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STUDY ON BROWN RICE DRYING

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ABSTRACT

This study was investigated to evaluate whether brown rice drying could reduce the rice production cost. Characteristics of brown rice drying was experimentally determined. With brown rice drying, the higher energy efficiency could be obtained. Therefor, this method is effective to cost reduction. However, there are some problems, for example occurrence of fissuring and preservation of rice quality.

Key Word : Drying, Brown rice, energy efficiency, Fissuring, Taste

INTRODUCTION

In Japan, rice is one of the important staple foods, but the production cost is the highest among the rice growing countries in the world. One reason causing this is the high cost of construction of processing facilities and operation cost. Japan is faced with the problem of high costs of rice processing. Reduction of these costs is currently one of the main concerns of all rice processing engineers.

Artificial drying of rice grain is usually performed with paddy's form. Paddy drying requires a large drying space in the drying bins and also a large storage space in silos, necessitating spacious dryers and many silos to dry and store the paddy during and after drying. It is then necessary to find a cheaper way of drying and storing rice grain. If the husk is removed, the remaining moisture to be removed from brown rice is then little and it is thought that the drying time is thereby greatly reduced. From the viewpoint of drying cost reduction, the brown rice drying is advantageous (Yamashita et al(1989), Omar et al(1989), Yamashita (1993)). Therefore, authors have considered about application of brown rice drying to the practical use. This type of study has just been started because paddy drying was commom sense for rice drying. There are some technical problems in this method. As brown rice is easily fissured,the drying speed has to be restricted by regulating the drying air temperature and relative humidity.

EXPERIMENTAL METHOD

Two kinds of experiment were carried out. Experiment I is for the determination of proper drying conditions including temperature, relative humidity, air flow to grain rate etc., from the viewpoint of avoiding the occurrence of fissuring. Experiment II was done for applying the brown rice drying to practical use.

1. Experiment I (Preliminary experiment)

1) Drying apparatus

Small sized drying apparatus in which there are cooling unit, heater, humidifier and small blower was used in this experiment. Therefore, the drying condition including temperature, relative humidity and air flow to grain rate can be controlled.

2) Drying method

(1) Determination of proper drying condition

As is generally known, brown rice is easy to be fissured during drying in comparison with paddy. We then have to determine the drying condition in which fissuring does not occurs. Drying temperatures are 30, 35, 40°C, relative humidities are 30, 50, 70% for every levels of temperature, and air flow to grain rate is constant of 0.025 $m^3/(s.kg\text{-}grain)$; this experiment is then thought as thin layer drying.

The drying characteristics change according to the grain's initial moisture content, so the drying experiments were carried out with 3 levels of initial moisture content.

The tempering drying system is effective not only to avoid the occurrence of fissuring but also to obtain the high net drying rate. Therefore, the experiments of various combinations of drying time and tempering time were carried out.

The evaluation of drying condition was done using fissuring rate and broken rice rate after milling.

(2) Estimation of drying rate

In order to estimate the drying rate for the drying air condition in the practical use, the drying experiments were carried out under the controlled drying air temperature, relative humidity and air flow to grain rate. The amount of material is 300 g. Temperature is ranged from 25 to 35°C, 35 to 65% for relative humidity and 4, 8, 12 $m^3/(s.t\text{-}grain)$ for air flow to grain rate. The combination of drying time and tempering time was 5 minutes and 15 minutes, respectively on the assumption of experiment II (experiment for practical use).

2. Experiment II (Experiment for practical use)

1) Drying apparatus

The tempering dryer of circulation type for paddy drying was used. The capacity is approximately 200 kg-paddy, that is 300 kg-brown rice, and the least operation amount is 50 kg-paddy, 60 kg-brown rice. Capacity of drying section is 16 kg–brown rice. Grain circulating rate can be changed by setting timer.

The air of constant temperature and relative humidity is controlled by the device mentioned above. The temperatures and relative humidities of drying air before and after the grain drying layer and the air flow rate in the duct were measured and recorded.

