벼의 乾燥特性 및 乾燥施設에 關한 試驗研究

A Study on the Drying Characteristics and Efficient Facilities for Rough Rice (Ⅲ)

李 哲 周
Chul Choo Lee

Ⅳ. The Large Scale Batch-Type Drier

1. Aum

The structure is the same as the small batch-type drier but four times larger. This drier is considered as a suitable drier for the larger farm economic situations in Korea. The objective here is to compare the data obtained with the utilization of the small and large driers.

2. Equipment

1) Drying facility

This drier is 6 feet long, 6 feet wide and 3 feet high. The walls are made of veneer board. 1.1 feet from the bottom is located a screen tray (6 feet × 6 feet) and above this tray is a drying chamber (6feet × 6 feet × 1.9 feet). The heated air is blown from the floor level. At the upper front of the drying chamber is an exhaust duct and on the lower site side is the heated air inlet. Outside is a propeller fan with on electric motor ($\frac{1}{2}$ H.P.) which is conected with the oil burner.

2) Apparatus

The same laboratory equipments were used in this experiment as in the small batch-drier. Nineteen thermometers were utilized.

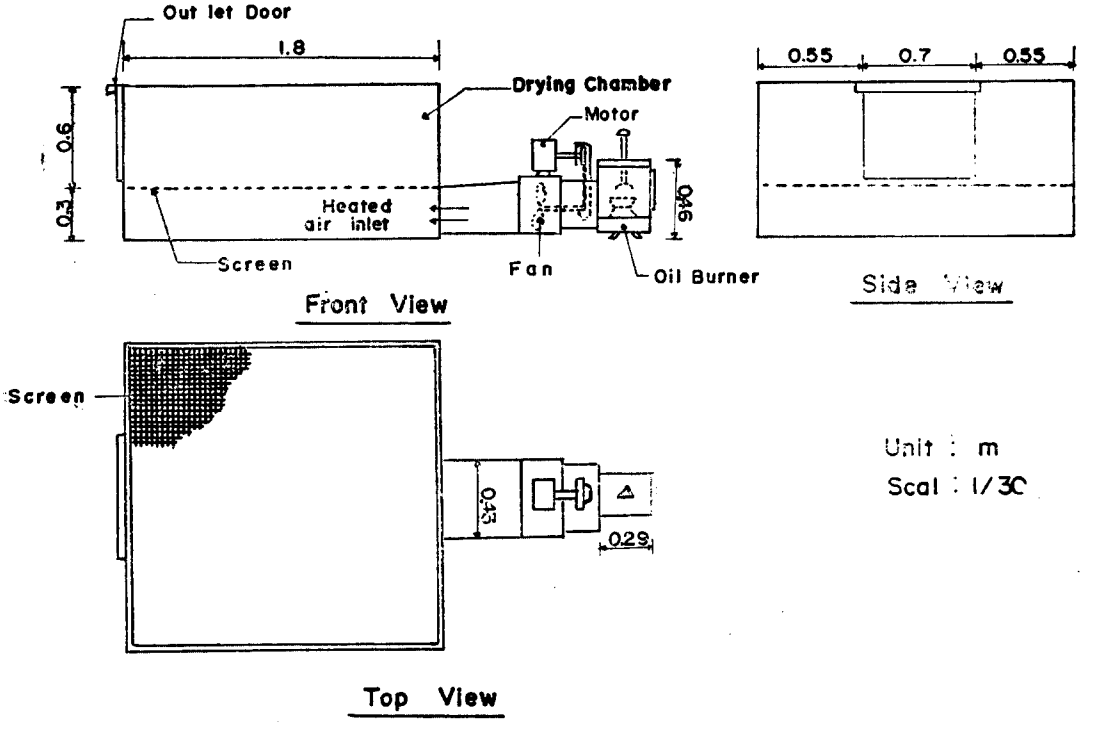

Fig-12 Plan of Large Batch Type Drier

3) Samples

The rewetted samples were the same materials used in the former small batch-drier experiment. New rough rice Nong Rim No. 6 was purchased from Suwon rural farm markets for this work.

4) Fuel

Kerosene was purchase on the local market.

3. Testing method

The testing method used was almost the same but the H. P. motor was replaced by a 1/2H. P. motor blow to produce exessive amount of air movement for drying.

