Physical and chemical characteristics of oyster mushrooms flour (Pleurotus ostreatus) using rotary vacuum dryer type batch

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Abstract. Harvested oyster mushrooms with high moisture content are easily damaged by enzyme and microorganism. Drying the mushroom into flour using sun drying or artificial dryer can extend the storage time. Rotary vacuum dryer, an artificial dryer, works on vacuum conditions with automatic material reversal technology. The vacuum conditions can reduce boiling point and minimize the nutrition damage. The purpose of this study is to compare the physical and chemical characteristics of oyster mushroom flour produced by rotary vacuum dryer and sun drying. Rotary vacuum dryer works at 60°C for 8 hours while sun drying requires 6 hours for 4 days. Next, 80 mesh hammer mill is used to grind the dried oyster mushroom. The process includes physical and chemical test analysis with the statistical results followed by t test to understand the two treatments average differences. The results show that all chemical characteristics: moisture content, protein, ash, dietary fiber, produced by rotary vacuum dryer is not significantly different from sun drying. The physical characteristics: color (lightness) and the water activity are not significantly different. But the water holding capacity and bulk density are significantly different.

1. Introduction
Oyster mushroom (Pleurotus ostreatus) are ones of the agricultural products developed in Indonesia. In 2014, it resulted in 37,410 tons from 586 hectares cultivated land [1]. Oyster mushrooms and straw mushrooms are in demand by the public because of their attractive appearance, delicious taste, rich nutrients and low fat which makes them good for consumption.

The high moisture content of 86.6-90% when harvested causes easy damage to the mushrooms. The higher the moisture content in food, the faster it could be impaired due to microorganism activity. Hence, it is necessary to take action to extend the shelf life of oyster mushrooms after being harvested by reproducing them into flour.

One important step in producing mushroom flour is drying. This stage is meant to reduce the moisture content in the material so that the growth of microbes and undesirable reactions can be impeded. Normal drying which is usually carried out is by exposing it the sun. This method is considered less effective because of its dependency on weather conditions and also the resulting product is less hygienic because of its possible contamination to dust or other contaminants from the air. Accordingly, it is necessary to do a more effective drying technique which is with a dryer.

In [2] has designed and invented a rotary vacuum dryer which works in vacuum conditions and the reversal of materials during drying occurs automatically because of the rotation of drying drum which is equipped with a material carrier flight while rotating from below carrying material. Then when it is
above, the material will be poured out. Drying under vacuum condition leads to the reduction of water boiling point so that the water contained in the material can evaporate below 100°C. By the decrease in the boiling point, the nutritional content such as carbohydrates, fiber, protein, and vitamins in oyster mushrooms are not damaged. With that being said, it is hoped that the nutritional content of mushroom flour can still be maintained. To verify this estimation, it is necessary to know the characteristics of oyster mushroom flour resulted by using a rotary vacuum dryer to be compared with oyster mushroom flour resulted by using sun drying.

2. Materials and methods

2.1. Material and tool

The tools used to produce mushroom flour are rotary vacuum drayer type batch, analytical scales basin, digital scales, pans, knives, cutting board, moisture meters, stationery, destruction units, distillation units, soxhlet furnaces, waterbath, ovens, burettes, Colour reader.

The main ingredients used are oyster mushrooms obtained from farmers, \( \text{H}_2\text{SO}_4 \), \( \text{Na}_2\text{SO}_4 \text{HgO} \), \( \text{NaOH} \), \( \text{Na}_2\text{S}_2\text{O}_3 \), \( \text{HCl} \), dry paper, distilled water, Luff school solution, methanol, protease, aluminum foil and alcohol.

2.2. Methodology

This research begins with sorting fresh oyster mushrooms, weighing to determine oyster mushrooms, cutting oyster mushrooms, and drying which is in form of two different treatments namely drying to the sun for 24 hours and drying by a rotary vacuum dryer at -76 cmHg and temperature of 60°C for 8 hours of drying time. The dried mushrooms are rolled by a hammer mill with 60 mesh sieves. The parameters to determine the quality of oyster mushroom flour include physical properties such as the degree of white using a color reader [3] [4], water holding capacity (Anderson Centrifugation Method, quoted by [5], water activity (aw) and bulk density [6] while chemical properties include the moisture content [7], ash content [7], total protein content of the Kjeldhal method [8] and dietary fiber [9]. Student's t test is applied to compare the average values of all quality parameters between oyster mushroom flour produced by sun drying and rotary vacuum dryer.