2) Experimental method

Just before the drying experiment, raw paddy is husked by the impeller type husker. Unhusked paddy is not returned to the husking part since the husking ratio is very high, more than 95%. Husked brown rice is filled in the dryer, and aeration starts. In order to get the drying process by detecting grain's moisture content, sample is taken from the dryer every 20 minutes. Aeration is finished when the moisture content has reached 15%(WB). Measurement of fissuring rate is performed after 2 days from drying. Dried brown rice is stored with the sealed vinyl bag in the constant temperature chamber of 4°C and 15°C, and under the ambient atmosphere. After that, the examination of rice taste by organoleptic test is carried out. Experiments were done from the following viewpoints; i) difference in required heating energy between brown rice drying and paddy drying, ii) difference in quality change according to combination of drying and tempering time, iii) difference in quality change according to the initial moisture content of raw brown rice. The experimental plots are shown in table 1.

RESULTS AND DISCUSSION

1. Experiment I

1) Occurrence of fissuring

The relationship between drying condition and fissuring rate in case of both paddy drying and brown rice drying is shown in Fig.1. When the relative humidity of drying air is 30%, fissuring rate of brown rice is more than 70%, which is remarkably higher than the value of paddy at the same drying condition. Therefore, it is necessary to take notice of occurrence of fissuring on brown rice drying. The relationship between the drying air condition and fissuring rate in brown rice drying is also shown in Fig.1. As the temperature becomes lower and relative humidity becomes higher, the fissuring rate decreases. Therefore, by considering the proper air condition, the occurrence of fissuring can be restricted. From this result and drying rate, it is decided that standard condition of drying air is 30°C or less and 50%R.H..

The relationship between the fissuring rate and initial drying rate, which is the average drying rate in the first one hour of drying process, is shown in Fig.2. It became clear that the fissuring rate is dependent on the initial drying rate. As the initial drying rate increases, fissuring occurrence increases. In order to restrict the fissuring rate to less than 5%, the initial drying rate should be less than 3%(DB)/h.

2) Control of fissuring

(1) Effect of initial moisture content

In case that the drying condition is the same, 30°C-50%R.H., the relationship between initial moisture content and fissuring rate is shown in Fig.3. The lower the initial moisture content is, the lower the fissuring rate is. It is caused that when the initial moisture content is low, the initial drying rate is low in comparison to the grain of higher moisture content. Therefore, it is effective to make the system in which rice grain is dried with paddy form to a certain level of moisture content before the brown rice drying.

(2) Effect of tempering drying

The relationship between the tempering to drying time rate, which is defined as the rate of tempering time to drying time, and the fissuring rate is shown in Fig.4; the drying condition is 30°C-50%R.H.. The tempering to drying time rate of zero means the continuous drying, and that of 3 means that grain is dried for 5(10) minutes, and after that tempered for 15(30) minutes. There are two cases in this experiment; one is 5 minutes of drying time, and another is 10 minutes. As the tempering to drying time rate increases, fissuring rate becomes low. However, after the tempering to drying time rate exceeds 3, change of fissuring rate is small. Then the tempering to drying time rate should be more than 3. Adding the results of fissuring rate in tempering drying on Fig.2, Fig.5 can be obtained. Even if the initial drying rate becomes high owing to tempering drying, the fissuring rate can be restricted. From this characteristics, it became clear that the tempering drying system is very effective from the viewpoint of energy saving and quality preservation.

3) Drying rate

The effect of drying air condition on the initial drying rate was obtained by the drying experiments under the various conditions of temperature, relative humidity and air flow to grain rate. When the initial moisture content of material is similar, 28%(DB) in this experiment, the initial drying rate becomes high as the temperature increases, the humidity decreases and the air flow to grain rate increases. The relationship between the drying condition and the initial drying rate is shown in Fig.6 and described BY Eq.(1) within the range of this experiment.

$$R = 0.098T - 0.053H + 0.072F + 1.34 \quad (1)$$

where, R: Initial drying rate (%(DB)/h)
T: Drying air temperature (°C)
H: Drying air relative humidity (%)
F: Air flow to grain rate (m^3/(s.t-grain)

Using Eq.(1), the initial drying rate can be controlled by the combination of drying condition.