1) Qutline of study

Sample weighings, temperature changes, material moisture contents, temperature distribution, air velocities and thermal efficiency calculations were handles in the same manner as in the small batch-type drier.

(A) Measuring of consumed fuel

The consumption rate of fuel was supplied and measured from a graduated fuel tank.

2) Various conditions changes

The various conditions were changed according to Table 11 bleow.

Table 11. **Various Condition Changes.**

No.	Item	Unit	Dimension	Change
1	Drying Temperature	°C	0	40°C 50°C
2	Drying period	minutes	T	10cm 15cm 20cm 25cm
3	Sample layer thickness	cm	L	10cm 5cm 7cm

4. Results of analysis

Tables 12 and 13 show that the experiment were carried out with new rough rice and rewetted rough rice from the College Farm. It had a high initial moisture content (14%-15%). Variety Nong Rim No. 6 had a little higher initial moistur content than the other varieties(18%) and the rewetted sample also had higher initial moistur contents. The results of the experiment are as follows:

1) Results.

Table 12. **Results of Experiment with Large Type Dryer(40°C New Rough Rice).**

Test No.	Factors			Time (min)	Group W. B. % A	B	C	D	E	F	Total Average
1	Date	(1968)	11. 28	0	14. 69	14. 69	14. 69	14. 69	14. 69	14. 69	14. 69
	Inlet temp.	(°C)	40	60	12. 30	12. 30	11. 87	12. 30	12. 55	11. 97	12. 20
	Thick.	(cm)	1. 0	120	11. 99	11. 56	11. 02	11. 15	11. 84	11. 25	11. 47
	Dry per.	(min)	150	150	11. 53	10. 79	10. 79	10. 72	11. 53	10. 79	11. 83
	cons. fuel	(gr)	33, 000								
	Initi. wei	(gr)	33. 000								
	Fina. wei.	(gr)	30, 750								
2	Date	(1968)	11. 28								
	Inlet temp.	(°C)	40								
	Thick.	(cm)	5. 0	0	14. 56	14. 56	14. 56	14. 56	14. 56	14. 56	14. 56
	Dry. per.	(min)	180	60	13. 01	13. 01	13. 15	13. 13	12. 98	12. 49	12. 97
	Cons. fuel	(gr)	2, 825	120	12. 36	12. 79	11. 96	11. 98	12. 32	11. 59	12. 17
	Initi. wei.	(gr)	117, 250	180	11. 48	11. 02	11. 12	11. 24	11. 58	11. 67	11. 35
	Fina. wei.	(gr)	89, 450								

Test No.	Factors			Time (min)	Group W. B. (%) A	B	C	D	E	F	Total Average
3	Date	(1968)	11. 29								
	Inlet temp.	(°C)	40								
	Thick.	(cm)	10. 0	0	13. 98	13. 98	13. 98	13. 98	13. 98	13. 98	13. 98
	Dry per.	(min)	120	60	11. 92	11. 98	11. 93	11. 68	12. 05	11. 47	11. 84
	Cons. fuel	(gr)		120	11. 30	11. 14	10. 98	11. 13	11. 41	11. 19	11. 19
	Initi. wei	(gr)									
	Fina. wei	(gr)									
4	Date	(1968)	11. 30								
	Inlet temp.	(°C)	40	0	14. 56	14. 56	14. 56	14. 56	14. 56	14. 56	14. 56
	Thick.	(cm)	15. 0	60	11. 55	11. 54	11. 42	12. 02	12. 17	11. 66	11. 67
	Dry per.	(min)	180	120	11. 04	11. 00	10. 73	10. 81	10. 83	10. 52	10. 82
	Cons. fuel	(gr)	4, 855	180	10. 45	11. 00	10. 08	10. 62	10. 50	10. 28	10. 41
	Initi. wei	(gr)	325, 000								
	Fina wei	(gr)	287, 000								

Inlet temp. : Inlet temperature, Thick. : Thickness, Dry. per. : Drying period,
Cons. fuel: Consumed fuel, Initi. wei. : Initial weight, Fina. wei. : Final weight.

