Drying Characteristics and Water-soluble Polysaccharides Evaluation of Kidney Shape *Ganoderma lucidum* Drying in Air Circulation System

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**Abstract.** In this project, drying kinetic of kidney shape *Ganoderma lucidum* fruiting body in air circulation system was studied. The drying experiments were conducted at 40, 50 and 60°C with air flow rate of 1.3 ms⁻¹. Samples were weighted periodically until no change in sample weight was recorded, and then the samples were analyzed for its moisture content. Four different thin-layer mathematical models (Newton, Page, Two-term, Midilli) were used and compare to evaluate the drying curves of kidney shape *G. lucidum*. The water-soluble polysaccharides were evaluated in order to find the best drying temperature condition. The results indicates that Midilli model was the fittest model to describe the characteristic of kidney shape *G. lucidum* in the air circulation drying system and temperature of 50°C was the best drying condition to get highest value of water-soluble polysaccharides.

1. **Introduction**

*Ganoderma lucidum* (Fr.) Karst (Polyporaceae), is a traditional Chinese mushroom which commonly known as Ling-Zhi in Chinese and Reishi in Japanese language. *G. lucidum* contains some bioactive ingredients, such as water soluble polysaccharides, triterpenoids, adenosine, and lectin. Previous studies have reported that water soluble polysaccharides in *Ganoderma* fruiting body have pharmacological effects as anti-tumor (through immunomodulation and anti-angiogenesis) and antioxidant [1].

As an agricultural commodity with high catabolism process, preservation of *G. lucidum* is a must. Drying is a common method to preserve *G. lucidum*. Several drying methods have been conducted to preserve *G. lucidum*, i.e., drying under direct sunlight with and without black fabric coverage [2], drying in the shades [2], drying using oven without circulation [2-4], and drying using oven with air circulation [2-6]. To find an appropriate drying method, some drying aspects such as drying time, energy consumption and minimum quality reduction need to be considered. Drying under direct sunlight is the easiest and cheapest drying method. However, this method has some drawbacks, such as unhygienic aspect and poor quality product [7]. Meanwhile, the drying process of *G. lucidum* under the shades or in direct sunlight with black fabric coverage needs more time to reach its equilibrium moisture content [2]. On the other hand, the drying process using oven with and without air circulation would reduce the drying time in which drying with air circulation will require a shorter time [2-4]. According to previous studies, it was found that oven drying with air circulation was a better method than others to preserve *G. lucidum* [2]. It was also found that drying *G. lucidum* in kidney shaped resulted a product with better quality than in sliced shape [2].

Optimization of drying methods including drying conditions, machine design, and product quality is important to minimize losses in the drying process. The evaluation of drying characteristics and determination of drying time are necessary for drying optimization [8]. Since the drying process of *G. lucidum* in oven with air circulation was found to be an appropriate method [2], it is important to evaluate its drying characteristics and the effect of temperature on
dried G. lucidum quality (in water-soluble polysaccharides content). Therefore, the aim of this study was to investigate the drying characteristics and water-soluble polysaccharides contents of G. lucidum dried by oven with air circulation.

2. Materials and methods
2.1. Materials
Kidney shape G. lucidum mature fruiting body was obtained from cultivation area in Gunungkidul, Yogyakarta, Indonesia. The fruiting body was swiped to remove dirt soon after being harvested, then packed in plastic bag in order to prevent evaporation of its volatile content. The fruiting body was taken from plastic bag soon before drying process.

2.2. Drying Procedure
Drying process was performed using air circulation drying technique at hot air temperatures of 40, 50, and 60°C with air velocity of 1.30 ms⁻¹ in a laboratory scale hot air circulation oven (Memmert, Germany). The oven was conditioned into selected temperature for about 30 minutes before the samples were placed in. The weight of samples were measured at initial condition, at 1 hour interval (at 1° until 12th hour), at 2 hour interval (after 12th until 24th hour), and 3 hour interval (after 24th hour). The drying process was stopped after the weight of samples reach constant. The data of sample weight was then converted into moisture content. Moisture content was stated on dry basis in unit of gram of water per gram of bone dry sample.

