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Effects of intermittent drying on moisture content, energy efficiency, and chlorophyll content of *Moringa Oleifera* leaves

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Abstract

Moringa Oleifera leaves are known to contain many nutrients such as fat, protein, carbohydrates, minerals, amino acids and vitamins. The high nutritional content of *Moringa Oleifera* leaves must be maintained so that they are not easily damaged. One way to maintain the nutrition of *Moringa Oleifera* leaves is by drying. This research uses a combination of intermittent drying and dehumidification using zeolite on *Moringa Oleifera* leaves to overcome the problem of weather dependence in solar research and high drying energy in convective drying. The research was carried out at drying operating temperatures of 40°C, 60°C, and 80°C. Drying was carried out for 120 minutes. Drying is carried out continuously and intermittently using zeolite dehumidification. Next, moisture content, energy efficiency and chlorophyll content are calculated. The results show that the intermittent drying method combined with zeolite can be used as an alternative drying method. This is because this method is proven to have low water content, high energy efficiency, and does not damage the contents, for example chlorophyll.

Keywords: Dehumidification, drying, energy efficiency, intermittent, *Moringa Oleifera* leaves.

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1. Introduction

Moringa Oleifera, sometimes known as the "drumstick tree" or "horseradish tree," is a multipurpose and highly nutritious plant that has received worldwide attention for its ability to fight malnutrition, assist sustainable agriculture, and provide a variety of health benefits [1–3]. Its leaves are high in critical nutrients like as vitamins, minerals, and antioxidants [4, 5]. Moringa Oleifera leaves have acquired reputation as a superfood and a helpful dietary supplement in recent years [4]**.** *Moringa Oleifera* leaves drying is an important step in keeping their nutritional value and prolonging their shelf life. Proper drying processes not only preserve essential compounds but also limit the risk of deterioration and microbiological contamination [6]. *Moringa Oleifera* leaves have been dried using a variety of ways, including sun drying, fluidized bed drying [7], and greenhouse drying [8] . However, traditional drying processes have drawbacks such as energy consumption, time requirements, and the potential destruction of beneficial components such as chlorophyll. The effects of intermittent drying as an environmentally friendly option for retaining the drying properties and chlorophyll content of *Moringa Oleifera* leaves are investigated in this study. Intermittent drying, which involves alternating between drying and resting phases, has the potential to improve the overall quality of dried *Moringa Oleifera* leaves [9]. It expects to gain insight into drying process improvement and the retention of chlorophyll, a critical bioactive component with diverse health-promoting qualities, by exploring the impact of this unique drying approach. This study examined the effects of intermittent drying on *Moringa Oleifera* leaves, including moisture content, energy efficiency and chlorophyll content. As the comparison, the drying process was also conducted in conventional continous drying method. It expects the findings of this study will help to create new drying procedures that will help preserve the nutritional integrity of *Moringa Oleifera* leaves, allowing them to be used more widely in food, medicinal, and nutraceutical applications.

2. Materials and methods

2.1 Materials

Moringa Oleifera leaves for the drying process were harvested in August 2023 from Banyumanik District in Semarang, Central Java, Indonesia. The *Moringa Oleifera* leaves are sorted to get a uniform size and color. Then, the initial moisture content of the *Moringa Oleifera* leaves samples was determined using gravimetry.

2.2 Drying Process

The drying process of *Moringa Oleifera* leaves was carried out in a food dehydrator. The drying scheme and equipment were depicted in Figure 1. The ambient air with a relative humidity of 80% was used for drying process which was then dehumidified using a zeolite adsorbent. Then the drying air was heated to a certain air temperature. The drying process was conduted using continous and intermittent drying method. The *Moringa Oleifera* leaves to be dried were weighed as much as 250 grams. Then the *Moringa Oleifera* leaves was arranged on an aluminum tray and put into a food dehydrator at a predetermined temperature (40°C, 60°C, and 80°C). While fo the intermittent drying, the drying process was carried out for 20 minutes. After drying for 20 minutes, the sample is removed from the dryer and put into a desiccator at room temperature for 10 minutes. This step was repeated throughout the drying process. Both continuous and intermittent method, the drying process is carried out for 120 minutes and every 10 minutes the sample is checked to determine the moisture content.

