 1.30 | 3.66 | 1.00 | 3.72 | 2.00 | 3.78 |
| 2.00 | 3.59 | 1.30 | 3.72 | 2.30 | 3.75 |
| 2.30 | 3.57 | 2.00 | 3.71 | 3.00 | 3.70 |
| 3.00 | 3.56 | 2.30 | 3.70 | 3.30 | 3.68 |
| 3.30 | 3.55 | 3.00 | 3.68 | 4.00 | 3.61 |
| 4.00 | 3.52 | 3.30 | 3.67 | 4.30 | 3.57 |
| 4.30 | 3.51 | 4.00 | 3.66 | 5.00 | 3.57 |
| 5.00 | 3.50 | 4.30 | 3.64 | 6.00 | 3.55 |
| 6.00 | 3.49 | 5.00 | 3.62 | 7.00 | 3.55 |
| 7.00 | 3.48 | 6.00 | 3.61 | 8.00 | 3.55 |
| 8.00 | 3.47 | 7.00 | 3.61 | 9.00 | 3.55 |
| 9.00 | 3.46 | 8.00 | 3.60 | 10.00 | 3.55 |
| 10.00 | 3.46 | 9.00 | 3.60 | 11.00 | 3.55 |
| 11.00 | 3.46 | 10.00 | 3.60 | 12.00 | 3.53 |
| 1.00 | 3.45 | 11.00 | 3.59 | 2.00 | 3.53 |
| 3.00 | 3.44 | 1.00 | 3.58 | 4.00 | 3.50 |
| 5.00 | 3.42 | 4.00 | 3.57 | 6.00 | 3.50 |
| 7.00 | 3.40 | 8.00 | 3.56 | 8.00 | 3.49 |
| 9.00 | 3.40 | 10.00 | 3.56 | 10.00 | 3.49 |
| 11.00 | 3.40 | 12.00 | 3.56 | 12.00 | 3.48 |
| 2.00 | 3.40 | 2.00 | 3.56 | 2.00 | 3.48 |
| 5.00 | 3.40 | 5.00 | 3.56 | 5.00 | 3.48 |
| 9.00 | 3.40 | 8.00 | 3.56 | 9.00 | 3.48 |
| 12.30 | 3.40 | 11.00 | 3.56 | 12.00 | 3.48 |
| | | | | 5.00 | 3.48 |

Table-3 Results of Large Sample Drying Utilizig Fundamental Drying Facilities (New rough rice)

| Time (Min.) | Moisture content(%) of respective drying shelf | | | | | | | | | | | | | | |
|----------------|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 40°C | | | | | 50°C | | | | | 60°C | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 0 | 18.15 | 18.15 | 18.15 | 18.15 | 18.15 | 17.60 | 17.60 | 17.60 | 17.60 | 17.60 | 17.00 | 17.00 | 17.00 | 17.00 | 17.00 |
| 60 | 16.85 | 15.75 | 15.50 | 17.05 | 17.15 | 14.32 | 14.25 | 14.49 | 14.84 | 15.45 | 12.45 | 13.05 | 13.43 | 13.43 | 13.35 |
| 120 | 16.60 | 14.80 | 15.75 | 16.25 | 15.76 | 13.59 | 13.35 | 12.90 | 13.13 | 12.93 | 13.59 | 13.35 | 12.90 | 11.80 | 12.00 |
| 180 | 14.20 | 14.00 | 14.60 | 15.70 | 14.70 | 11.55 | 11.90 | 11.90 | 12.20 | 12.20 | 11.00 | 11.40 | 11.00 | 11.10 | 11.10 |
| 240 | 13.57 | 13.60 | 13.80 | 17.10 | 14.00 | 11.20 | 11.20 | 11.20 | 11.30 | 11.30 | | | | | |
| 300 | 12.70 | 12.90 | 13.00 | 13.30 | 13.20 | | | | | | | | | | |
| 360 | 12.30 | 12.30 | 12.30 | 12.70 | 12.20 | | | | | | | | | | |
| 420 | 11.90 | 11.90 | 11.90 | 12.40 | 12.30 | | | | | | | | | | |