2. Experiment II

1) Drying rate and required energy

The drying rate with the dryer in practical use was fairly constant through the drying process in this experiment. Conditions of ambient atmosphere and drying air, initial drying rate, average drying rate, heating energy for evaporation of 1 kg water are shown in table 2. The drying processes of paddy (Ex.1) and brown rice (Ex.2) are shown in Fig.7. Though the drying air temperature for brown rice is lower than that for paddy by 10°C, the average drying rates are almost similar each other. The consumed electric energy for evaporation of 1 kg water in brown rice drying is one sixth of that in paddy drying. It became clear from this result that remarkable energy saving can be obtained by brown rice drying. However, the degree of energy saving in comparison with paddy drying varies depending on the temperature of ambient atmosphere.

2) Fissuring and broken rice rate

Fissuring rate and broken rice rate after milling are shown in table 2. It can be said that there is little difference in fissuring rate between paddy drying and brown rice drying. However, the broken rice rate of brown rice drying is a little higher than that of paddy drying. The relationship between fissuring rate and broken rice rate is shown in Fig.8. There is a tendency in which as fissuring rate increases, broken rice rate increases, but there is some difference between milling of abrasive type and frictional type. It may be caused by difference in the surface state, so it is necessary to consider the milling condition for the rice grain of brown rice drying. After all, it is thought that there is no problem from the viewpoint of fissuring and broken rice if the drying condition and milling condition are proper.

3) Evaluation of rice taste

The result of organoleptic test for rice of brown rice drying is shown in table 3. The rice of paddy drying was used as the standard for evaluation (Ex.1, Ex.3 and Ex.6). This test was carried out by the special organization of cereal grain examination. For one experimental plot, variety of Shirayukihime, the comprehensive evaluation of rice of brown rice drying was valued inferior to that of paddy drying. However, except for this item, there is no significant difference in all test items between paddy drying and brown rice drying. It is thought from this result that rice taste does not drop with brown rice drying.

CONCLUSION

Characteristics of brown rice drying was examined from the viewpoints of occurrence of damaged grain, energy efficiency and rice taste after milling. However, The problem of quality change along the storage term is not surveyed in this study. Because the bran layer is injured during circulation, fat in the bran layer may be easily oxidized. Therefore, it is necessary to mill as quickly as possible after brown rice drying. Another way to keep quality is the low temperature storage after drying. We are examining the quality of stored rice by fat acidity value, taste value with rice taste meter and change of grain's surface color.

The results obtained from these Experiments are as follows.

1. In order to prevent the occurrence of fissuring, condition of aerated air should be 30°C or less of temperature and around 50% of relative humidity.
2. The fissuring rate depends on the initial drying rate. When the initial drying rate is less than 3 %(DB)/h, fissuring does not occur.
3. The higher the initial moisture content is, the higher the fissuring rate is. So, it may be effective to make system in which paddy drying and brown rice drying are combined according to its moisture content.
4. Tempering drying system is effective to get high net drying rate and to prevent fissuring. The tempering to drying time rate should be more than 3.
5. The initial drying rate is described by equation using temperature, relative humidity and air flow to grain rate.
6. The same average drying rate could be obtained between paddy drying and brown rice drying even if there was temperature difference by 10°C. In this case, the consumed electric energy for evaporation of 1 kg water in brown rice drying is one sixth of that in paddy drying.
7. There is little difference in fissuring rate between paddy drying and brown rice drying if the drying condition is proper.
8. There is no difference in rice taste between paddy drying and brown rice drying.