2.3 Energy Efficiency

Energy efficiency in drying *Moringa Oleifera* leaves can be determined using the following equation [10] .

$$\boldsymbol{\eta} = \left(\frac{\boldsymbol{Q_{evap}}}{\boldsymbol{Q_{dryer}}}\right)\mathbf{100}\% \qquad (\mathbf{1})$$

$$\boldsymbol{\eta} = \left(\frac{\boldsymbol{M_d}(\boldsymbol{q_{w,0}} - \boldsymbol{q_{w,f}})\boldsymbol{\lambda}}{\boldsymbol{FC_P}(\boldsymbol{T_i} - \boldsymbol{T_o})\boldsymbol{t_d}}\right)\mathbf{100}\% \qquad (\mathbf{2})$$

Where $\boldsymbol{\eta}$ was Energy efficiency (%), $\boldsymbol{Q_{evap}}$ was Total energy required to evaporate water content (kj/hour), $\boldsymbol{Q_{dryer}}$ was Total energy required for the system from the dryer (kj/hour), Md was Mass of product entering the dryer (kg), $\boldsymbol{q_{w,0}}$ was Initial moisture content (dry basis), $\boldsymbol{q_{w,f}}$ was moisture content at t time (dry basis), $\boldsymbol{\lambda}$ was atent heat (kj/kg), F was Air flow rate (Kg/hour), and $\boldsymbol{T_i}$ and $\boldsymbol{T_o}$ were Inlet and outlet temperatures to the dryer (°C).

2.4 Chlorophyll content measurement

The measurement of total chlorophyll in this study uses a spectrophotometric method with the principle of absorbing the color spectrum in the blue area and the color spectrum in the red area which is then transmitted and reflected as green [11]. The absorbance value of these two wavelengths will later be calculated as total chlorophyll, where the color intensity of the solution is directly proportional to the concentration of the solution. The chlorophyll content, Cc (in mg/L), can be calculated as follows:

$$\boldsymbol{Cc} = (\mathbf{20} \times \boldsymbol{Abs}\mathbf{664}) - (\mathbf{6.1} \times \boldsymbol{Abs}\mathbf{647}) \quad (\mathbf{3})$$

3. Results and Discussions

3.1. Moisture Content Observation

This research aimed to observe the effect of intermittent drying and continuous drying techniques on moisture content. The moisture content of drying *Moringa Oleifera* leaves was shown in Figure 2 with drying carried out every 120 minutes with weighing intervals every 10 minutes. Drying was carried out at temperatures of 40°C, 60°C, and 80°C. The experimental results showed a decreasing trend in moisture content during the drying time. The final moisture content was ranging from 4.34-12.49%. This phenomenon occurs for all temperature variables, whether intermittent or continuous. This is because the longer the drying time, the more water content is evaporated on the surface of the *Moringa Oleifera* leaves into the environment [12]. In the higher drying temperature resulted the lower moisture content. For example, the final moisture content in drying at 80°C was 1.34-1.76 times lower than at temperature 40°C. In higher drying temperature. Increasing the drying temperature resulted the decreasing of air relative humidity. Since there will be less humidity in the air, there will be more of a driving force for drying, as seen by a decrease in water content and a quicker drying time [13]. Additionally, the tendency for the decrease in moisture content to occur more effectively in intermittent drying compared to continuous drying. This is because during the tempering process, free water in the middle of the *Moringa Oleifera* leaves diffuses to the surface which will diffuse into the environment when the drying process continues [14]. Therefore, the process of releasing or evaporating free water in *Moringa Oleifera* leaves using the intermittent method is faster than the continuous method.

3.2 Energy Efficiency Analysis

The energy efficiency during the drying process at various drying condition was presented in the Figure 3. The results showed that the energy efficiency in intermittent drying was higher than the continuous drying at the same temperature. The drying efficiency of the continuous method was ranging from 16,85% - 76,83%. Meanwhile, the drying efficiency using the intermittent method reached 18,75% - 96,69%. The heat and mass transport of the product's centre to its surface during the tempering phase can helps the product's temperature and moisture content become more uniform. The water and heat gradients produced during the drying phase often diminish during the tempering phase [9]. As the result, the drying process proceeds more quickly, which lowers energy usage and enhance the drying efficiency. Moreover, in higher drying temperature, the air relative humidity was low. The driving force for drying is increased, the energy required is reduced, and it is also possible to reduce the drying temperature [15-17]. As a result, the energy efficiency was enhanced. The energy efficiency obtained ffrom this stury was higher than another *Moringa Oleifera* leaves drying such as greenhouse dryer [8] and tray dryer [15].

