『벼의 乾燥特性 및 乾燥施設에 關한 試驗硏究』

"A Study on the Drying Characteristics

and

Efficient Facilities for Rough Rice"

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(E) Conclusions

It is recommended that the optimum drying temperature for rough rice must be within the range of 40°C-50°C. The relative humidity must be decreased as drying takes place but the grain should not be over dried(below 15%). The optimum temperature will be determined for the present model or actual batch-type drier experiment by a synthetic study of the thermal efficiency, thickness of drying samples in the drier, economical analysis, etc.

Ⅱ. Batch-type Drier Model

1. Aim

This batch-type drier is a simple structure. The aim of this experiment is to study various constructed driers operated under various temperatures and humidities.

2. Equipment

1) Drying facility

This drier is 3 feet high, 3 feet long and 3 feet wide with drying chamber walls made of veneer board material. A screen tray 3 feet × 3 feet is located 1.1 feet from the floor. Above the tray is a drying chamber 3 feet by 3feet by 1.9 feet. The heated air is blown from beneath this tray. The heated air is blown by a fan from an electric heater and controlled from the panel board. In the upper-front of the drying chamber is the exhaust duct and opposite it is the heated air inlet. The electricity consumed is measured by an electrometer.

2) Equipment or apparatus

(A) Thermometers

One thermometer is installed at the air inlet, three on one of the side wall(upper, middle and lower positions) and one at the exhaust duct. A total of 5 were installed.

(B) Steinlite electronic grain moisture instrument was used for obtaining grain-moisture contents.

(C) Kett P.B.-I.K. moisture meter also was used for obtaining sample moisture contents.

(D) Balance

Ten-kilograms and three-kilograms scales and a balance with an accuracy of 1/100g were used.

(E) Fan and motor

1/4 H.P. motor was used to move the heated air.

(F) Electrometer

Consumption of electricity was automatically measured by a electrometer.

(G) Drying oven

To obtain oven-dry weights, an automatic controlled electric oven set at 100°C, ±5°C was used.

(H) Potentiometer

Every position of the drying chamber was measured by potentiometer.

3) Samples

Rough rice produced at the College of Agriculture Farm was used. The rough rice was steeped in water for 12 to 15 hours and then taken out to stand in the air for drainage of the excessive water for three hours. The new rough rice had 17 to 19% moisture

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and the rewetted new rough rice had over 25%. The maximum moisture content of the rice was 34%.

3. Testing method

Rough rice and rewetted samples were used in this experiment.

1) Investigation

(A) Sample weighings

As above mentioned new rough rice and rewetted new rough rice samples were steeped (12 to 15 hours in water and 3 hours standing in the air for drainage) and then weighed and spreaded on the tray. At every regular interval of the drying period. 100 grams of each sample were collected from the upper, middle and lower layers on the trays (six divided different parts of the drying materials) in the drier and the moisture content of each sample was measured by the moisture meter and then dried until the final moisture content was lowered to 10 or 20%.

(B) Temperature distribution

The temperature of each part of the drying chamber was measured by the thermometers in the drier and then recorded.

(C) Moisture contents

The oven dry weights which are neccessary for the many moisture-content calculations were obtained by conversion of initial moisture content at 105°C ± 5°C, drying method. As the initial miosture contents of the samples were different, the average of them was used for the B.D.W. calculations.

(D) Air velocity

The air velocity measuring meter was installed at the exhaust duct at the upper position of the drying chamber and the air velocities were measured at three selected intervals.

(E) Thermal efficiency

The thermal efficiency was calculated as follows: the differences of the total weights before drying and total weights after drying were considered as the evaporated moisture during drying. The heat energies required for evaporation and the consumed electricity in energy terms were converted into thermal terms for the efficiency calculations.

2) Various condition changes

The various conditions are changed as shown in Table 5.

Table 5 The Experiment of Various Condition Changes.

Test No.	Kind		Unit	Demension	Change
1	New Rough rice	Drying Temperature	°C	O	40°C
2	Rewetted Rough rice	Drying Temperature	°C	O	40°C 50°C 60°C
3	Rewetted Rough rce	Drying Period	Min	T	1cm 5cm 7cm
4	Rewetted Rough rice	Sample layer Thickness	dm	L	10cm 15cm 20cm 25cm
5	New Rough rice	Sample layer Thickness	dm	L	5cm 15cm 20cm

4. Results and analysis

The drying temperature was fixed at 40°C and the loaded sample thickness was recored. As the initial moisture contents were different in every case, the average was recorded as their initial moisture content. In order to compare the drying state of different layers of the samples, the thickness was divided to three layers as upper, middle and lower. The following Tables are the results of this research work.