Table 13. Results of Experiment of Large Batch Type Dryer Rewetted New Rough Rice 50°C

Test No.	Factors			Time (min)	Group W. B. % A	B	C	D	E	F	Total Average
20	Date	(1968)	12. 13								
	Inlet temp.	(°C)	50	0	33. 65	33. 65	33. 653	3. 65	33. 65	33. 65	33. 65
	Thick.	(cm)	10	60	20. 93	21. 55	20. 302	3. 22	23. 77	22. 20	22. 00
	Dry. per.	(min)	240	120	13. 73	13. 97	12. 401	2. 90	13. 31	11. 73	13. 00
	Cons. fuel	(gr)	7, 264	180	11. 13	11. 39	10. 571	0. 44	10. 99	9. 83	10. 72
	Initi. wei.	(gr)	216, 000	240	10. 47	9. 86	9. 35	8. 73	9. 88	8. 72	7. 50
	Fina. wei.	(gr)	53, 550								
21	Date	(1968)	12. 17	0	31. 34	31. 34	31. 34	31. 34	31. 34	31. 34	31. 34
	Inlet temp.	(°C)	50	60	24. 82	22. 86	25. 28	22. 45	28. 74	25. 96	24. 20
	Thick.	(cm)	15	120	19. 79	18. 72	19. 44			17. 61	18. 44
	Dry. per.	(min)	360	180	18. 16	16. 39	16. 74	15. 39		14. 71	16. 52
	Cons. fuel	(gr)	8, 093	240	13. 54	14. 74	12. 66	12. 25	12. 25	12. 03	12. 96
	Initi. wei	(gr)	290, 000	350	11. 68	11. 69	10. 84	11. 16	10. 90	9. 68	10. 99
	Fina. wei.	(gr)	229, 750	360	9. 65	10. 74	9. 43	9. 67	10. 16	9. 22	9. 82
22	Date	(1968)	12. 17	0	33. 68	33. 68	33. 68	33. 68	33. 68	33. 68	33. 68
	Inlet temp.	(°C)	50	60	29. 22						28. 33
	Thick.	(cm)	20	120	23. 18	22. 31		24. 12		25. 87	23. 99
	Dry. per.	(min)	470	180	20. 91	79. 07	23. 61	21. 03	23. 36	21. 18	21. 79
	Cons. fuel	(gr)	2, 315	240	12. 46	16. 76	11. 43	17. 00	17. 41	15. 97	15. 18
	Initi. wei.	(gr)	410, 000	300	11. 79	11. 82	10. 76	11. 78	12. 79	11. 08	11. 67
	Fina. wei.	(gr)	306, 950	360	11. 65	9. 98	9. 85	11. 03	11. 51	10. 40	10. 79

Inlet temp. : Inlet temperature, Thick, : Thickness, Dry. per. : Drying period.
Cons. fuel: Consumed fuel. Initi. wei. : Initial weight. Fina. wei. : Final weight.

According to Table 13 the thermal efficiency was high when the inlet temperature was high (60°C) and the sample layers were thick. When the sample had a low initial moisture content, the thermal efficiency was lower than when the initial moisture content of the material was high.

(B) The comparison of the drying states of upper and lower layers.

The drying states of the upper and lower layers was investigated based on a 12 to 13% final moisture content.

Table 14. **Comparison of the Drying Data from Upper and Lower Layers with Temperature Changes.**

Test No.	Tempera-ture	Thick-ness	Final moisture content of 12 to 13% dry basis		
			Upper W. B. %	Lower W. B. %	Differences
	(°C)	(cm)	(%)	(%)	(%)
4	40	15	12.07	11.25	0.82
9	50	15	13.58	10.85	2.73
16	40	15	14.50	11.62	2.88
21	50	15	15.50	10.65	4.85

Table 14 shows that the higher the temperature and the higher the initial moisture content, the higher is the final moisture content difference under constant sample-layer thickness. The final moisture-content differences of new rough rice are smaller than rewetted samples.

(c) The drying temperature distribution

In order to investigate the temperature distribution of respective layer, thermometers were installed and the temperatures found are recorded in Table 15.

