

A NEW PREDICTING MODEL FOR THE DRIED YIELD RATE OF WET PADDY: USING THE KERNEL HUSK RATIO

Dai-chyi Wang

Mechanical Engineering Department, De-lin Institute of Technology

No.1, Ln. 380, Qingyun Rd., Tucheng Dist, New Taipei City 236, Taiwan (R.O.C)

Abstract

In Taiwan, farmers traded with grain buyers on the basis of wet paddy, and evaluate on dried rice. The conversion factor between newly harvested wet paddy and dried grain from dryer is defined as dried yield rate (DYR). The difference between raw paddy and dried rice concluded moisture and foreign materials. The current prediction model which is based on the linear relationship between DYR and moisture content (M.C.) results mean estimated error 3.83% and standard deviation 5.03%.

This study brings up a new model to predict DYR with kernel husk ratio (KHR). With the weight relationship between rice kernel and rice hull in plump rice of various MC, DYR of newly harvested paddy rice will be more precisely evaluated by measuring brown rice weight and sample MC.

The procedure of deriving the KHR function was developed upon 66 batch of Japonica rice. Verifying the DYR of wet paddy predicted by using the KHR with the with the experiment data, the average estimated error is 3.26% and standard deviation is 2.02 %.

Key words: Kernel-husk ratio, dry yield rate, paddy quality, rice drying, wet rice trading standard

1. INTRODUCTION

Taiwan is a subtropical island surrounded by the sea. Paddy of high moisture content (MC wb %) is often harvested in the season of typhoon or rainy. Due to geographical environment, climate and farm land utilization factors, paddy would not be dried naturally in rice field. For effective use of dryers, grain buyer dried farmer's wet paddy in large dryers which are operated by professional technicians to control quality.

During drying period, moisture and foreign materials which include fine rice stems, straw segment, flat grain cereals, rice husk miniature, immature green grain will be expelled from dryer. The weight ratio of dried clean plumb grain after drying and newly harvest wet paddy is defined as dried yield rate, DYR. Farmers traded with grain buyers on the basis of wet paddy, and evaluate on the basis of dry rice. Since waiting 20-24 hours to obtain real dried grain weight waste much time for famers. It's also not economy to dry individual farmer's wet grain in large grain dryer. Basically, measuring the exact DYR for individual farmer on trading site is impossible.

Government provided a reference standard table 1 for predicting the DYR of various MC. This conversion relationship was averaged and established on experiment data regression. The quality of individual harvest rice will not be distinguished. According to this reference standard, grain buyers trade with individual farmer by testing the sample MC. The DYR (%) will be look up and the weight of dried clean rice will be evaluated. The actual DYR of the same MC was depended on the management of each individual farm land. The exact DYR should not be derived only from MC of the grain.

Table 1. Reference standard for evaluating DYR of various MC

	Calculating function	Applicable range(w.b)
COA	$DYR = -1.1495 \times MC + 114.94$	MC:13.5~36%
A FA	$DYR = -1.1494 \times MC + 112.64$	MC:24~35%
B FA	$DYR = -1.1494 \times MC + 113.7896$	MC:15~34%
C FA	$DYR = -1.1387 \times MC + 113.8023$	MC:15~34%
D FA	$DYR = -1.0 \times MC + 110.0$	MC:15~34%

Note1 : DYR: Dried yield rate(%), MC: Moisture Content (%)

Note 2: COA: Commission of Agriculture FA: Farmer association

Note 3. This table was still working in 2013.