REFERENCES

1.R.Yamashita et al, 1989. New Method of Postharvesting on Rice Grain (Part I), Journal of JSAM 51(4): 71-76

2.S.J.OMAR et al, 1989. New Method of Postharvesting on Rice Grain (Part II), Journal of JSAM 51(5): 91-96

3.R.Yamashita, 1993. NEW TECHNOLOGY IN GRAIN POSTHARVESTING, FMI, Tokyo

Table 1 Experimental Plots of Experiment II

Exp.	Material	Init. M.C.	Temp.	R.H.	Air flow	Drying -Tempering	Atmosph.	
		%(DB)	°C	%	m3/s·t	minute	°C	%R.H.
Ex.1	Paddy (Shirayukihime)	29.3	38	35	3.9	5-15	25	50
Ex.2	B/rice (Shirayukihime)	28.0	28	50	3.3	5-15	25	65
Ex.3	Paddy (Nihonbare)	32.5	Natural Drying				24	48
Ex.4	B/rice (Nihonbare)	32.2	26	45	5.5	5-15	24	48
Ex.5	B/rice (Nihonbare)	32.0	27	45	5.5	10-30	20	76
Ex.6	Paddy (Nihonbare)	18.5	Natural Drying				17	62
Ex.7	B/rice (Nihonbare)	19.1	35	50	5.5	5-15	17	64
Ex.8	B/rice (Nihonbare)	19.5	28	50	5.5	5-15	17	62

Table 2 Experimental Results of Experiment II

Exp.	Init. Dry rate	Ave. Dry rate	Efficiency	Fissuring	Broken rice	
					Abrasive	Frictional
	%d.b./h	%d.b./h	kW.h/kg-H2O	%	%	%
Ex.1	1.3	1.3	1.26	0.7	0.6	13.3
Ex.2	0.9	1.3	0.20	2.7	1.0	18.6
Ex.3				18.3	1.6	5.9
Ex.4	3.0	2.2	0.28	15.0	4.7	27.2
Ex.5	2.4	1.9	0.75	17.7	3.3	26.1
Ex.6				9.7	1.5	5.5
Ex.7	1.4	1.3	1.59	10.3	1.9	10.8
Ex.8	1.9	1.9	1.82	10.0	1.8	10.7

Table 3 Evaluation of Rice Taste with Organoleptic Test

Exp.	Evaluation	Appearance	Flavor	Taste	Stickiness	Hardness	Comprehensive
Ex.2	Average	+0.050	−0.300	−0.200	+0.300	−0.550	−0.450
	Deviation	±0.553	±0.553	±0.452	±0.602	±0.452	±0.352
	Judgement	±	±	±	±	−	−
Ex.4	Average	+0.208	−0.250	−0.042	+0.083	−0.167	−0.083
	Deviation	±0.271	±0.230	±0.374	±0.426	±0.343	±0.374
	Judgement	±	−	±	±	±	±
Ex.5	Average	+0.292	0.000	+0.042	−0.292	0.000	+0.042
	Deviation	±0.271	±0.230	±0.374	±0.426	±0.343	±0.374
	Judgement	+	±	±	±	±	±
Ex.7	Average	+0.458	0.000	+0.333	−0.167	+0.042	+0.208
	Deviation	±0.271	±0.230	±0.374	±0.426	±0.343	±0.374
	Judgement	±	±	±	±	±	±

Judgement + : superior significantly
− : inferior significantly
± : no significant difference