Table 15. **Temperature Distribution of Respective Drying Layers.**

Test No.	Inlet temp	Layer surface temperature (°C)	Lower layer temperature	Outlet temp
1	39.6°C	18.0 18.0 16.0 17.0	35.3 37.0 37.0 32.0	34.5
2	43 4	20.0 16.3 14.7 19.5	38.0 41.7 39.0 35.7	39.1
3	42.0	19.2 20.0 17.7 18.5	34.5 40.8 40.0 34.0	43.0
4	41.4	28.5 25.8 27.8 26.8	34.7 38.5 39.8 36.5	42.7
5	51.0	24.4 46.0 48.0 45.0	46.0 49.0 40.0 47.0	47.7
6	50.0	29.2 24.0 21.0 35.6	42.6 47.0 49.1 48.0	49.2
7	49.6	30.2 30.8 31.0 35.2	46.8 45.4 46.2 41.6	48.8
8	49.4	27.0 28.4 28.4 56.4	47.4 46.2 48.0 43.0	50.4
9	51.1	28.8 26.5 32.4 32.6	42.3 48.0 49.0 46.6	48.8
10	50.0	23.0 22.0 25.0 25.4	43.5 48.8 49.2 47.3	49.0
12	40.0	34.5 29.5 34.0 36.7	33.2 36.0 37.3 35.6	37.8
13	40.0	32.0 25.0 26.0 27.4	30.0 36.7 38.2 35.0	39.9
14	40.8	26.3 35.3 33.0 22.2	33.6 37.7 39.5 36.3	39.8
15	40.1	21.3 22.6 21.5 19.0	32.3 37.1 39.1 30.9	38.5
16	40.0	18.3 17.2 20.0 17.0	32.0 36.2 38.0 33.3	38.0
17	40.0	23.0 26.3 23.0 20.0	34.5 38.0 39.8 36.0	39.0
18	52.0	30.8 33.4 40.4 43.0	46.5 46.5 46.7 42.3	45.0
19	50.6	32.2 38.4 29.0 33.0	44.4 37.8 44.0	44.4

5. Discussion

The data from the experiment with the large batch-type drier are compared with the small type-drier data in this section.

1) Drying temperatures The new rice and rewetted samples were dried at 40°C and 50°C The equalization of the different initial moisture contents was attempted at the beginning of the study but this was found difficult. The experiment was therefore started with samples having a 4 to 5% differential initial moisture content.

The data from the drying of low initial moisture content samples are shown in Figure12. According to the steep curve shown in Figure 12, the low initial moisture content samples dried at 50°C gave a rapid drying rate in spit of the 4.2% higher initial moisture at 40°C. The rewetted samples with high initial moisture contents at the higher temperature dried at a more rapid drying rate. However, in the thick-layer drying experiment with temperature changes, the higher the initial moisture content the larger the differences between the upper and lower layers of materials. New rough rice with layers 15cm. thick, the differences of final moisture 0.5 to 0.7% at 40°C but in the rewetted samples drying, under the same conditions, the differences were 2.5% to 3.3%. At 50°C drying temperature the differences were 4.5% to 5.5%. Such a drying phenomena means that the higher the initial moisture content and the higher the drying temperature, the more rapid was the drying rate and the greater the differences in the upper and lower layers final moisture contents.

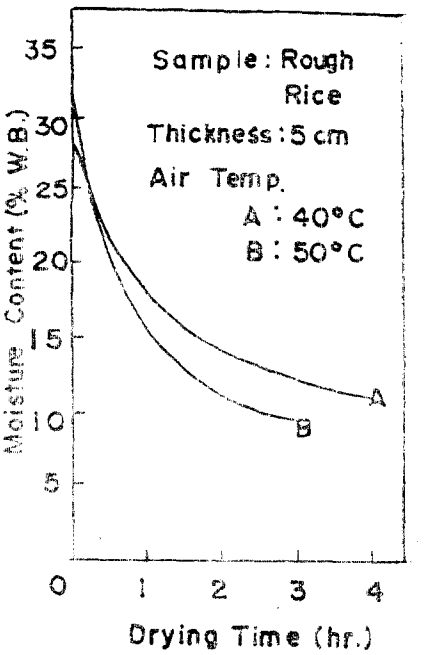

Fig. 14 Drying temperature effects on drying curve of thin layer.

