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Isotherm Curve Model of Ciherang and Ciliwung Grain Varieties

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ABSTRACT

The advancement of post-harvest technology in Indonesia has provided accurate models for predicting grain behavior during storage. This study aimed to determine the best sorption isotherm model for describing the equilibrium moisture content of Ciherang and Ciliwung rice varieties. Rice samples were stored in 18 desiccators containing salt solutions with relative humidity (RH) levels of 10–80% at temperatures of 30, 40, and 50°C. Water content parameters were measured and three models (Oswin, Kuhn, and Chung-Pfost) were evaluated based on their coefficient of determination (R^2). The results indicated that the Chung-Pfost model yielded the highest R^2 values for both varieties. For Ciherang, the R^2 values were 0.921 (30°C), 0.938 (40°C), and 0.931 (50°C), while Ciliwung showed R^2 values of 0.894 (30°C), 0.915 (40°C), and 0.920 (50°C). The study concluded that the Chung-Pfost model effectively represents water absorption behavior in these rice varieties, with higher temperatures reducing the equilibrium moisture content.

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1. INTRODUCTION

In recent years, rice production in Indonesia has been quite high. In 2024, rice production was recorded as 53.14 million tons of milled grain (GKG) (Badan Pusat Statistik Indonesia, 2025). South Sulawesi Province, one of the national food barns, has recorded a production of 4.8 million tons of GKG (Badan Pusat Statistik Provinsi Sulawesi Selatan, 2024). In addition to the local varieties, Ciherang and Ciliwung are widely adopted by farmers (Taufik & Nurjanani, 2019). Abundant rice production requires proper post-harvest handling, which is currently supported by various technological advancements in the post-harvest sector. The application of modern technology in the post-harvest handling process, such as drying using machines or vacuum dryers, can help increase the efficiency and quality of the drying results. This has a positive impact on the durability and quality of agricultural products with increasing added value, supporting the development of the processing industry in Indonesia, especially in the agricultural sector (Syafrun, 2019).

The grain was separated from the stalk during the harvesting process. Naturally, grains require special attention to maintain their quality during storage. to reduce the moisture content to meet the quality standards. Several types of dryers can be used for grains, such as oven-drying and sun-drying. Ibrahim et al. (2024) used a Fluidized Bed Dryer, where an increase in the moisture content and drying rate affected the drying rate obtained in this study. The drying rate pattern decreased when the air velocity affected the drying rate, and the air velocity affected the cracked grain. process is very important because a high moisture content in the grain can increase the risk of damage during storage, such as the growth of fungi or other microorganisms that can damage the grain. By maintaining the moisture content within specified limits, the stored grain can maintain its quality and be safe from the risk of damage during the storage period.

Storage of harvested to maintain a certain quality. Suboptimal storage management can result in several problems, including the occurrence of respiration, which causes damage and decreases the quality of the harvested products. Respiration is a biological process in which plants or fruits produce energy by decomposing organic substances such as carbohydrates. Therefore, it is important to implement good storage practices, including monitoring the temperature and humidity, regulating ventilation, selecting appropriate storage containers, maintaining optimal conditions, and preventing excessive respiration (Megawati, 2022).

Proper postharvest handling during the drying and storage processes has positive impacts, such as maintaining quality and extending shelf life (Prasad, 2024). To achieve this, the characteristics of water activity (aw) must be understood through the sorption isotherm curve model. Using this information, we can predict the equilibrium moisture content to determine the optimal storage conditions and prevent damage due to excessive humidity. Additionally, the drying process can be optimized to achieve the desired moisture content with high efficiency, as it helps reduce the drying time and improve the quality of the results (Aviara, 2020)

The sorption isotherm curve is a graphical representation of the relationship between water activity (aw) or relative humidity (RH) in equilibrium with the water content per gram of a food material. This curve shows how the water content in the material changes along with variations in the relative humidity or the water activity of the surrounding environment. Using the sorption curve, we can understand how the material absorbs or releases water vapor in response to changes in environmental conditions such as changes in temperature or relative humidity. The difference in water content between the material and its surrounding environment causes the transfer of water vapor, which is reflected in the sorption curve. This sorption isotherm curve is very important in drying techniques because it can help predict the behavior of water absorption or the release of food vapor under various environmental conditions (Hudji et al., 2019).