Market price of rice depends on the rice quality. Rice quality was affected by the drying process and the quality of original material (wet paddy). There were simulation models to predict drying process and control drying quality. Courtois et al.(2001) predict the sound kernel rate with the Fick and Fourier theorem. Abud-Archia et al. (2000) developed a dynamic model to predict the sound kernel rate with rice temperature and moisture ingredient. The quality of wet paddy depends on the growing condition in field. According to the growing characteristic of grain, the more mature grain grows the less MC grain will be. But the linear relationship between DYR and MC was indicated by Wang and Fong (2004) to be only moderate significant for Japonica rice. The linear relationship among DYR, FMR by winnowing and bulk density was not significant. The determinant of linear equation regressed by multiple variables which included bulk density, FMR winnowing, MC and DYR was only 0.5584. Evaluating DYR with only MC as table 1 was simple and less cost. But it is not a fair and appropriate way since the average estimated error will reach 3.83% and the standard deviation of estimated error will be 5.03%.(Wang, 2005)

The aim of this study is focus on deriving a precise predicting model for evaluating DYR. The procedure of testing kernel husk ratio will be defined. The predicting model will be verified by experiment.

2. METHOD

2.1 Model deduction

As DYR defined, dried yield ratio is the ratio of the weight of clean plump dried rice that is without FM(foreign material) after drying and the weight of newly harvested wet paddy. The weight composition of these two status are shown as figure 1.

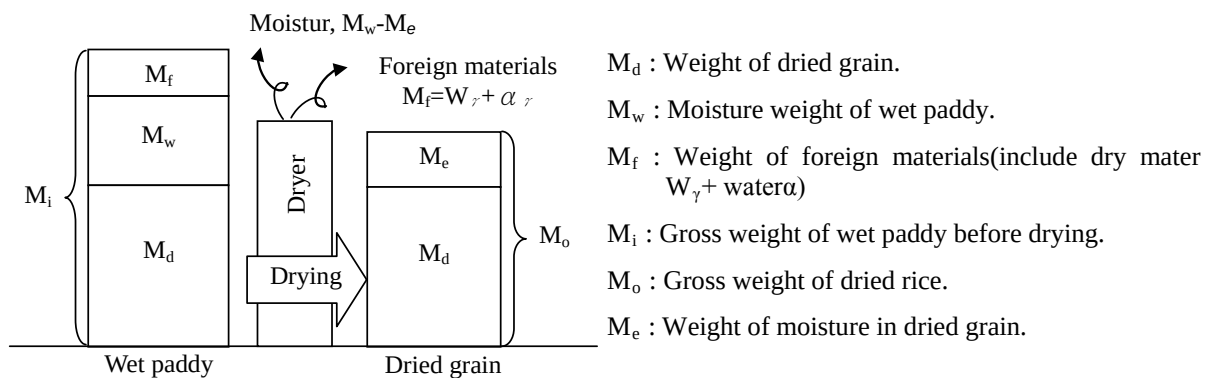


Figure 1. Illustration of weight variation during grain drying

The value of DYR will be affected by the final moisture content after drying. The DYR will be calculated in Equation (1).

$$\text{DYR}(\%) = \frac{\text{Gross weight of clean dried grain}}{\text{Gross weight of wet newly harvested paddy}} = \frac{M_d + M_e}{M_d + M_w + M_f} = \frac{M_o}{M_i} \quad \text{-----(1)}$$

A new concept of predicting DYR with kernel husk ratio was briefly introduced as which there is a mature brown rice in wet paddy grain, there will be the plump rice in dried grain. According to the standard linear equation of kernel husk ratio, derived from the weight ratio of brown rice and hull of various MC in clear mature plump wet paddy rice, the weight of plump clean wet rice will be evaluated. Base on the changing function of grain weight during drying process, the weight of clean dried rice after drying will be predicted and the DYR of wet paddy will be exactly evaluated. The deriving procedure will be illustrated as following.

2.1.1 Composition of rice

2.1.1.1 Clean plump completed dried rice

The weight composition of full dried rice (MC=0%) is shown as figure 2. The rice of 13%MC is winnowing by vertical fan separator to obtain clean plump rice grain. The husk and brown rice was separate by impact-type rice husker. The weight of dried materials can be measured after dried by oven (103°C, 24 hours). The specific kernel husk ratio for completely dried rice, as equation (2), will be constant for each species.