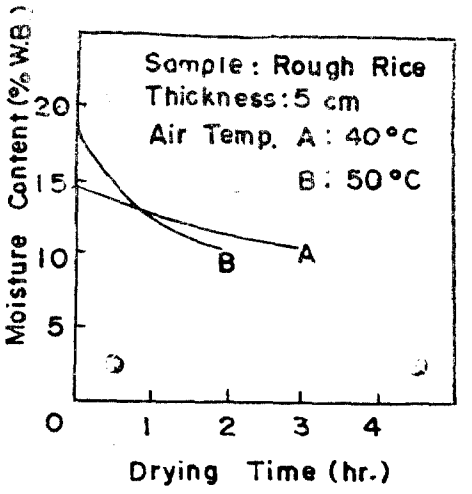

Fig 13. Temperature effects on drying.

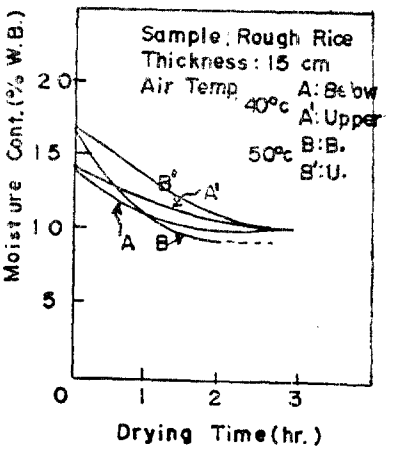

Fig 15. Upper and lower layers drying temperature effects.

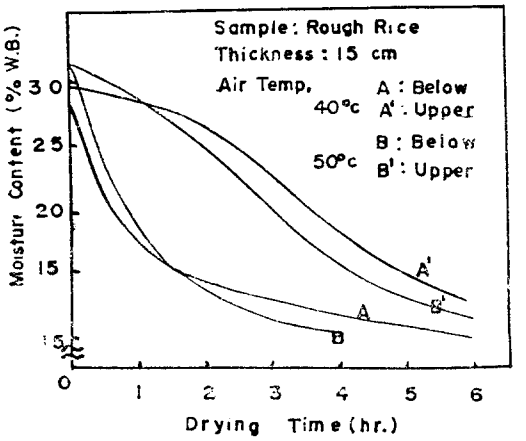

Fig 16 Upper and lower layer drying effects

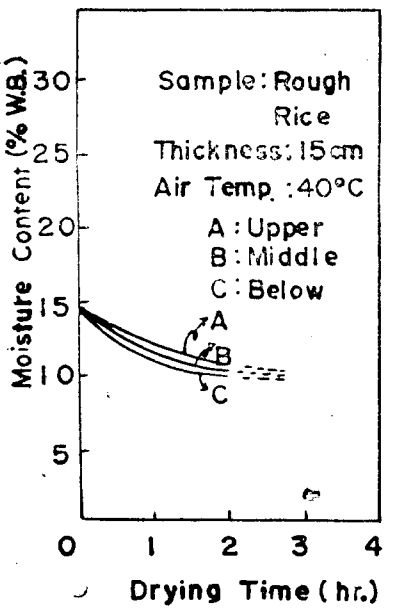

Fig 17. Drying curves from located layers (rough rice).

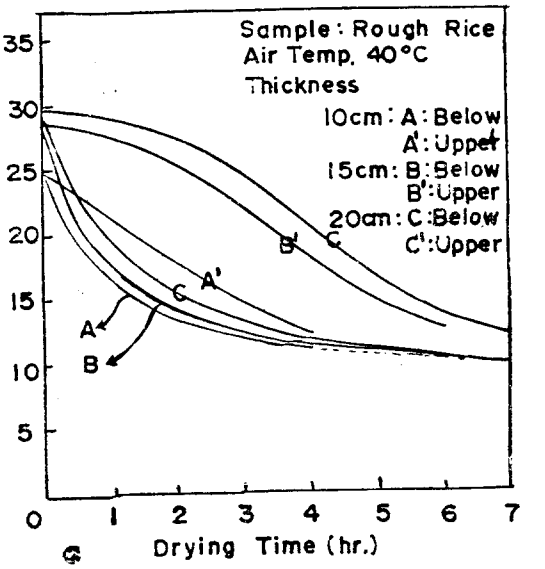

Fig 18. Drying rates of respective layers (rewetted rough rice).