The sorption isotherm curves for grains from the Ciherang and Ciliwung rice varieties have not yet been established. Therefore, this study aimed to determine an appropriate sorption isotherm curve model for these grain varieties that could later be used for optimal postharvest handling processes, particularly during drying and storage.

2. MATERIALS AND METHODS

2.1 Materials

The tools used in this study included storage boxes with adjustable temperature, ovens, desiccators containing salt solutions with varying relative humidity (RH) from 10-80%, aluminum foil containers, digital scales, cameras, and thermometers. The materials used were dry harvested rice of the Ciherang and Ciliwung varieties obtained from PT. Sang Hyang Seri Persero, Sidrap Branch.

2.2 Research Procedure

This research was experimentally carried out using a Randomized Design. This research method uses a salt solution with a Relative Humidity (RH) between 10-80%, as shown in Table 1.

Table 1. Salt solution used

Solution	Water activity	RH solution in desiccator (%)
NaOH	0.10	10
MgCl	0.33	33
K_2CO_3	0.40	40
$NaNO_2$	0.70	70
NaCl	0.75	75
KCl	0.80	80

Three different temperatures were used in this study: 30 °C (room temperature), 40 °C, and 50 °C. At room temperature, the material will be stored in the Processing Laboratory workspace of the Agricultural Engineering Study Program, while at temperatures of 40 and 50 °C, the material will be stored in a storage box, each temperature containing six desiccators and salt solution. The following is a sketch of the storage box used:

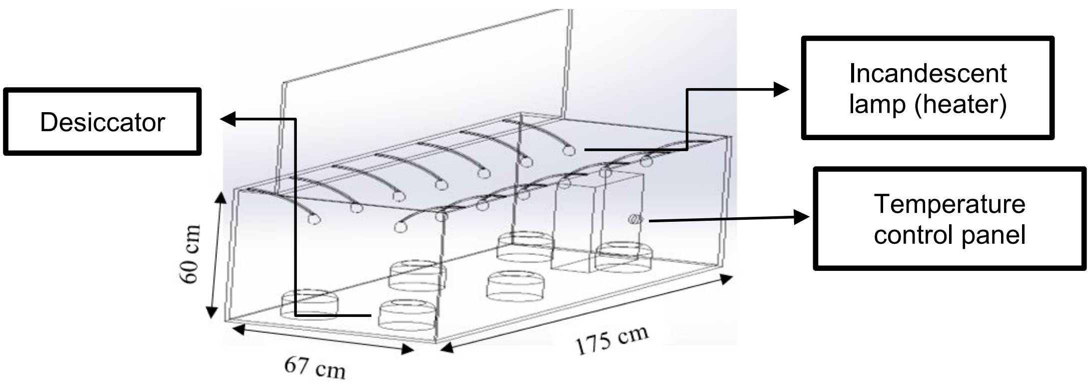

Figure 1. Storage box sketch.

2.3 Research Implementation

2.3.1 Determination of Water Content and Storage Stage

The dry harvested grain from the Ciherang and Ciliwung varieties was prepared to determine the initial moisture content of the grains. The grain samples of the Ciherang and Ciliwung varieties were placed in aluminum foil containers. The containers were weighed first, and then add a 10-gram sample and stored in a desiccator. The 36 samples in 18 desiccators were stored with relative humidity (RH) ranging from 10 to 80%, with each desiccator containing two grain samples. Subsequently, the samples were placed in storage boxes at 30 °C (room temperature), 40 °C, and 50 °C, with six arrangements at each temperature level. The samples were then removed from the desiccator and weighed. The moisture content of the samples was measured every two weeks using a digital scale. Once the material reached a constant weight, the samples were returned to the oven at 105 °C. The samples were then removed and weighed until the final solid mass weight was obtained, which was then used to calculate the wet basis moisture content (Kabb) and dry basis moisture content (Kabk).

2.4 Research Parameters

The research parameters were RH, storage room temperature, initial weight, and final weight of the sample at the end of the storage period.