W_x	W_y
Weight of brown rice	Weight of rice hull

Figure 2. Composition of fine dried grain (MC=0%)

$$\text{Specific kernel husk ratio} = \frac{W_x}{W_y} = \Omega_s = \text{constant (for each species after completely dried)} \text{-----(2)}$$

2.1.1.2 Newly harvested wet paddy

The composition of newly harvested wet paddy (MC%) include dry matter which are brown rice W_x , rice husk W_y , foreign materials W_γ and moisture W_z (moisture in brown rice α_x + moisture in rice hull α_y + moisture in foreign materials α_γ) as shown in figure 3.

$W_z = \alpha_x + \alpha_y + \alpha_\gamma$			$\Leftrightarrow$	α_x	α_y	α_γ
W_x	W_y	W_γ		W_x	W_y	W_γ

Figure 3. Composition of newly harvested wet paddy

The moisture content of wet paddy is related as equation (3).

$$MC\% = \frac{W_z}{W_x + W_y + W_\gamma + W_z} \times 100\% \text{-----(3)}$$

2.1.1.3 Plump clean wet paddy

The dry material in wet clean (without foreign materials) plump rice of MC_a should be the same as specific dried rice described in figure 2. The kernel husk ratio of wet rice is a function of moisture as equation (4).

$$\text{Kernel husk ratio of wet paddy, } MC_a(\Omega_{R, \alpha}) = \frac{W_x + \alpha_x}{W_y + \alpha_y} = f(MC_a) \text{-----(4)}$$

2.1.1.4 Grain after drying

During drying process, the foreign materials will be expelled by dusting device and the moisture content decrease officially to $MC_\lambda = 13\%$. The moisture after officially dried contains moisture in brown rice λ_x and moisture in rice hull λ_y . The composition of rice grain was shown as Figure 4 and the kernel husk ratio will be derived as equation (5).

λ_y	λ_x	The foreign materials will be expelled by dusting device during drying process
W_y	W_x	

Figure 4. Composition of officially dried rice, $MC_\lambda (=13\%)$

$$\text{Kernel husk ratio of officially dried rice, } MC_{\lambda}(\Omega_R, \lambda) = \frac{W_x + \lambda_x}{W_y + \lambda_y} = f(MC_{\lambda}) \text{-----(5)}$$

Within moisture content range of newly harvested paddy(20~34%), the weight percentage of brown rice and average granular weight of matured and plump rice grain are the linear function of moisture $f_1(MC)$, $f_2(MC)$ as shown in equation (6), (7). The two functions derived from the experiment data of kernel husk ratio fundamental testing.

$$\text{Weight percentage of brown rice} = f_1(MC) = \frac{\Omega_R}{1 + \Omega_R} \text{-----(6)}$$

$$\text{Average granular weight of matured and plump rice grain} = f_2(MC) \text{-----(7)}$$

2.1.2 Algorithms of predicting DYR with kernel husk ratio

In terms of availability, the newly harvested wet paddy of MC_{α} % moisture content is composed of moisture W_z , dried brown rice W_x and dried impurities $W_{\text{impurities}}$. Weight of moisture contain brown rice moisture α_x , rice hull moisture α_y and foreign materials moisture α_{γ} . Dried impurity contained W_y , the dried hull of matured brown rice, and W_{γ} , dried foreign materials which include fine rice stems, straw segment, flat grain cereals, rice husk miniature, immature green grain. After husking the wet paddy sample, the wet brown rice and wet impurities can be separated by winnowing and weighed as shown in figure 5.