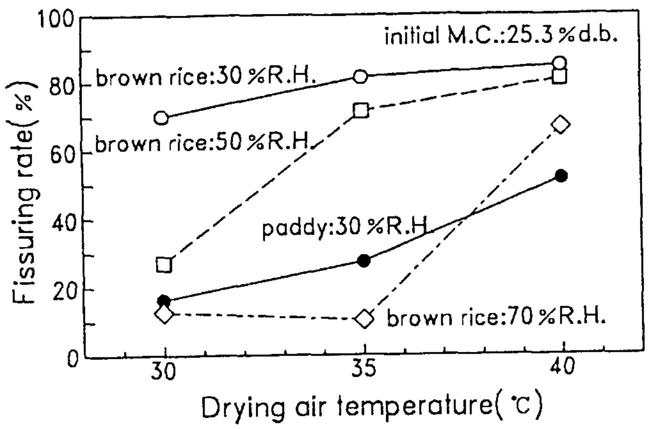

Fig.1 Relationship between Drying Condition and Fissuring Rate

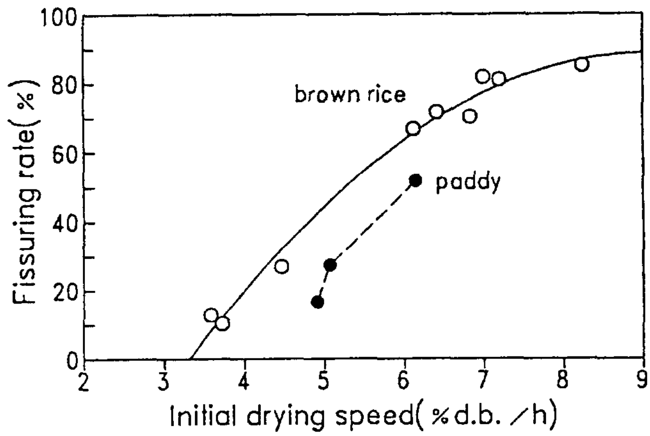

Fig.2 Relationship between Fissuring Rate and Initial Drying Rate

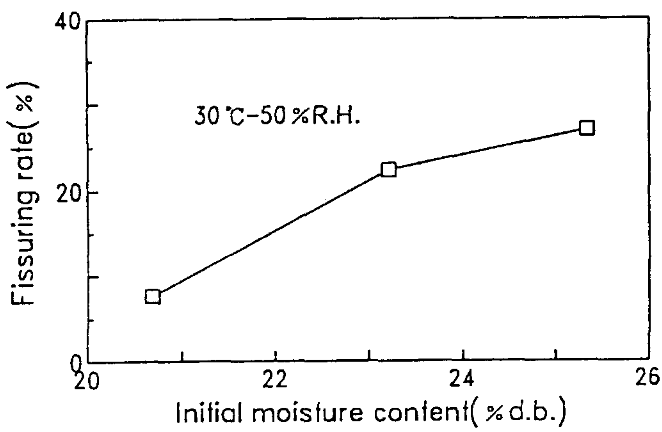

Fig.3 Relationship between Initial Moisture Content and Fissuring Rate

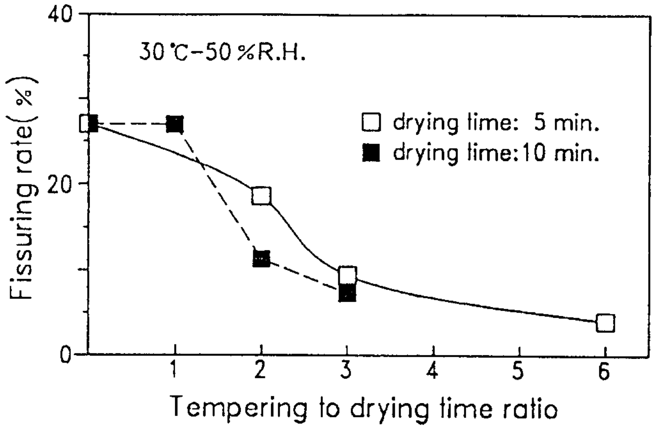

Fig.4 Relationship between Tempering Ratio and Fissuring Rate