1) Results.

Table 14 shows that when the heated air inlet temperature was 60°C, the thermal efficency was higher than 40°C and even with the same temperature the thicker sample layers showed high thermal efficiency than thinner ones. However, in the case of 50°C, different results were obtained.

Table 6. Results for Batch Type Drier Experiment (1) Dried New Rough Rice.

Test No.	Factors			Time (min)	Group W.B. % A	B	C	D	E	F	Layer W.B. % Upp.	Mid.	Low.	Total Aver-age
	Date	(1968)	11.1											
	Inlet temp.	(°C)	40											
	Thick.	(cm)	5	0	13.32	13.35	12.70	13.85	13.55	13.50	13.44		13.30	13.38
	Dry per.	(min)		30	12.80	12.75	12.75	12.67	13.15	12.95	12.98		12.76	12.88
1	Cons. elc.	(K.W)	14	60	11.95	11.80	11.85	11.95	11.75	11.80	11.90		11.75	11.85
	Initi. wei.	(gr)	20,500	120	11.20	11.05	11.40	11.30	11.20	11.10	11.30		11.07	11.20
	Fina. wei.	(gr)	11,500											
	Air velo.	(f/m)												
	Date	(1968)	11.6	0	18.30	18.30	18.30	18.30	18.30	18.30	18.30		18.30	18.30
	Inlet temp.	(°C)	40	60	16.80	17.40	16.50	17.85	18.10	17.45	17.90		17.00	17.45
	Thick.	(cm)	15	120	15.50	15.40	16.60	15.55	16.30	16.30	16.46		15.50	15.92
	Dry per.	(min)	420	180	14.55	14.40	14.30	15.30	15.85	15.15	15.05		14.80	14.90
2	Cons. elc.	(K.W)	23	240	14.50	13.70	13.65	14.65	14.50	14.15	14.60		13.75	14.10
	Initi. wei.	(gr)	60,580	300	12.35	12.50	12.95	13.10	12.50	12.55	13.20		12.08	12.60
	Fina. wei.	(gr)	56,814	360	12.50	11.80	12.70	12.85	12.60	12.40	12.55		12.40	12.50
	Air velo.	(f/m)		420	11.50	11.90	12.15	12.00	12.20	11.40	11.80		11.60	11.70
	Date	(1968)	11.8	0	17.90	17.90	17.90	17.90	17.90	17.90	17.90		17.90	17.90
	Inlet tem.	(°C)	40	60	16.70	16.60	16.40	16.30	16.60	15.20	16.50	16.50	15.95	16.30
	Thick.	(cm)	20	120	15.00	15.70	15.40	15.80	15.10	15.20	16.50	15.60	14.70	15.56
	Dry per.	(min)	420	180	13.60	14.70	14.60	14.80	14.30	13.50	15.00	14.30	13.60	14.30
3	Cons. elc.	(K.W)	23	240	13.80	13.10	13.10	13.80	13.38	12.95	13.38	13.13	12.94	13.30
	Initi. wei.	(gr)	95,550	300	12.70	12.70	12.60	12.70	12.50	12.00	13.00	12.60	12.06	12.60
	Fina. wei.	(gr)	86,150	360	12.30	12.30	12.70	12.70	12.30	12.80	12.85	12.28	11.97	12.30
	Air velo.	(f/m)		420	11.30	11.30	11.90	11.70	11.40	11.30	11.40	11.20	11.20	11.40

Min.: minutes, Inlet temp.: Inlet temperature, Thick: thickness, Dry per.: Drying period. Cons. elc.: Consumed electricity, Initi. wei.: Initial weight, Fina. wei.: Final weight. Air velo: Air velocity Upp.: upper, Mid.: Middle, Low.: Lower.

Table 7. Results for of Batch Type Drier Experiment (4) Rewetted New Rough Rice 60°C.