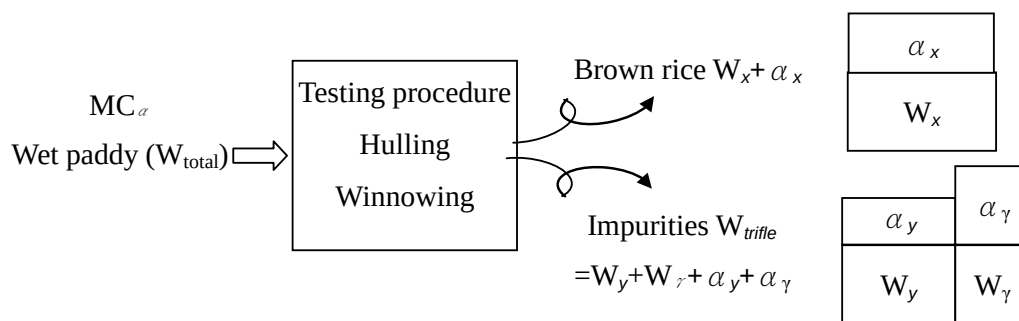


Figure 5. Illustration of DYR testing

By using the kernel husk ration function, equation (6), plump rice grain weight of moisture content MC_{α} will be derived by equation (7) as $(W_x + \alpha_x) + (W_y + \alpha_y)$.

$$(W_x + \alpha_x) + (W_y + \alpha_y) = \frac{W_x + \alpha_x}{f_1(MC_{\alpha})} = (W_x + \alpha_x) \times \frac{1 + \Omega_{R,\alpha}}{\Omega_{R,\alpha}} \text{-----(8)}$$

After drying to MC_{λ} (=13%), the weight of plump rice grain decrease to be $W_{\text{total},\lambda}$ by equation (9).

$$W_{\text{total},\lambda} = (W_x + \lambda_x) + (W_y + \lambda_y) = (W_x + \alpha_x) \times \frac{1 + \Omega_{R,\alpha}}{\Omega_{R,\alpha}} \times \frac{f_2(MC_{\lambda})}{f_2(MC_{\alpha})} \text{-----(9)}$$

And then, the DYR of the wet paddy will be derived by equation (10).

$$\text{DYR} = W_{\text{total},\lambda} / W_{\text{total},\alpha} = (W_x + \lambda_x + W_y + \lambda_y) / W_{\text{total},\alpha} = \frac{(W_x + \alpha_x)}{f_1(MC_{\alpha})} \times \frac{f_2(MC_{\lambda})}{f_2(MC_{\alpha})} / W_{\text{total},\alpha} \text{-----(10)}$$

2.2 Experiment instruments

1. Vertical winnowing separator, as shown in figure 6.
2. Single Kernel Moisture Tester (SHIZUOKA SEIKI CTR-800)

3. Precision electronic scales(Explorer OHAUS E1RW60)
4. Oven(YOUNG CHENN Model CON-545SD)
5. Sample Impeller Husker (Long-good Model FC2K, as shown in figure 7)
6. Parallel sample drying system with reversible ventilation (10 drying tubes), as shown in figure 8

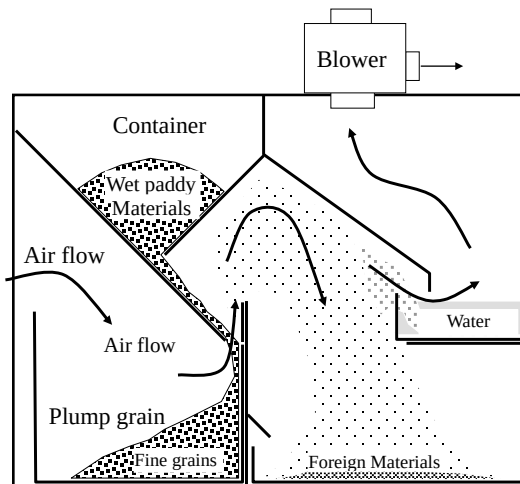


Figure 6. Vertical winnowing separator (air velocity of winnowing section is 6.90 m/s)



Figure 7. Sample impeller husker



Figure 8. Parallel sample drying system

2.3 Experimental procedure

2.3.1 Fundamental kernel husk ratio experiment

1. 66 batches of wet Japonica paddy samples were under experiment in Taiwan.
2. Moisture content of wet paddy without foreign materials was measured in 103°C oven for 24 hours.
3. 200 plump matured wet grains were picked up by hands from newly harvest paddy and the gross weight are measured by precision electronic scales.
4. Those 200 grains were husk by sample impeller husker and brown rice and husk were separated by winnowing separator. And the weight of brown rice and husk are measured separately.
5. The function of brown rice weight percentage and the function of

2.3.2 Verification test for dried yield rate

The verification test for dried yield rate for 46 batches of wet paddy samples were unmistakably complete.