3. Results and discussion

3.1. The analysis result of physical characteristics of oyster mushroom flour dried by rotary vacuum dryer and sun drying

The analysis result of physical characteristics of oyster mushroom flour dried by rotary vacuum dryer and sun drying can be seen in table 1.

| No | Physical Characteristics | Sun drying | Rotary vacuum dryer | Note     |
|----|--------------------------|------------|---------------------|----------|
| 1  | Colour/Lightness L        | 60.71      | 63.05               | ns       |
| 2  | Water holding capacity (%)| 433.8119   | 213.5306            | *        |
| 3  | Water activity (%)        | 0.390      | 0.350               | ns       |
| 4  | Bulk density (g/ml)       | 1.9263     | 3.4985              | *        |

Note: ns = not significantly different
* = significantly different

3.1.1. Color. Color is one of most important parameters to determine the quality of flour products. In general, consumers will prefer flour with a high degree of white. The measurement of the degree of white is done by using a color-reader. With this tool the white degree of flour will be read quantitatively as the value of \( L \). The \( L \) value has a range of scores from 0-100. The brighter the flour measured, the \( L \) value will get closer to 100 and vice versa. Based on the analysis of the difference in
the two averages using t test, it showed that the lightness (L) of the oyster mushroom flour which was dried with a rotary vacuum dryer 60.71 was not significantly different from the lightness L of the oyster mushroom flour dried with sun drying 63.05 (see table 1). This is allegedly because the rotary vacuum dryer uses a temperature of 60°C but the drying time is quite short which is 8 hours. While for the sun drying method uses a temperature of ± 32°C, 6 hours per day for 4 days or in total, the drying time is 24 hours so that both methods cause a slight browning reaction. The flour colour resulted from rotary vacuum dryer and sun drying can be seen in fig 1.

![Figure 1. The flour colour resulted from rotary vacuum dryer and sun drying](image)

3.1.2. Water holding capacity. [10] defines the water holding capacity (WHC) of water as the ability of materials to hold the amount of water without any external force except the force of gravity and atmospheric pressure. The results of the test of the water holding capacity of oyster mushroom flour by using sun drying and using a rotary vacuum dryer can be seen in fig 2.

The results of the measurement of the ability of oyster mushroom flour dried by rotary vacuum dryer in binding water is 213.5306% while by sun drying amounted to 433.8119%. Based on the statistical analysis of the comparison of the average water holding capacity of the two drying methods, it is significantly different because through drying by a rotary dryer temperature of 60°C causes cell elasticity to decrease so that the absorbing ability of flour to water is reduced. The better the level of cell wall elasticity, the better the absorption of water and the better the ability to absorb water [11].

![Figure 2. The flour water holding capacity resulted from rotary vacuum dryer and sun drying](image)
3.1.3. Water activity. The water activity is related to the moisture content in materials towards storability [12]. Storability and quality of the material are affected by fluctuated rate of water activity in the material. The smaller the value of water activity on the material the longer the shelf life of the material, while the greater the water activity the smaller storability of the material will be.

The heating temperatures and high electrical conductivity cause low water activity [13]. The value of oyster mushroom water activity resulted from drying by a rotary vacuum dryer is 0.350% while drying by sun drying is 0.390%. Based on the statistical analysis of the comparison of the average water activity of oyster mushroom flour dried by sun drying and rotary vacuum dryer machine is not significantly different. This is because the final moisture content in the oyster mushroom flour resulted from both methods are also not significantly different. The flour water activity resulted from rotary vacuum dryer and sun drying can be seen in fig. 3.

![Figure 3](image-url)

**Figure 3.** The flour water activity resulted from rotary vacuum dryer and sun drying

3.1.4. Bulk density. Bulk density is the mass of particles which occupy a certain volume or space. The value of the bulk density of oyster mushroom flour dried by sun was 1.9263% while the drying by a rotary vacuum dryer was 3.4985% (can be seen in fig 4).

The results of the statistical analysis of the average test showed that the bulk density of the oyster mushroom flour resulted from rotary vacuum dryer was higher and significantly different from oyster mushroom flour resulted from sun drying. This was due to the rotary dryer using 60 °C so that the drying process could be faster which caused contraction stress between oyster mushroom structures during the drying process was also faster and can affect changes in shape and texture due to the contraction stress between oyster mushroom structures, so that porous structures are damaged and constricted. As a result of shrinkage, the flour produced has a fairly large bulk density.