Test No	Factors			Time (min)	Group W.B. % A	B	C	D	E	F	Layer W.B. % Upp.	Mid.	Low.	Total Aver-age
	Date	(1968)	11.13	0	33.85	33.85	33.85	33.85	33.95	33.85	33.85		33.85	33.85
	Inlet temp.	(°C)	60	30	26.46	26.14	27.61	24.86	27.18	24.38	29.30	27.94	21.12	26.12
	Thick.	(cm)	15	90	21.74	22.05	21.99	20.60	24.92	21.02	26.46	22.06	15.66	21.39
16	Dry per.	(min)	390	150	17.47	18.78	17.94	16.38	17.95	16.53	21.50	18.60	12.65	17.58
	Cons. elc.	(K.W)	75.35	210	14.92	15.63	15.12	14.27	14.15	13.51	18.60	14.45	10.70	14.58
	Initi. wei.	(gr)	75.000	270	10.90	11.13	10.71	9.68	9.37	9.82	11.15	10.51	9.14	10.27
	Fina. wei.	(gr)	47.350	330	9.32	9.38	9.38	9.14	9.90	8.59	9.95	9.14	8.60	9.23
	Air velo.	(f/m)	530	390	8.17	9.08	7.79	7.93	8.11	8.11	8.51	8.00	7.85	8.12
	Date	(1968)	12.14	0	29.70	29.70	29.70	29.70	29.70	29.70	29.70	29.70	29.70	29.70
	Inlet temp.	(°C)	60	60	28.85	26.85	25.58	24.98	29.02	26.50	26.10	27.48	21.09	26.59
	Thick.	(cm)	20	120	22.80	21.67	23.37	20.74	21.43	21.40	27.74	24.92	12.88	21.80
	Dry per.	(min)	420	180	18.97	17.05	19.19	18.32	20.13	19.96	25.03	21.01	10.79	18.70
17	Cons. elc.	(K.W)	37	240	17.07	15.97	17.20	14.97	14.18	17.94	22.69	18.05	9.76	16.83
	Initi. wei	(gr)	99,000	300	14.24	14.58	14.32	13.21	17.68	16.90	22.12	16.25	9.10	15.16
	Fina. wei	(gr)	65,300	360	9.96	9.30	10.87	11.71	11.11	9.43	13.62	9.61	7.90	10.38
	Air velo.	(f/m)	495	420	8.10	9.55	9.17	7.40	8.11	8.81	9.83	8.15	7.58	8.52
	Date	(1968)	12.16	0	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50
	Inlet temp.	(°C)	60	60	23.38	22.35	22.61	21.61	21.64	21.67	24.15	23.62	19.36	22.38
	Thick.	(cm)	25	120	20.65	21.23	21.18	20.87	22013	21.16	23.30	23.00	17.70	21.16
	Dry per.	(min)	540	180	19.37	20.19	19.73	20.12	19.92	19.33	22.75	21.49	15.09	19.78
18	Cons. elc.	(K.W)	49	240	18.08	17.82	19.25	18.30	18.30	18.75	17.14	22.10	17.61	13.31
	Initi. wei.	(gr)	133,000	300	17.30	16.54	17.37	16.01	16.40	16.23	21.04	17.11	11.73	16.64
	Fina. wei.	(gr)	91,800	360	18.47	15.16	15.31	14.86	14.55	14.36	18.95	15.80	10.40	15.07
	Air velo	(f/m)	421	420	12.72	12.65	12.57	12.70	13.46	12.00	16.76	11.95	9.25	13.69

Min.: Minutes Inlet temp.: Inlet temperature, Thick: Thickness, Dry per.: Dying period, Cons, Elc.: Consumed electricity, Initi. wei.: Initial weight, Fina. wei.: Final weight, Air velo.: Air velocity, Upp.: Upper Mid.: Middle, Low.: Lower.

(B) The drying state comparison of upper and lower sample layer.

The drying state of upper and lower layer of 12 to 13% final moisture content samples were analysed as shown in Table 8.

Table 8. Drying State of Upper and Lower Layers.