3.3 Chlorophyll content

Chlorophyll is a green pigment found in chloroplasts as well as xanthophyll and carotene pigments [16]. In green plants, most chlorophyll is found in two forms, chlorophyll a is less polar and bluish green in color and chlorophyll b and c are polar and greenish yellow in color. Chlorophyll has antioxidative properties, because chlorophyll can capture DPPH radicals due to the porphyrin structure of chlorophyll [17]. Chlorophyll in leaves is bound to protein. In the heating process, proteins are denatured, and chlorophyll is released [18].

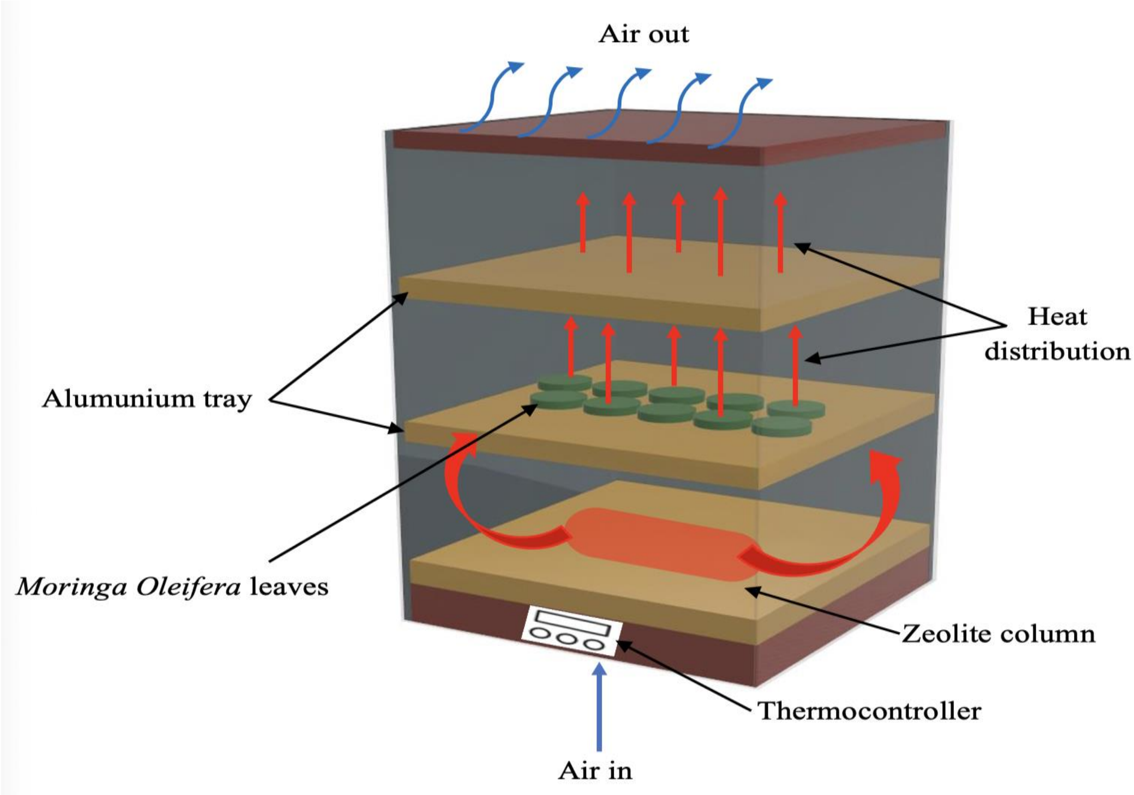

Figure 1: Schematic diagram of *Moringa Oleifera* leaves drying

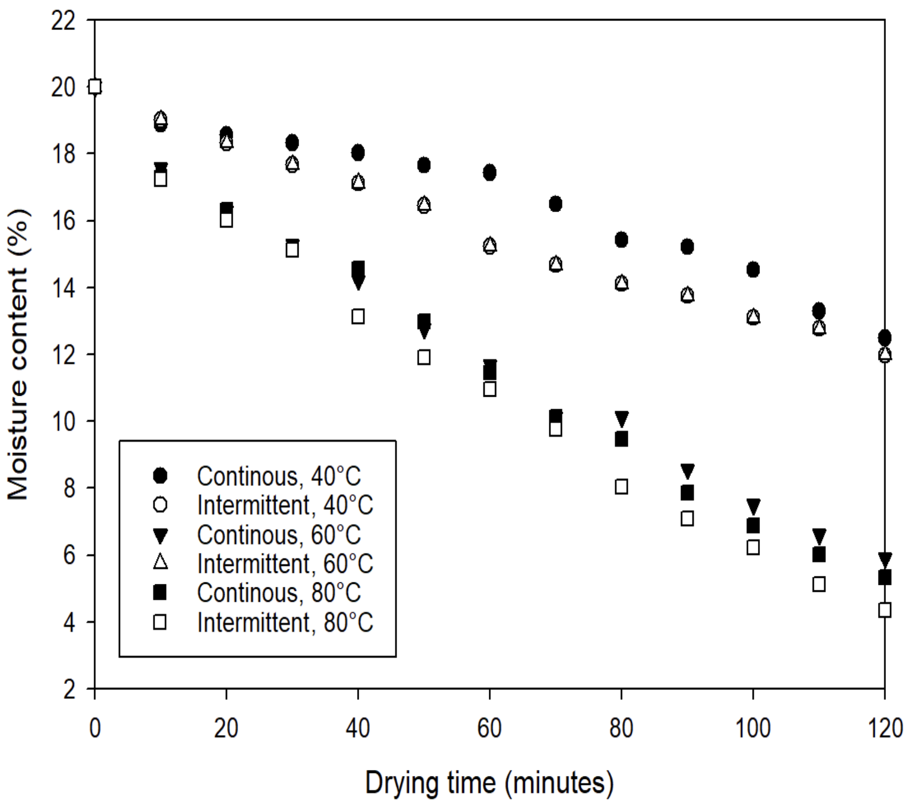