1. The moisture content of 20 g samples from newly harvested wet paddy was test in 103°C oven for 24 hours.
2. 250g of sample were hulled by impeller husker. Brown rice and husk were separated by winnowing separator. And the weight of brown rice was measured.
3. 2000g of sample were dried by parallel sample drying tube. The air was heat by electric heater and blow to the drying tubes in drying system. The ventilation air direction was reversible by automatic control.
4. During drying process, the weight of sample was measured and stirred in one hour interval.
5. Drying process stopped when the target weight of 13% MC was measured. Dried sample was sealed in tight PE bag for 24 hours.
6. The foreign materials were separated from dried sample by vertical winnowing separator. The weight of clean dried rice was measured.
7. The final moisture content of dried clean rice was test in 103°C oven for 24 hours.

3. DISCUSSION

3.1 Fundamental kernel husk ratio experiment

From the Fundamental kernel husk ratio experiments that the average weight of granular grains is a linear equation of moisture content as figure 9. Since the data collected from nine species, grain characteristic discrepancy exists among species. The determinant of linear relationship is 0.6735.

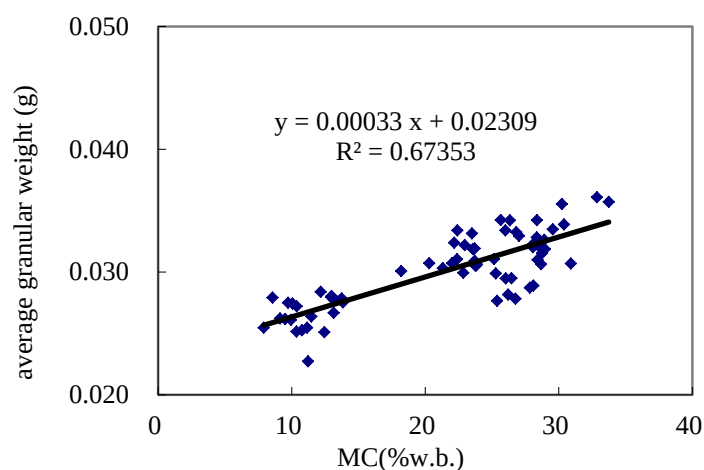


Figure 9. The relationship of average granular grain weight and moisture content

$$\text{Average granular grain weight (g/granular)} = 0.00033 \times \text{MC}(\%w.b.) + 0.0231, \quad R^2 = 0.674 \text{ -----(11)}$$

Equation (11) which is the function $f_2(MC)$ predicts the weight deviation of plump dried grain in drying process.

The relationship between brown rice weight percentage of plump rice grain and moisture content is shown as figure 10. Brown rice weight percentage (kernel husk ratio) decreases as moisture content increasing. This is caused significantly by grain surface moisture. When moisture content increase, the weight percentage of rice hull will increase.