Test No.	Temperatue (°C)	Thickness of sample layer (cm)	Upper layer (W.B. %)	Lower layer (W.B. %)	The W.B. % with 12 to 13 final moisture content
8	40	20	13.03	12.20	0.83
12	50	20	14.34	8.59	5.75
18	60	25	16.76	9.35	7.41

The above Table shows the higher the drying temperature the greater the difference of final moisture content even with the same sample-layer thickness. When the drying temperature was 40°C the final moisture content was only 0.83% at 60°C 7.41 %

(C) Temperature distribution

The temperature of the upper, middle and lower three layer were measured whenever the sample layer thickness was changed.

Table 9. Temperature Distribution According to Changing Sample Layer Thickness.

Test No.	Layer Thickness	Inlet Temperature	Upper layer Temperature			Lower layer Temperature			Outlet Temperature
Unit	Cm.	°C	°C			°C			°C
1	15	40	28.0	25.0	18.9	32.0	39.7	34.5	39.0
2	20	42	23.0	26.4	23.9	40.7	41.4	35.6	42.6
3	20	41	18.5	18.1	18.1	36.6	38.6	40.0	39.8
4	1	40	29.8	30.9	24.3	38.0	39.0	36.0	40.0
5	5	40.5	26.1	26.2	19.5	39.0	35.5	40.2	40.6
6	7	40.5	22.0	19.5	18.8	38.0	31.6	39.6	41.5
7	15	40.7		20.8	14.8	14.8	33.4	40.0	40.7
8	5	50.0	29.4	26.6	26.4	43.4	44.1	42.3	43.8
9	10	50.0	27.0	23.0	23.0	45.6	46.8	46.0	48.1
10	20	52.0	23.0	21.0	19.0	49.0	50.0	49.0	51.0
11	5	60.0	25.0	29.0	29.7	60.0	61.3	59.9	61.1
12	7	60.0	35.4	30.5	27.5	57.5	59.0	57.0	52.8
13	15	60.0	26.6	23.5	24.4	57.0	55.0	55.7	56.0
14	20	59.7	26.6	26.2	26.3	56.4	55.6	57.7	57.8
15	25	59.2	26.4	22.3	21.7	58.2	59.2	58.6	58.2

5. Discussion

The experiment on the influential factors of drying such as temperature, loading amount, and initial moisutre content were included in the present research.

1) The drying temperature effects.

Drying temperature is one of the most effective factor on drying. In the present experiment, two different thickness of sample layer were tested, below 5 cm. thickness was termed as thin layer and over 15 cm. was termed as thick layer.

(A) Drying temperature effect on thin layers (lower layers)

Drying temperatures were varied (40°C, 50°C and 60°C) and the results are shown in Figure 7.

Figure 7 shows that the higher the drying temperature the more rapid is the drying rate, the drying curve suddenly falls and the required drying period is greatly affected by the temperature. Thus, the drying period required to obtain 13% final moisture content material was decreased about 1.0 to 1.5 hours for every 10°C increase under constant conditions such as air velocity, drying material thicknsse, etc. This was mainfested in the decreasing drying rates during the drying periods.

(B) Drying temperature effects on thick layer (upper layer).

The experiment with the thick layers was carried out under constant drying conditions as in the thin layer experiment(see Figure 9). The higher the drying temperature the more rapid is the drying rate with a slow fall in the curve. However, it was shown that the moisture content of the sample was increased over the initial moisture content when the drying temperature was low. This phenomenon occured by the movem ent of the heated air from lower to upper layer and the vapor remains in the undried upper layer. As the drying state of the upper layer is not uniform, the drying curve shows that the moisture content is remarkably different according to the collecting method for each sample.

(C) The effects of thickness of sample layer

Figures 16 and 17 show that increasing the thickness of sample layers with the same drying temperature increases the drying period as the air amount per unit area was reduced. The thicker the thickness the greater the difference of drying between the upper and lower layers. The effect of thickness is the important factor for the most effective drying. The thickness experiment was performed at 40°C, 50°C and 60°C drying temperatures and the drying curve of the upper layers was determined from the average of the data in the tables. The values are much different according to the sample position at the time of the collection.

(D) The effects of the initial moisture content.

As the samples were rewetted rough rice, that had high initial moisture contents. They were mnch different. The drying state of the rewetted samples with high moisture contents and the new rough rice with low moisture contents were comparable as shown in Figure 18. When the initial moisture contents were high (especially the higher the temperature), the drying curves were steep and when the temperatures were low the curves were more gentle in slope.

Table 10. Drying Periods Required.