2.4.1 Water content

By knowing the dry weight of the material after being oven-dried, Kabb and Kabk are calculated using the following formula (Mukmin et al., 2021)

a. Wet basis water content

$$Ka_{bb} = \frac{w_t - w_d}{w_t} \times 100\% \quad (1)$$

where Kabb is the moisture content of the dry basis (%), W_t is the initial weight (g), and W_d is the weight of the solids (g).

b. Dry basis water content

$$Ka_{bk} = \frac{w_t - w_d}{w_d} \times 100\% \quad (2)$$

where Kabk is the moisture content of the dry basis (%), W_t is the initial weight (g), and W_d is the weight of the solids (g).

2.4.2 Isothermic Model Testing

The isotherm model can be explained by plotting equilibrium moisture content data with experimental results of Relative Humidity (RH) or water activity (aw). Three isotherm curve models were tested: the Oswin, Khun, and Chung-Pfost models. These models were chosen because previous studies have used them and provided the best models for describing the isotherm sorption curves of paddy and rice (Luthra et al., 2020; Purohit & Rao, 2017).

a. Oswin

$$w = A\left[\frac{a_w}{(1-a_w)}\right]^B \quad (3)$$

Where W is dry basis moisture content (%), A is constant value, B is constant value, a_w is water activity.

b. Kuhn

$$w = \left(\frac{A}{\ln a_w}\right) + B \quad (4)$$

Where W is dry basis moisture content (%), A is constant value, B is constant value, a_w is water activity.

c. Chung and Pfost

$$w = A \ln\left[\frac{B}{(\ln a_w)}\right] \quad (5)$$

Where W is dry basis moisture content (%), A is constant value, B is constant value, a_w is water activity.

2.4.3 Determination of the Best Model

The constant values of A and B contained in the model were calculated using MS Excel Solver. The data that needed to be entered into MS Excel Solver included the value of W (equilibrium moisture content of the material) and the value of aw. The MS Excel Solver automatically determined the values of the constants A and B in the model. The RSQ function in Microsoft Excel was used to determine the R2 value for each model. The model with the highest R2 value was declared the best model.

3. RESULTS AND DISCUSSION

3.1. Effect of temperature on water content

The impact of decreasing the temperature can cause an increase in the water content of the grain under the same air humidity during the grain storage process, and vice versa.

Table 2. Average water content of the Ciherang grain variety before storage.

Solution	Kabb Ciherang (%)			Kabk Ciherang (%)		
	30 ºC	40 ºC	50 ºC	30 ºC	40 ºC	50 ºC
NaOH	11.430	11.252	11.486	12.905	12.679	12.977
MgCl	11.637	11.415	11.448	13.170	12.885	12.928
K_2CO_3	11.283	11.831	11.126	12.718	13.419	12.520
$NaNO_2$	11.599	11.127	11.252	13.121	12.520	12.679
Nacl	11.372	11.042	11.188	12.831	12.413	12.598
KCl	11.559	11.326	9.684	13.070	12.773	10.723
Average	11.480	11.332	11.0312	12.969	12.781	12.404
Grand Average		11.281			12.718	

Table 3. Average water content of the Ciliwung grain variety before storage.

Solution	Kabb Ciliwung (%)			kabk Ciliwung (%)		
	30 ºC	40 ºC	50 ºC	30 ºC	40 ºC	50 ºC
NaOH	10.913	10.360	10.912	12.250	11.557	12.249
MgCl	10.901	10.846	10.782	12.235	12.166	12.084
K_2CO_3	10.890	10.613	10.393	12.220	11.873	11.599
$NaNO_2$	10.768	10.404	10.329	12.067	11.612	11.519
Nacl	10.999	10.411	10.360	12.359	11.621	11.558
KCl	11.851	10.471	10.278	13.444	11.696	11.456
Average	11.054	10.518	10.509	12.429	11.754	11.744
Grand Average		10.693			11.976	

As shown in Table 2, the results of the water content measurements before storage showed that the grand average value of the initial water content of the Ciherang variety grain samples for Kabb was 11.281%, whereas Kabk was 12.718%. Table 3 showed the grand average of the Ciliwung variety grain samples for Kabb and Kabk were 10.693 and 11.976%, respectively. There was variation in the water content between samples, ranging from 11 to 12%. Sang Hyang Seri Persero Sidrap Branch, which is 12%.