Table-4 Results of Large Sample Drying Utilizing Fundamental Drying Facilities (Rewetted new rough rice)

| Time (Min) | Moisture content (%) of respective drying shelf | | | | | | | | | | | | | | |
|---------------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 40°C | | | | | 50°C | | | | | 60°C | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 0 | 27.20 | 27.20 | 27.20 | 27.20 | 27.20 | 27.40 | 27.40 | 27.40 | 27.40 | 27.40 | 15.65 | 17.15 | 17.15 | 18.55 | 20.25 |
| 0 | 19.85 | 21.25 | 23.40 | 25.65 | 26.20 | 18.15 | 18.95 | 19.75 | 20.80 | 21.05 | 13.10 | 13.10 | 13.70 | 15.30 | 17.50 |
| 120 | 18.50 | 19.50 | 19.60 | 19.90 | 20.30 | 14.10 | 16.65 | 16.55 | 17.25 | 17.33 | 11.00 | 11.10 | 12.00 | 11.80 | 12.20 |
| 180 | 16.60 | 17.10 | 17.50 | 17.90 | 18.20 | 13.37 | 13.62 | 14.12 | 13.82 | 14.37 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 |
| 240 | 15.20 | 15.80 | 16.10 | 16.50 | 16.70 | 11.90 | 11.90 | 12.60 | 12.60 | 13.35 | | | | | |
| 300 | 13.60 | 14.00 | 14.40 | 14.45 | 15.10 | 11.30 | 11.30 | 11.30 | 11.40 | 11.70 | | | | | |
| 360 | 12.75 | 13.05 | 13.30 | 13.70 | 14.00 | | | | | | | | | | |
| 400 | 12.20 | 12.30 | 12.40 | 12.40 | 12.60 | | | | | | | | | | |

※ The moisture content in the above table was measured by Kett P.B.-J.K. moisture measurimeter.

2) Discussion

(A) Equilibrium moisture content

The equilibrium moisture content was obtained by the dynamic method (2). The equilibrium moisture content rates of new rough rice (rewetted) was higher than old ones (rewetted) by 1 to 2% in respective relative humidities. The equilibrium moisture content rates of rough rice was shown in Fig-1

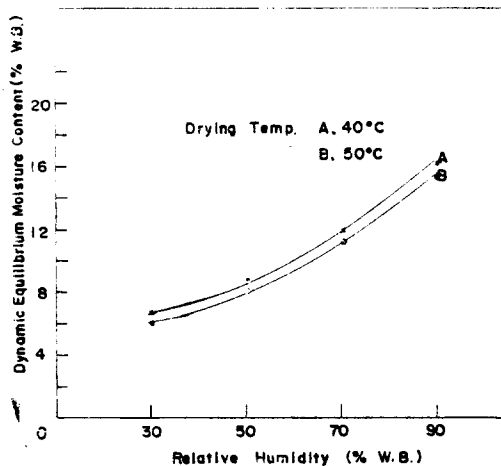


Fig-1 Dynamic equilibrium moisture content of rough rice

(B) The required drying period for obtaining 13% moisture product

Although the base of current moisture content of rice in the Korean market is around 16%, it is

not optimum moisture content percentage for storage and milling. Generally the periods required to obtain 13 to 13.5% of moisture rice by the changes in humidity and temperature is shown in Fig-2. The drying curves show a secondary functional relation between the relative humidity and drying periods

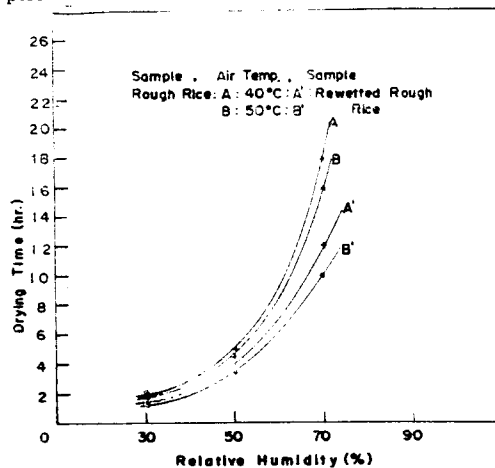


Fig-2 Drying curves for obtaining 13% final moisture content

(C) The temperature and humidity effects on drying

Only the temperature and humidity were varied as these factors are considered as the most effective on drying. Other factors including air velocity,

were not varied.

i) The effects of various drying temperatures

In Fig-3 Curve A and B the drying temperature were changed while relative humidity (%) in the drying chamber were not controlled. The new rice was affected by temperature and dried more slowly than old rice. In Fig-4 curves A and B the relative humidity was fixed at 50% and the drying temperature varied. The drying period to dry 13% moisture was much reduced as the temperature was raised.