2.3. Mathematical Modelling
Drying curves of this experiment were fitted using non-linear least square regression solved by Microsoft Excel into four models of moisture ratio thin–layer drying. The chosen models were Newton, Page, Two-term, and Midilli (Table 1). The fitted curves were evaluated from the root mean square error (RMSE), coefficient of correlation (r) and reduced chi square (χ²). The better goodness of fitted curves were indicated with higher value of r and lower value of RMSE and χ².

| Model name     | Model equation                                      |
|----------------|----------------------------------------------------|
| Newton         | MR = exp(-kt)                                      |
| Page           | MR = exp(-ktⁿ)                                     |
| Two-term       | MR = a exp(-kt) + (a₁) exp(-k₁t)                   |
| Midilli        | MR = a exp(-ktⁿ) + a₁t                             |

2.4. Water-soluble Polysaccharides Content Evaluation
The evaluation of total water-soluble polysaccharides were based on the color of reaction of polysaccharides and their derivatives with phenol and concentrated sulfuric acid [10-12]. Total water-soluble polysaccharides were determined as total glucose as a results of polysaccharides hydrolysis. The sample of G. lucidum were ground into powder using a mechanical grinder. The polysaccharides were extracted in hot water at temperature of 95°C with the addition of hydrochloric acid 2 M to accelerate the extraction rate. The 1 mL of extract solution were pipetted and 0.5 mL of 5% phenol solution was added. The mixture was shaken for 2 min. The 2.5 mL of 98% v/v sulfuric acid was added into mixture and were shaken for another 5 min. The determination of total water-soluble polysaccharides concentration were conducted by measuring the absorbance of solution at wavelength 490 nm. Standard glucose (Sigma, Milwaukee, WI, USA) was used as standard solution and distilled water was used as blank solution for plotting the standard curve.
3. Results and discussions

3.1. Drying Rate

The average drying rate of kidney shape *Ganoderma lucidum* at air velocity 1.30 m s\(^{-1}\) were ranged from 0.0373-0.0536 g\(_{\text{water}}\) g\(_{\text{dry matter}}\)\(^{-1}\) h\(^{-1}\) at temperature 40, 50 and 60°C. The drying rate as function of time was shown in Figure 1. The higher drying rate was obtained at initial phase of drying and then decrease as drying time reach end phase. The results showed that there was no constant drying rate period. Falling rate drying period dominated this process. This result was in line with previous study in oyster mushroom drying conducted by Tulek [13].

The effect of moisture content and drying temperature on drying rate was shown in Figure 2. The highest drying rate was obtained at drying temperature of 60°C. Drying time was also decrease as drying temperature increased. As drying temperature increased, the temperature difference between *G. lucidum* body and air temperature was increasing. This phenomenon stimulate the increasing of evaporation driving force which further enhanced the drying rate [3]. Drying rate would reach its maximum as drying temperature increase [14]. Drying process reached minimum time (48 hours) at temperature of 50 and 60°C. Despite of same drying time, drying temperature of 60°C slightly had lower final moisture content (0.1247 g\(_{\text{water}}\) g\(_{\text{dry matter}}\)\(^{-1}\)) than at 50°C (0.1261 g\(_{\text{water}}\) g\(_{\text{dry matter}}\)\(^{-1}\)). Further increasing of drying temperature would decrease drying time. However further increasing of drying temperature was not recommended as the harmful effect on product quality [3,13]. Therefore in this study, drying process at temperature of 50°C obtained better result than 60°C.

Moisture content of *G. lucidum* also affected its drying rate. Drying rate decreased as moisture content of *G. lucidum* decreased. Similar results were obtained at each drying temperature, this phenomenon was in line with previous study in eggplant drying conducted by Ertekin and Yaldiz [14]. Drying rate reached its highest value at the start of drying process which moisture content was still high, and then decrease until its lowest value at the end of drying process which moisture content of samples reached equilibrium moisture content. At the start of drying process, the kidney shape *G. lucidum* still had large amount of moisture at its surface which accelerated drying rate. As time went on, moisture content in surface area decrease and then it triggered moisture in the interior part of the body to travel into surface area. At this stage, moisture required longer distance which it increased time required by moisture before being evaporated at the surface.

![Figure 1. Drying rate as function of time](image-url)
Figure 2. Effect of drying temperature and moisture content on drying rate

3.2. Evaluation of thin layer mathematical models

The correlation between moisture ratio (MR) and drying time (t) of kidney shape *G. lucidum* was shown in Figure 3. These correlations then were fitted into four thin layer drying models (Newton, Page, Two-term, Midilli). The evaluation of each model were shown in Table 2. The values of $r$ for all models were ranged from 9.9967 x 10^{-1} to 9.9996 x 10^{-1}. Meanwhile RMSE were varied from 1.9161 x 10^{-4} to 1.1597 x 10^{-2} and $\chi^2$ from 2.1959 x 10^{-9} to 2.0008 x 10^{-6}. The results showed that Midilli model was found the most fitted model. It has highest $r$ value and lowest value of RMSE and $\chi^2$. This results were in line with drying of *Ganoderma tsugae* conducted by Chin et al. [3]. Similar results was also found in previous results at drying of some agricultural products [13-15].