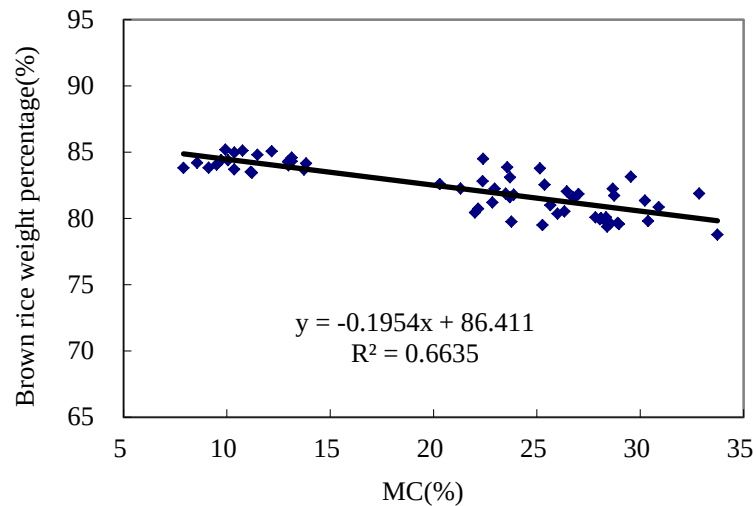


Figure 10. The relationship of kernel husk ratio and moisture content

The weight percentage of brown rice in plump rice is the linear equation, $f_1(MC)$, as shown in equation (12).

$$\text{Weight percentage of brown rice (\%)} = -0.1954 \times \text{MC(\%)} + 86.411, R^2 = 0.6635 \text{-----(12)}$$

3.2 DYR verification

The actual DYR (ADYR) of samples derived from experimental data of parallel sample drying system were plotted in figure 11. PDYR was predicted by using kernel husk ratio and Equation (10). The COA, AFA and BFA are the predicted value from table 1.

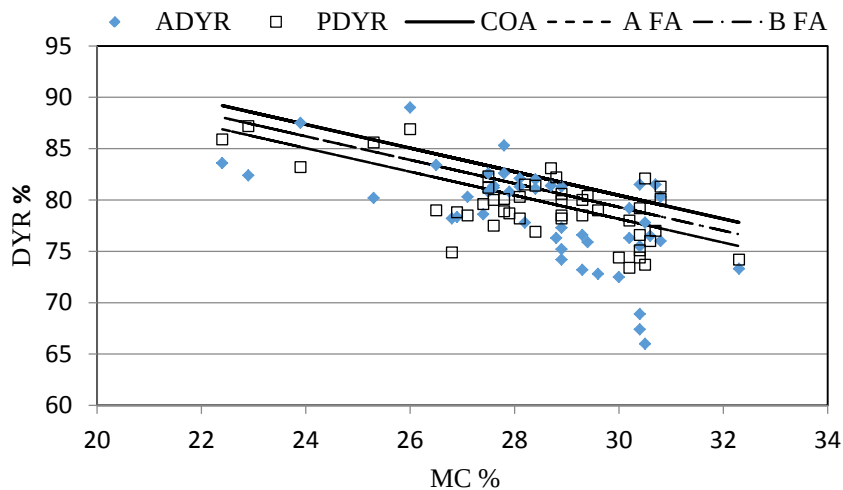


Figure 11. Verification of predicted DRY

The average estimated error is 3.26% and standard deviation is 2.02 % for predicted by using kernel husk ratio. Those currently applied reference standard are verified with actual DYR as shown in table 2. As comparison, DYR predicted by using kernel husk ratio causes less estimated error and deviation.

Table 2. Verification of predicted DYR with different model

	PDYR	COA	AFA	BFA
Average estimated error (%)	3.26	4.04	4.63	3.37
Standard deviation(%)	2.02	3.26	10.88	2.93

This model will be improved when the $f_1(\text{MC})$ and $f_2(\text{MC})$ for each rice species are more precisely derived. The precise $f_1(\text{MC})$ and $f_2(\text{MC})$ are base on sufficient kernel husk ratio experimental data for each rice species. The precise DYR for specific rice species will be predicted by using specific $f_1(\text{MC})$ and $f_2(\text{MC})$.

4. CONCLUSION

Objectively and accurately predict the DYR of farmers' wet paddy is very important. It maintains both benefit of rice buyers and farmers. Fair trading is helpful for encouraging farmers to actively cultivate rice field. Predicting DRY by using kernel husk ratio model developed in this study provides a more accurate rice trading standard.

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