The equilibrium moisture content is the condition under which a material or product reaches a stable water content level. This occurs when the rate of water absorption from the environment is balanced by the rate of water release into the environment. The following are the values from Tables 4 and 5 of the results of measuring the equilibrium moisture content on wet and dry bases:

Table 4. Measurements of wet basis equilibrium water content (Kabb) of the Ciherang grain variety.

Solution	RH (%)	Water Activity	Value KAbb Ciherang (%)		
			30 ºC	40 ºC	50 ºC
NaOH	10	0.10	3.686	2.924	2.343
MgCl	33	0.33	7.944	6.807	6.027
K_2C0_3	40	0.40	9.149	7.036	6.944
$NaNO_2$	70	0.70	11.118	9.172	8.586
NaCl	75	0.75	12.527	10.369	10.262
KCl	80	0.80	14.517	11.646	11.161

Table 5. Measurements of dry basis equilibrium water content (Kabk) of the Ciherang grain variety.

Solution	RH (%)	Water Activity	Value Kabk Ciherang (%)		
			30 ºC	40 ºC	50 ºC
NaOH	10	0.10	3.828	3.013	2.399
MgCl	33	0.33	8.629	7.305	6.413
K_2C0_3	40	0.40	10.070	7.569	7.462
$NaNO_2$	70	0.70	12.509	10.098	9.392
NaCl	75	0.75	14.321	11.569	11.436
KCl	80	0.80	16.982	13.181	12.563

Based on the data in Tables 4 and 5, the equilibrium values of Kabb and Kabk in the Ciherang variety paddy were obtained for each type of solution used with different RH factors and three storage temperatures, which produced varying water content. At 30 °C, there was an increase in water content, whereas at 40 and 50 °C, there was a decrease in water content. This trend was consistent across all types of solutions used. Higher storage temperatures were more effective in reducing the paddy water content. This indicates that, in addition to temperature, the type of storage solution significantly affects the water content of rice, and that higher storage temperatures result in lower water activity. This aligns with the statement by Selpiah et al. (2023), who stated that water activity (aw) is influenced by temperature; as storage air temperature increases, water activity decreases.

Table 6. Measurements of the wet basis equilibrium water content (Kabb) of the Ciliwung grain variety.

Solution	RH (%)	Water Activity	Value Kabb Ciliwung (%)		
			30 ºC	40 ºC	50 ºC
NaOH	10	0.10	3.914	3.481	2.593
MgCl	33	0.33	8.072	6.957	6.260
K_2C0_3	40	0.40	9.090	7.724	6.977
$NaNO_2$	70	0.70	10.837	9.146	8.491
NaCl	75	0.75	12.822	10.271	9.965
KCl	80	0.80	14.940	11.441	10.844

Table 7. Measurements of the dry basis equilibrium water content (Kabk) of the Ciliwung grain variety.

Solution	RH (%)	Water Activity	Value Kabk Ciliwung (%)		
			30 ºC	40 ºC	50 ºC
NaOH	10	0.10	4.074	3.607	2.662
MgCl	33	0.33	8.781	7.478	6.678
K_2C0_3	40	0.40	9.999	8.371	7.500
$NaNO_2$	70	0.70	12.154	10.066	9.279
NaCl	75	0.75	14.708	11.447	11.068
KCl	80	0.80	17.563	12.919	12.163

Based on Tables 6 and 7, the data on Kabb and Kabk (dry basis moisture content) in the Ciliwung grain variety were measured at three different temperatures (30, 40, and 50 °C) using several humidity control solutions with variations in relative humidity (RH) and water activity (aw). However, as shown in Table 7, the Kabk value was higher than the Kabb value because Kabk considered the initial water reduction. A higher water activity results in a higher equilibrium water content; however, when the temperature increases, the water content decreases. For each type of solution, the water content at 30 °C was higher than that at 40 and 50 °C.

3.2. Best Model Testing

In this test, three isothermic models has been tested to detect the best model, including Oswin, Khun and Chung-Pfost, so that the highest R^2 value declared as the best model.