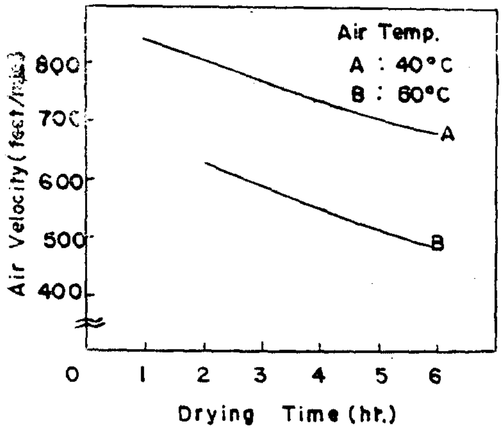
Inlet temperature	Thickness of sample	Drying period	Initial moisture	Final moisture	Average drying rate	Drying period for 13.5%
(°C)	(cm)	(hour)	(%)	(%)	(%)	(hour)
40	5.0	7.0	31.70	11.26	2.92	6.2
40	10.0	11.0	27.72	12.18	1.55	9.1
50	20.0	16.0	26.80	12.62	0.886	15.1
50	5.0	4.0	33.77	10.48	5.89	3.44
50	10.0	7.0	31.88	10.24	3.078	3.07
60	20.0	8.0	25.40	11.81	1.70	7.00
60	5.0	3.0	32.39	8.54	7.92	2.37
60	10.0	4.5	33.14	9.14	5.30	3.70
60	20.0	7.0	29.70	8.52	3.02	5.40

(E) The effects of air velocity

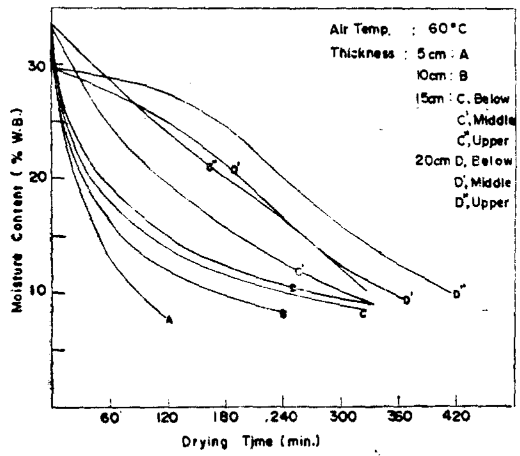
In order to find the effects of air velocities on drying, the initial, midway and final drying states are shown in Figure 19. The air velocity changes under simalar conditions were not carried out in the present experiment but only the exhaust air velocities weer measured. The thicker the sample layers and the weaker the air velocity, the higher the temperature of the drying chamber becomes.

(F) Drying periods

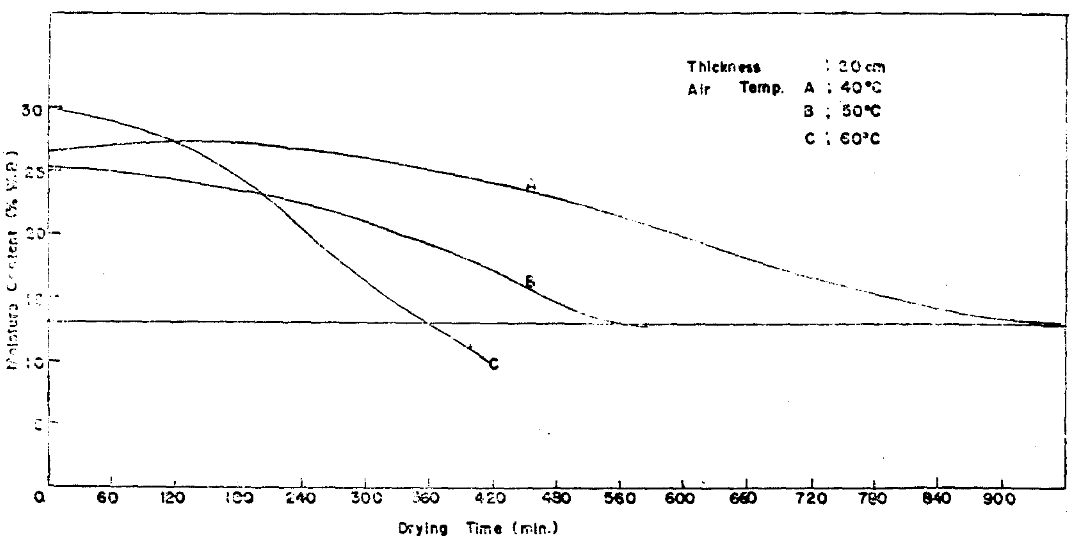
It was found that the drying period is closely related with drying temperatue and is much affected by sample thickness and air velocity and the higher the temperature of the drying chamber becomes. The experiment the drying periold was carried out at 40°C, 50°C, and 60°C temperatures and with various thickness. The average drying rates are shown in Table 10. (In this case, the initial moisture content was high).