3.2. The analysis result of chemical characteristics of oyster mushroom flour dried by rotary vacuum dryer and sun drying.

The analysis result of chemical characteristics of oyster mushroom flour dried by rotary vacuum dryer and sun drying can be seen in table 2

| No | Chemical Characteristics     | Sun drying | Rotary vacuum dryer | Note |
|----|------------------------------|------------|---------------------|------|
| 1  | Moisture content (%)         | 10,04      | 10,99               | ns   |
| 2  | Ash content (%)              | 4,79       | 4,81                | ns   |
| 3  | Protein content (%)          | 28,33      | 27,44               | ns   |
| 4  | Dietary fiber content (%)    | 12,18      | 11,79               | ns   |

Note : ns = insignificantly different
3.2.1. Moisture content. The moisture content contained in a material can affect the quality and durability of the material. Drying is aimed to reduce the moisture content to a certain extent so that it can inhibit the growth of microbes.

The moisture content of fresh oyster mushroom ranges from 90 to 95%. The moisture content of oyster mushroom flour produced by rotary vacuum dryer is 10.99% while the one dried by sun drying is 10.04% (fig 5). The results of the statistical analysis of the comparison t test showed that the average moisture content of oyster mushroom flour resulted from a batch type rotary vacuum dryer with sun drying was not significantly different. This is because the temperature of the rotary vacuum dryer used is 60 °C for 8 hours, while for sun drying temperature used is ± 32°C for 6 hours for 4 days which produces the same amount of evaporated water. The flour moisture content resulted from rotary vacuum dryer and sun drying can be seen in fig 5.

![Figure 4. The flour bulk density resulted from rotary vacuum dryer and sun drying](image1)

![Figure 5. The flour moisture content resulted from rotary vacuum dryer and sun drying](image2)

3.2.2. Ash content. The Ash content can indicate the total of minerals contained in food. It is assumed that the lower the ash content of white oyster mushroom flour, the better the quality. The ash content of oyster mushroom flour dried by rotary vacuum dryer is 4.81% while the one dried by the sun is
4.97% (fig 6). Based on statistical analysis comparison of the average ash content using the t test, it showed no significant different results. This is because the temperature of the rotary vacuum dryer used is 60°C for 8 hours, while temperature of sun drying is ± 32°C for 6 hours during 4 days which results in the same amount of evaporated water ensuing the same ash content. It is also added that the moisture content of the flour produced from the two drying methods is also not significantly different. The Ash content depends on the type of material, ashing method, time and temperature used in drying process [8]. In addition, [14] also states that the proportion of ash content in a food item is influenced by species, soil nutrient conditions, plant maturity, climate, growing areas, and planting treatment.

![Figure 6. The flour ash content resulted from rotary vacuum dryer and sun drying](image)

### 3.2.3. Protein content

In general, protein level contained in food can determine the quality of the food itself [15]. The higher the protein content of food, the better the quality of the material. The average protein content of oyster mushroom flour dried by rotary vacuum dryer was 27.44% while the one dried by sun drying was 28.33%. To be compared to research done by [16] which produced the best white oyster mushroom flour protein content of 16.95%, it can be concluded that the protein content produced in this study was higher. Based on statistical analysis of the comparison of the average protein content through t test, it shows that $t_{\text{stat}}$ is smaller than $t_{\text{critical}}$ so that $H_0$ is accepted, which means drying by sun drying or rotary vacuum dryer is not significantly different. The heating process can change the structure of proteins contained in the material so that it affects the levels of protein in the material. The higher the drying temperature, the greater the amino acids making up the protein in the material is damaged so that the protein level can be shrunk. The flour protein content resulted from rotary vacuum dryer and sun drying can be seen in fig 7.
3.2.4. Dietary fiber content. The dietary fiber contained in the oyster mushroom flour dried by a rotary vacuum dryer is 11.79% while the one dried by sun drying is 12.18% (fig 8). Based on the results of the statistical analysis of the two drying methods, it concludes that an average level of food fiber is not significantly different. [17] explains that the high fiber food has at least 6% dietary fiber, thus oyster mushroom flour is classified as a high-fiber food group.

4. Conclusion
The results show that all chemical characteristics: moisture content, protein, ash, dietary fiber produced by rotary vacuum dryer is not significantly different from sun drying. The physical characteristics: color or lightness and the water activity are not significantly different but the water holding capacity and bulk density are significantly different. It is necessary to test the performance of rotary vacuum dryer and the quality of oyster mushroom flour on a drying temperature (30 ± 2 °C).

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