Table 2. Evaluation of Thin-layer Drying Models

| Drying Condition | Model  | Model Parameters | R       | RMSE     | $\chi^2$   |
|------------------|--------|------------------|---------|----------|------------|
| 40°C             | Newton | $k = 0.0611$     | 9.9967E-01 | 1.3886E-02 | 2.0008E-06 |
|                  | Page   | $k = 0.0487$, $n = 1.0829$ | 9.9973E-01 | 1.5197E-02 | 1.4247E-07 |
|                  | Two-term | $a = 4.1761$, $k = 0.0850$, $a_1 = -3.1781$, $k_1 = 0.0951$ | 9.9978E-01 | 9.8347E-03 | 9.4962E-08 |
|                  | Midilli | $a = 1.0006$, $k = 0.0528$, $n = 1.0424$, $a_1 = -0.0004$ | 9.9996E-01 | 1.9161E-04 | 2.1959E-09 |
| 50°C             | Newton | $k = 0.0938$     | 9.9972E-01 | 2.2044E-03 | 6.6791E-07 |
|                  | Page   | $k = 0.0791$, $n = 1.0721$ | 9.9983E-01 | 4.5753E-04 | 3.0199E-08 |
|                  | Two-term | $a = 1.9716$, $k = 0.1170$, $a_1 = -0.9620$, $k_1 = 0.1483$ | 9.9979E-01 | 1.7989E-03 | 4.8842E-08 |
|                  | Midilli | $a = 1.0062$, $k = 0.1216$, $n = 1.0539$, $a_1 = -0.0001$ | 9.9984E-01 | 1.7143E-03 | 2.1714E-08 |
| 60°C             | Newton | $k = 0.1322$     | 9.9978E-01 | 1.9642E-03 | 2.4667E-07 |
|                  | Page   | $k = 0.1168$, $n = 1.0592$ | 9.9986E-01 | 1.9807E-03 | 1.9175E-08 |
|                  | Two-term | $a = 1.0452$, $k = 0.1388$, $a_1 = -0.0452$, $k_1 = 2.0649$ | 9.9995E-01 | 4.1431E-03 | 3.3257E-09 |
|                  | Midilli | $a = 1.0089$, $k = 0.1216$, $n = 1.0440$, $a_1 = 0.0000$ | 9.9987E-01 | 2.1362E-03 | 1.0750E-08 |
3.3. Evaluation of Water-soluble Polysaccharides

The results of water-soluble polysaccharides content at different drying temperature were shown in Table 3. The worst results was found at drying temperature of 40°C which had lowest water-soluble polysaccharides retention. This result was possibly affected by the long drying time which caused *G. lucidum* exposed with hot air longer than other condition and reduced more polysaccharides content. The highest water-soluble polysaccharides retention was found at drying temperature of 50°C and shortest drying time were found at temperature 50 and 60°C. Therefore the drying temperature of 50°C was the best drying condition of kidney shape *G. lucidum*.

**Table 3.** The water-soluble polysaccharides of *G. lucidum* at different drying temperature

| Drying temperature | Total drying time (h) | Water-soluble polysaccharides (% w/w DW) | Retention (%) |
|---------------------|-----------------------|------------------------------------------|---------------|
| Fresh sample        | –                     | 130.79 ± 0.52                            | 100           |
| 40°C                | 60                    | 95.97 ± 0.71                             | 73.38         |
| 50°C                | 48                    | 124.01 ± 0.59                            | 94.82         |
| 60°C                | 48                    | 107.06 ± 0.72                            | 81.86         |

Each value is expressed as mean ± standard deviation (n= 9)

4. Conclusion

Drying process of kidney shape *Ganoderma lucidum* in air circulation drying system has been conducted. The drying rate was affected by drying temperature. The drying rate increased as drying temperature increase. Kinetic data of this drying process were collected and then evaluated in four well-known thin layer drying model in order to determine the best fitted model. The Midilli model was found as the best model to interprete drying characteristic of kidney shape *Ganoderma lucidum*. The best drying condition in this study was found at temperature of 50°C which had highest water-soluble polysaccharides content.

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