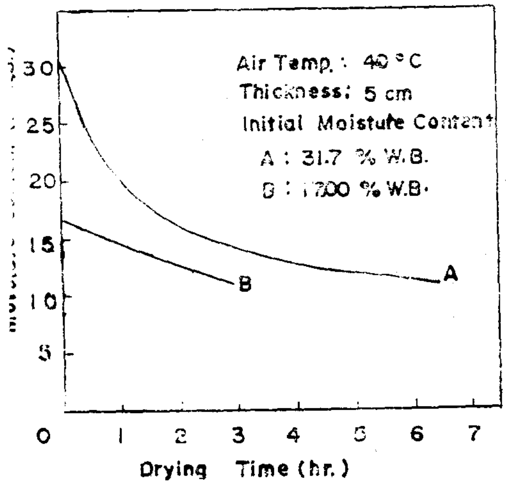
Fig—7. Temperature effects on drying of thin layers.



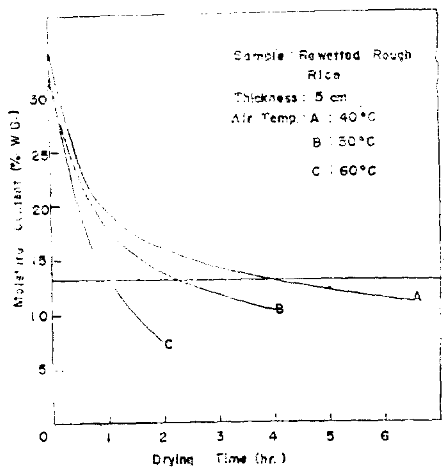
Fig—8. Sample layer thickness effects on drying (60°C)



Fig—9. Temperature effect on drying of thick layers



Fig—10. Drying curves based on initial moisture contents.



Fig—11. Temperature effects on air velocities on uniform layer thickness.

The results of new rough rice drying indicate hat the drying period required 3.5 hrs to 4.0 hours ɔ obtain 13.5% final moisture content material when ne temperature was 40°C and thickness 20cm. The verage drying rate was 1.42 and the initial moist-ıre content was 17.9%. Thus the drying period decreased when the drying temperature was high and the samle layer thickness was thin. with new rough rice, (initial moisture content was 20%), the drying period was about 4.6 hrs when the temper-ture was 40°C and the thickness was 20 cm. The drying period was 3.5 to 4.0 hours when the initial moisture content was 25%, temperature was 50°C and thickness was 20 cm.

(G) The cracked rice experiment

It was known that rice cracking was high when the initial moisture content and drying temperature were high. Especially the rewetted samples showed a high cracking rate on drying.

3. Conclusion

The drying experiments with new rough rice and rewetted samples were carried out by the batch-type drier. The results obtained are discussed herein.

(A) Drying capacity

The structure of the drier is simple, the operating method is easy and the cost of the facility is very-low. This batch-type drier is a suitable one for Korean farm situations. As the same drying temp-erature, the drying period of thick sample layers was slower than thin layers by about 2.0 to 2.3 times and the thermal efficiency was high. When the initial moisture content of rewetted new rough rice was 25 and the thickness was 5 cm, the drying period required was aproximately 13 hours.

(B) Drying states

The drying states were uniform when the sample layers were thin and the differences of final moisture content were great but the drying states were not as uniform as when the samples were larger and the layer were thicker. The drying rate of the thin layers was more rapad then the thick layers. Therefore, the unuiformly of the upper and lower layers indicate that the drier must be improved and that the horizontal area is more important for a given sample than the height.

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