Table 8. Testing of the best model for Ciherang variety grain

Models	Temperature (ºC)	A	B	R^2
	30	10.215	0.336	0.916
Oswin	40	8.141	0.331	0.930
	50	7.580	0.358	0.914
	30	5.574	15.883	0.827
Khun	40	4.411	12.608	0.858
	50	4.497	12.172	0.861
	30	8.630	-4.974	0.921
Chung-Pfost	40	6.877	-3.918	0.938
	50	6.334	-3.983	0.931

Table 9. Testing of the best model for Ciliwung variety grain

Models	Temperature (ºC)	A	B	R^2
	30	10.326	0.341	0.898
Oswin	40	8.472	0.287	0.911
	50	7.632	0.329	0.907
	30	5.584	16.048	0.763
Khun	40	4.031	12.472	0.879
	50	4.187	11.850	0.879
	30	8.751	-5.047	0.894
Chung-Pfost	40	7.256	-3.537	0.915
	50	6.430	-3.679	0.920

Based on the data obtained in Tables 8 and 9, Chung-Pfost was the best model, with R2 of Ciherang variety grain at a temperature of 30, 40, and 50 ºC were 0.921, 0.938 and 0.931, respectively. The R2 values of the Ciliwung variety grain at 30, 40, and 50 °C were 0.894, 0.915, and 0.920, respectively. Thus, the R2 value that obtains the highest value indicates that the model is the best and most appropriate model to describe the best water absorption. This is in accordance with the statement Adil et al. (2024) stated that to obtain information on isothermic sorption curves, there are several fairly good and fairly common equation models used in appropriate research, one of which is Chung-Pfost. This model provides a systematic and mathematical method for estimating water content based on temperature and water activity; therefore, it is useful in food technology and storage to determine optimal storage conditions for various food ingredients.

3.3 Observation vs Prediction Values in the Chung-Pfost Model

Figures 2, 3, and 4 show graphs of the relationship between Kabk and water activity in the Chung-Pfost model at temperatures of 30, 40, and 50 °C in the Ciherang variety grain, as follows:

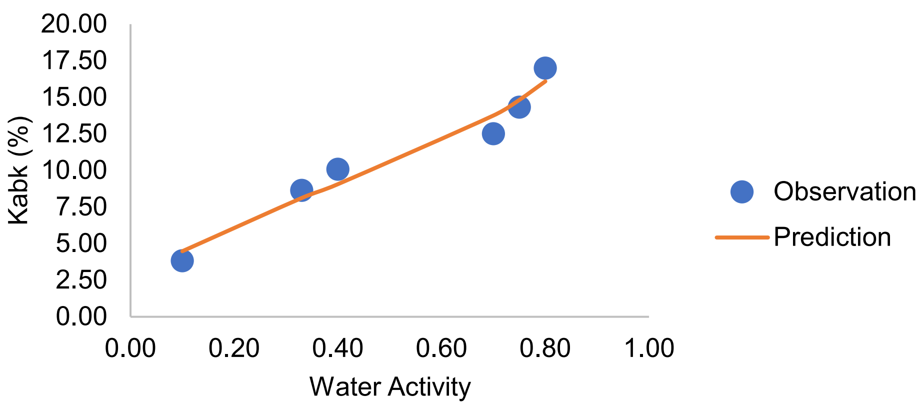

Figure 2. Graph of the relationship between Chung-Pfost model water activity at 30 ºC on Ciherang grain variety.

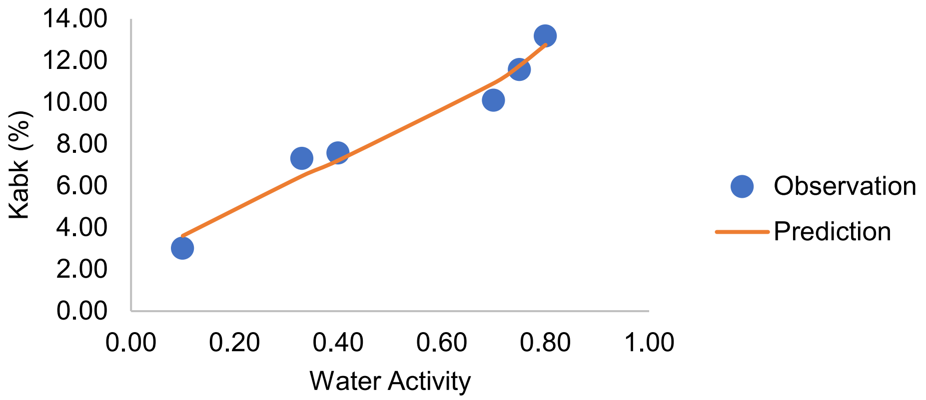

Figure 3. Graph of the relationship between Kabk and water activity in the Chung-Pfost model at 40 ºC in Ciherang grain variety.