2) The sample layer-thickness effects on drying

The thicknesses of the layers were 1, 5, 10, 20, and 25 cm. according to their different initial moisture contents. No differences were noted up to 10cm. but over 10cm. remarkable differences were manifested as shown in Figures and 20. In Figures 17, 18, 19, and 20 under the same conditions and with the same samples, great differences in drying rates were shown in the upper, middle and lower layers as the drying temperatures were raised.

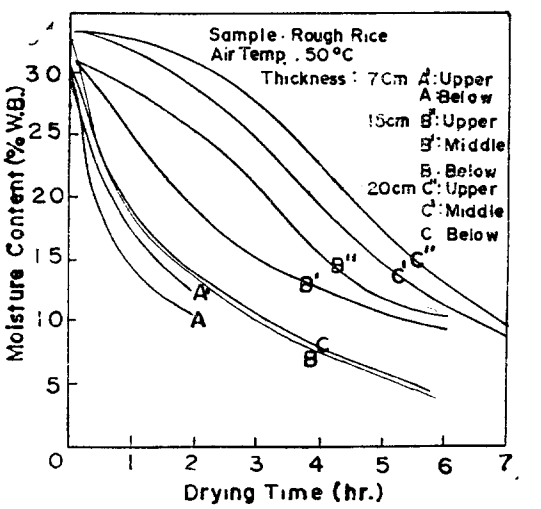

Fig 19. Drying rates of respective layers (rough rice, 50°C).

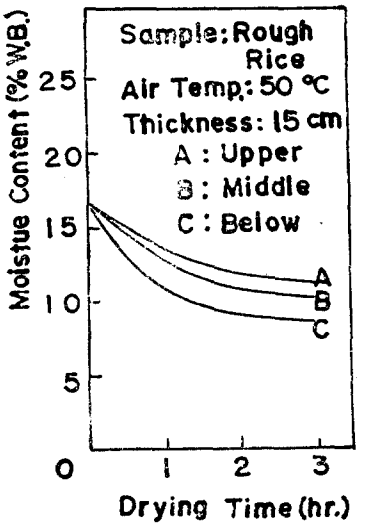

Fig 20. Drying rates of respective layers (rewetted rough rice 50°C).

Although the rate of drying of the lower layer were not greatly affected by different drying conditions, the upper layers were greatly affected. According by increasing the thickness of the sample layers, the air movement per unit sample volume was reduced and the drying rate was slower due to variations or differences in vapor pressure. It has been shown previously that the thickness of the material is an important factor affecting the drying processes.

3) The effect of initial moisture content of samples

This study was conducted with the small batch-type drier.

4) Drying period

The average drying rate was investigated at two temperatures (40°C and 50°C) on different layers of the meterial of different thickness. The data recorded in Table 26.

Table 16. **Various Drying Periods to 13.5% Moisture Materials.**

Test No.	Inlet temperature	Thickness	Drying Period	Initial moisture	Final moisture	Average drying rate	Drying period for 13.5%
	(°C)	(cm)	(hr)	(%)	(%)	(%/hr.)	(hr.)
2	40	5.0	3.0	14.56	11.35	1.07	1.0
6	50	5.0	2.0	18.76	10.67	4.06	1.3
13	40	5.0	4.0	28.43	11.71	4.18	3.57
15	40	10.0	4.0	25.10	11.98	3.28	3.53
17	40	20.0	6.0	28.92	10.98	3.00	5.14
18	50	5.0	2.0	32.39	11.45	10.22	1.80
20	50	10.0	3.0	33.65	10.72	7.64	2.63
22	50	20.0	5.0	33.68	11.62	4.40	4.58

It was found that the higher the temperature and the thinner the layer of samples, the more rapid is average drying rate. About 5.4 hours were required for drying the samples to 13.5% at 40°C 20cm thickness layers and the shortest period was 1.0 to 1.5 hours with thinner layers. Only 1.5 hours were required when the initial moisture content was 25% with the temperature at 50°C and the thickness 20cm.

6. Conclusion

1) Drying efficiency

The drying period with the large drier was about one half the time required with the small batch drier. About 3 to 4 times more sample was used but the thermal efficiency was lower.

2) Drying state

The drying states of the upper and lower layer with the large drier were not so uniform as with the small drier. Six sacks of rough rice wereo loaded in the large drier but the operating method must be improved to operate automatically and to savis labour and total time for total drying.