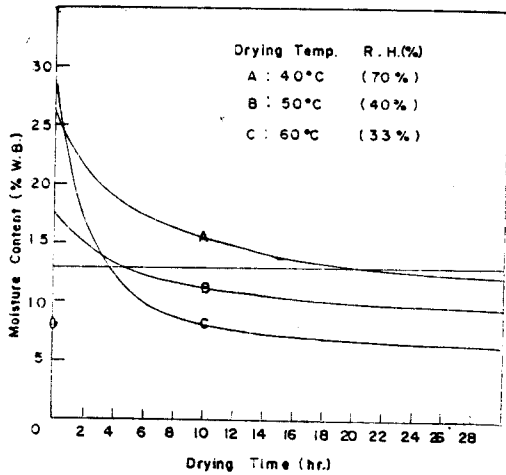


Fig-3 Temperature effects on drying (rough rice).

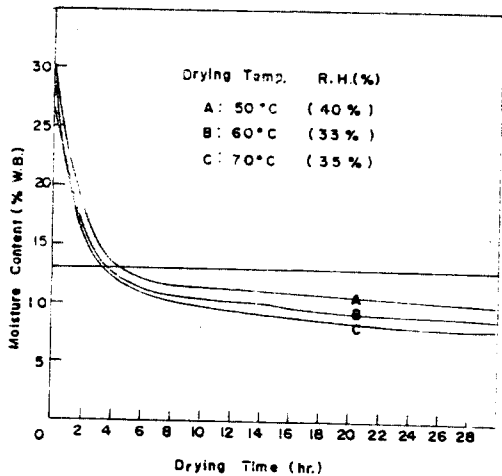


Fig-4 Temperature effect on drying curve (rough rice)

ii) The effect of relative humidity

Fig-5 curve A and B show that the effect of relative humidity is much greater than that of temperature: according to total relative humidity, the required drying period for obtaining 13% was increased with secondary functions and it was found that it was impossible to actually dry the grain when the relative humidity was over 70%. Especially new rough rice (rewetted) was much more affected by the relative humidity than old one or rewetted. The drying rate was slower.

(D) Drying temperature effect on drying curves in large amount sample drying.

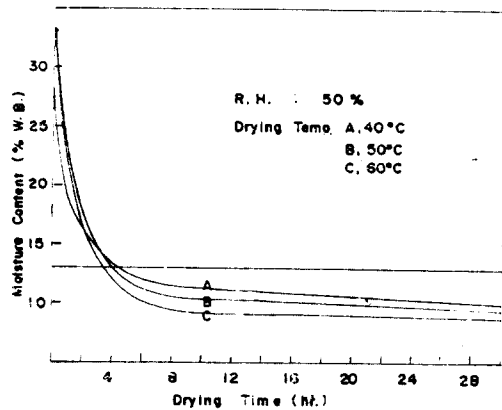


Fig-5 Temperature effect on drying (rewetted rough rice R. H. 50%)

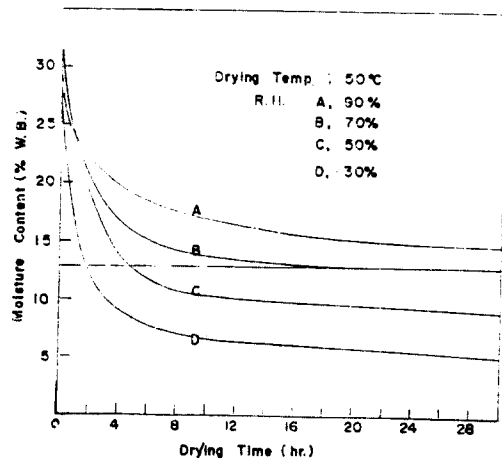


Fig-6 Drying curve by humidity changes (rough rice, 50°C)

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