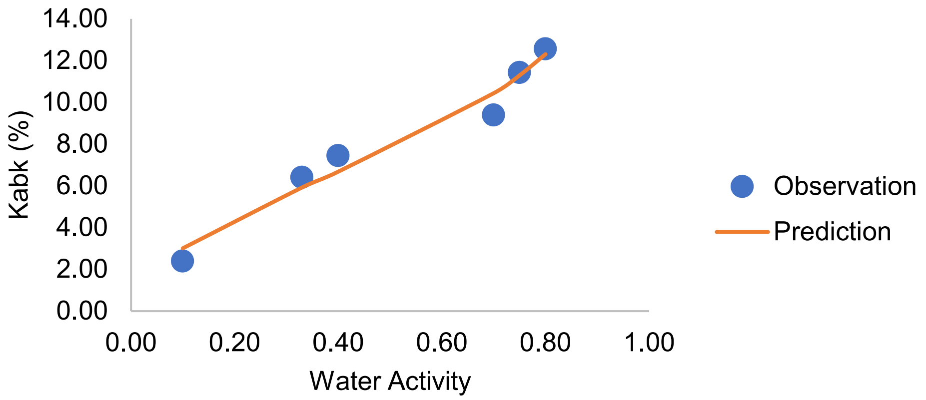

Figure 4. Graph of the relationship between Kabk and water activity in the Chung-Pfost model at 50 ºC temperature in Ciherang grain variety.

The graphs show the relationship between water activity (aw) and the equilibrium moisture content on a dry basis (Kabk) for Ciherang variety rice at three different temperatures: 30, 40, and 50 °C. At each temperature, the higher the water activity, the higher the equilibrium moisture content produced. This showed that rice absorbs more water when water activity in the surrounding environment increases. At 30 °C, the equilibrium moisture content reached its highest value, but at higher temperatures (40 and 50 °C), the equilibrium moisture content decreased. This indicates that higher temperatures can reduce the ability of rice to absorb water. Overall, the prediction model follows the trend of the observation data well, so that the Chung-Pfost model used is quite accurate in describing the isotherm curve.

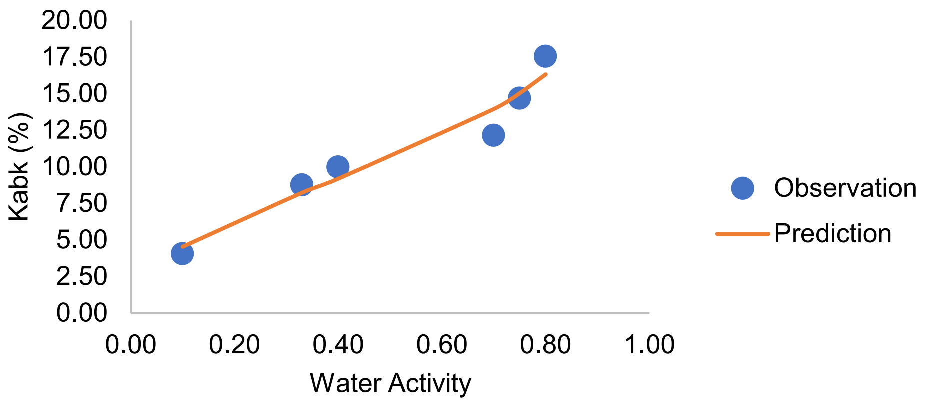

Figure 5. Graph of the relationship between Kabk and water activity in the Chung-Pfost model at 30 ºC in Ciliwung grain variety.