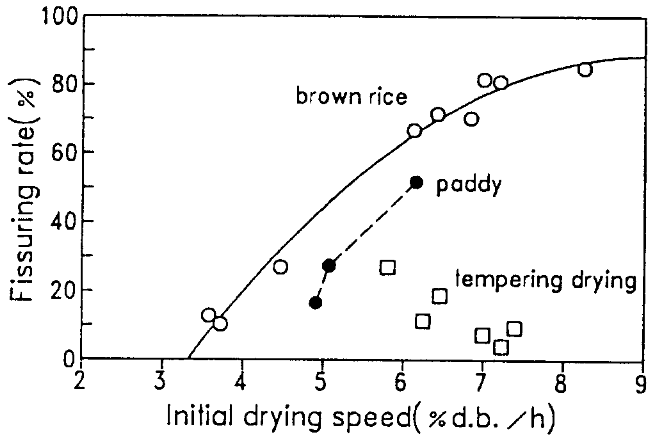

Fig.5 Effect of Tempering Drying on Prevention of Fissuring

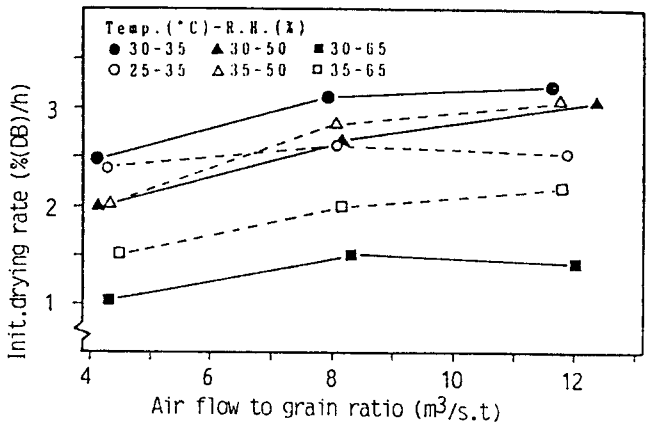

Fig.6 Relationship between Drying Condition and Drying Rate

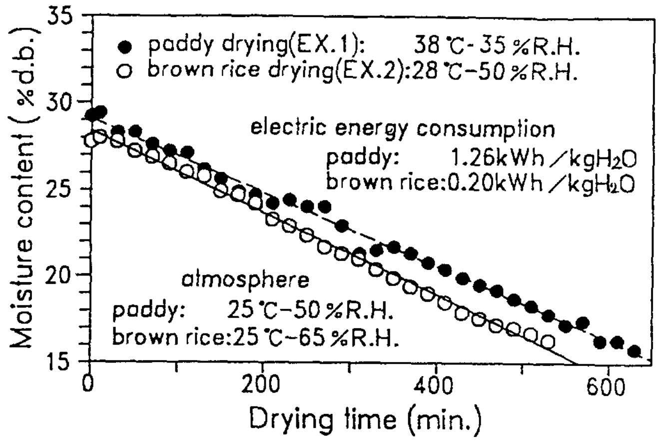

Fig.7 Comparison of Drying Process of Paddy and Brown Rice

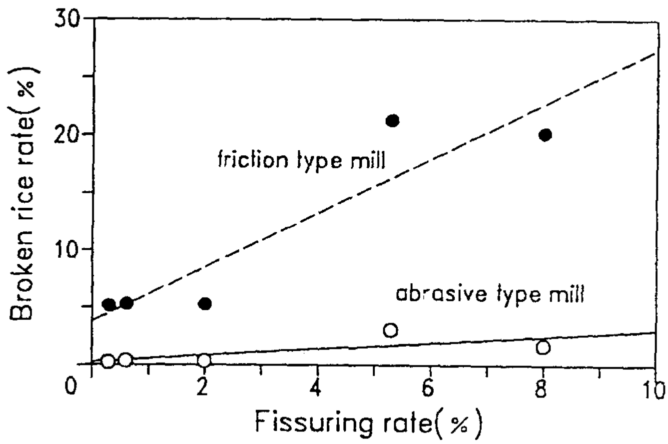

Fig.8 Relationship btween Fissuring Rate and Broken Rice Rate