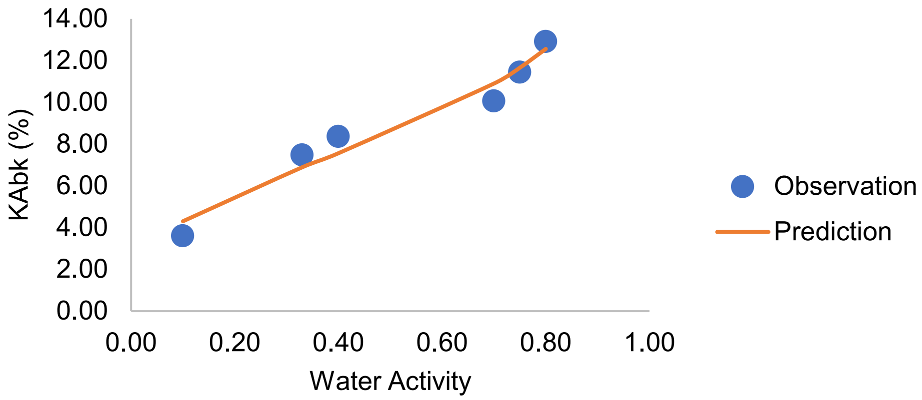

Figure 6. Graph of the Kabk relationship between water activity in the Chung-Pfost model at 40 ºC in Ciliwung grain variety.

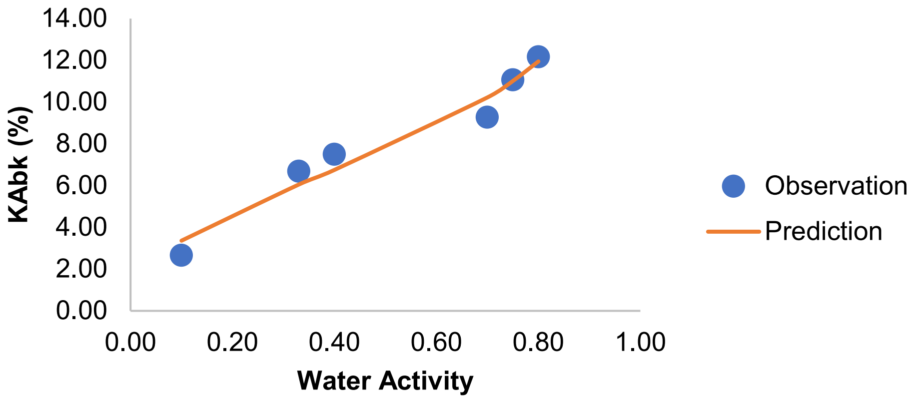

Figure 7. Graph of the relationship between Kabk and water activity in the Chung-Pfost model at 50 ºC in Ciliwung grain variety.

Based on Figures 5, 6, and 7, the Chung-Pfost model provided good and accurate results for describing water absorption. Based on R^2, the predictions produced by the Chung-Pfost model in Ciliwung grains were close to the observational data obtained from experiments at various temperatures (30, 40, and 50 °C). Other models, namely the Oswin and Khun models, have also been used to describe water absorption. In this analysis, the Chung-Pfost model had a higher R^2 value than the other two models. A higher R^2 value indicates that the Chung-Pfost model was better at explaining the relationship between water activity and water content in grains.

4. CONCLUSION

Based on the results of this research, it can be concluded that:

1. Among the three models tested (Oswin, Khun, and Chung-Pfost), the best model for estimating the behaviour of the equilibrium water content at temperatures of 30, 40, and 50 °C with an RH range of 10-80% was the Chung-Pfost model.
2. The Chung-Pfost model had the highest R^2 value for Ciherang variety grain at a temperature of 30 °C (0.921), 40 °C (0.938), and 50 °C (0.931), while for the Ciliwung variety at a temperature of 30 °C (0.894), 40 °C (0.915), and 50 °C (0.920).

REFERENCES

Adil, S., Muhidong, J., & Yumeina, D. (2024). Shelf-life prediction of sago flour (Metroxylon sagu Rottb) in polyethylene packaging. *BIO Web of Conferences*, *96*, 1–9. https://doi.org/10.1051/bioconf/20249602003

Aviara, N. (2020). *Moisture Sorption Isotherms and Isotherm Model Performance Evaluation for Food and Agricultural Products* (G. Z. Kyzas & N. Lazaridis (eds.)). IntechOpen. https://doi.org/10.5772/intechopen.87996

Badan Pusat Statistik Indonesia. (2025). *Pada 2024, luas panen padi mencapai sekitar 10,05 juta hektare dengan produksi padi sebanyak 53,14 juta ton gabah kering giling (GKG)*. Badan Pusat Statistik. https://www.bps.go.id/id/pressrelease/2025/02/03/2414/pada-2024--luas-panen-padi-mencapai-sekitar-10-

05-juta-hektare-dengan-produksi-padi-sebanyak-53-14-juta-ton-gabah-kering-giling--gkg--.html

Badan Pusat Statistik Provinsi Sulawesi Selatan. (2024). *Pada 2024, luas panen padi diperkirakan sebesar 0,95 juta hektare dengan produksi padi sekitar 4,80 juta ton gabah kering giling (GKG)*. Badan Pusat Statistik Provinsi Sulawesi Selatan. https://sulsel.bps.go.id/id/pressrelease/2024/11/01/851/pada-2024--luas-panen-padi-diperkirakan-sebesar-0-95-juta-hektare-dengan-produksi-padi-sekitar-4-80-juta-ton-gabah-kering-giling--gkg-.html

Hudji, M. R. D., Ahmad, L., & Antuli, Z. (2019). Analisis Umur Simpan Grits Bubur Jagung Instan Nikstamal Berdasarkan Kadar Air Awal Dan Kondisi Organoleptiknya. *Jambura Journal of Food Technology*, *1*(1), 68–78. https://ejurnal.ung.ac.id/index.php/jjft/article/view/7246

Ibrahim, A. M. F. Q., Salengke, S., Salim, I., & Hardinasinta, G. (2024). The Effect of Drying Air Velocity and Grain Mass on the Drying Rate of Inpari 42 Grain in a Fluidized Bed Dryer. *Salaga Journal*, *01*(1), 22–30. https://doi.org/10.70124/salaga.v1i1.1140

Luthra, K., Shafiekhani, S., Sadaka, S. S., & Atungulu, G. G. (2020). Determination of Moisture Sorption Isotherms of Rice and Husk Flour Composites. *Applied Engineering in Agriculture*, *36*(6), 859–867. https://doi.org/10.13031/aea.13822

Megawati. (2022). *Meaning of Grain Storage in Farmer Households (Case Study of Pattiro Village, Dua Boccoe District. Bone Regency, South Sulawesi)*. Hasanuddin University.

Mukmin, M., Muhidong, J., & Azis, A. (2021). The Evaluasi Kinerja Model Page Pada Pengeringan Lapisan Tipis Umbi Iles-Iles. *Jurnal Agritechno*, *14*(01), 18–25. https://doi.org/10.20956/at.v14i1.399

Prasad, N. R. (2024). Optimizing Post-Harvest Handling and Storage for Maximum Freshness of Horticultural Produce. *International Journal of Innovations in Agriculture Research*, *1*(2), 1–9.

Purohit, S. R., & Rao, P. S. (2017). Modelling and Analysis of Moisture Sorption Isotherm of Raw and Pregelatinized Rice Flour and Its Crystalline Status Prediction. *Food Analytical Methods*, *10*(6), 1914–1921. https://doi.org/10.1007/s12161-016-0745-6

Selpiah, S., Salengke, S., Salim, I., & Sapsal, M. T. (2023). Investigating the Influence of Blanching on the Drying Characteristics and Sorption Isotherm of Cherry Tomatoes (Lycopersicum Esculentum Var. Cerasiforme). *Salaga Journal*, *01*(1), 37–43. https://doi.org/10.70124/salaga.v1i1.1107

Syafrun, M. (2019). Analisis Perubahan Waktu Pengeringan Terhadap Variasi Tinggi Cerobong. *Jurnal Penelitian Enjiniring*, *22*(1), 1–8. https://doi.org/10.25042/jpe.052018.01

Taufik, M., & Nurjanani. (2019). Analisis Penyebaran Varietas Unggul Baru Padi Dalam Upaya Pencapaian Swasembada Berkelanjutan di Sulawesi Selatan. *Buletin Inovasi Teknologi Pertanian*, *16*, 65–73.