Figure 2: Effect of intermittent and continous drying on moisture content

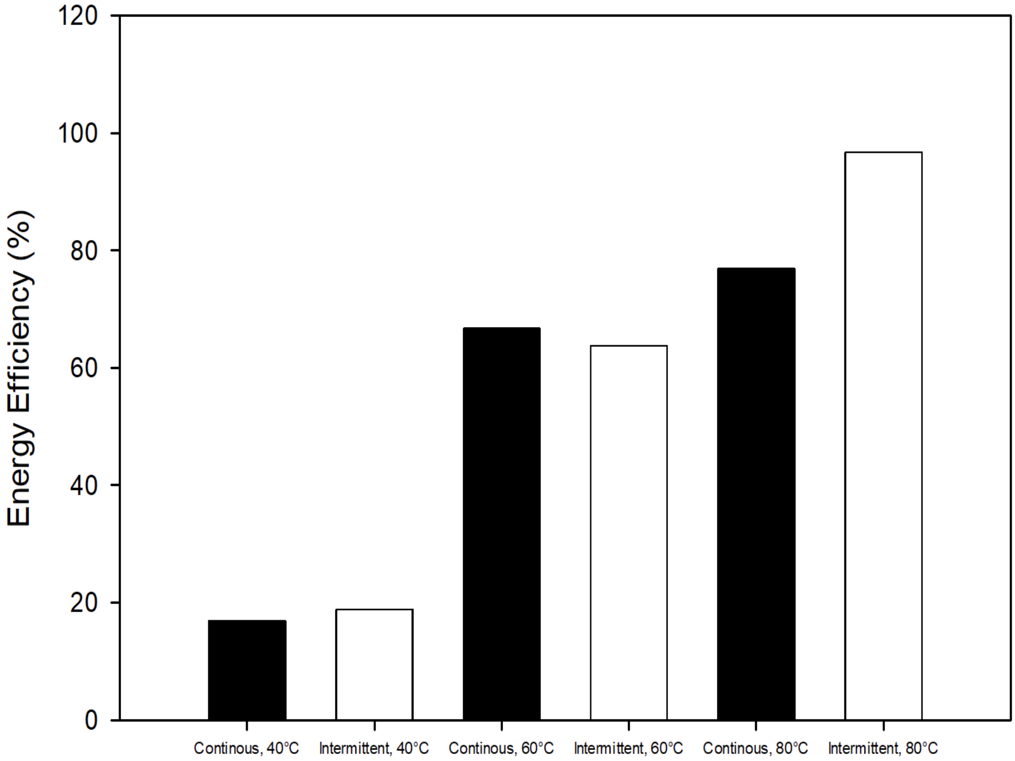

Figure 3: Effect of intermittent and continous drying on energy efficiency

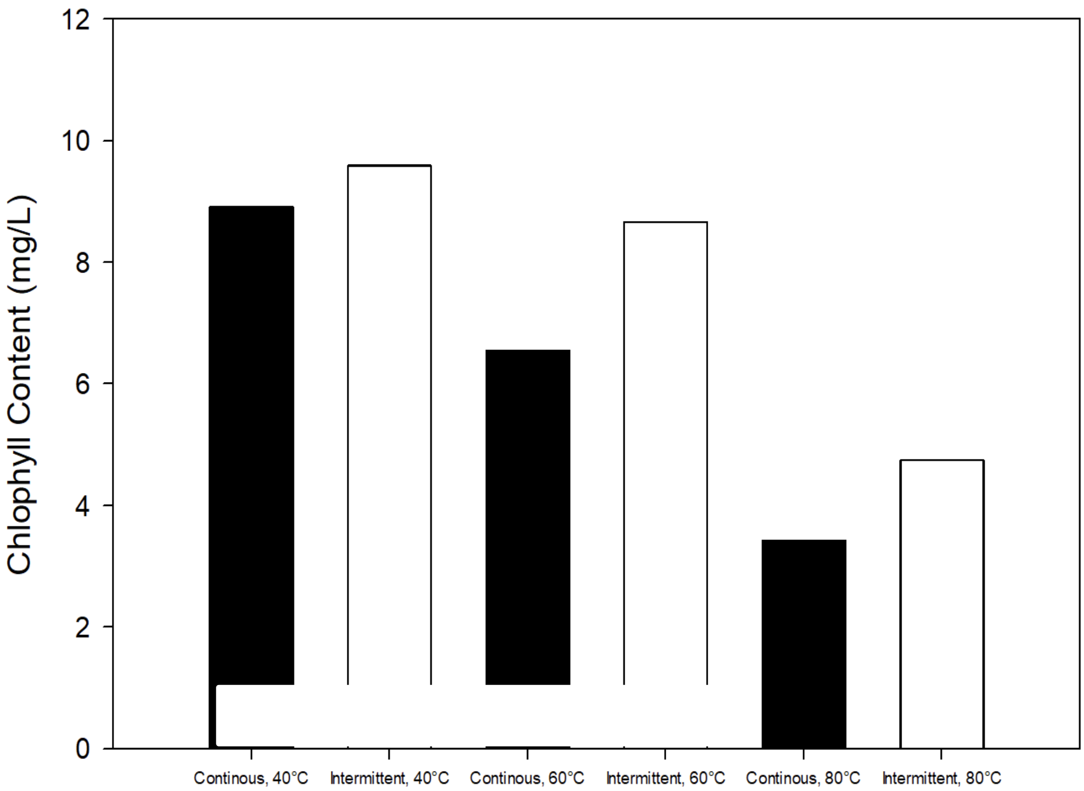

Figure 4: Effect of intermittent and continous drying on chlorophyll content

From the Figure 4, the concentrations of chlorophyll during intermittent and continuous drying for various drying temperature can be seen. The fresh *Moringa Oleifera* leaves contain 18.41-19.25 mg/L of chlorophyll [11]. After the drying process, the concentration of chlorphyll decreased. The decreased in chlorophyll during the drying process indicates that chlorophyll is damaged by heat because heat can denature proteins that form complex bonds with proteins so that the organic acids in chlorophyll are released [18]. If drying at high temperatures is carried out continuously, the amount of chlorophyll released will increase. This happens because the outer layer of the leaf loses water content more quickly than the inner part. Apart from that, high temperature drying can also cause possible differences in the state of the leaves on the inside. To overcome this, the tempering phase is used.

The tempering phase is a situation where heat energy and air flow are stopped in such a way that the rate of water leaving the product is lower than water diffusing from the inside to the outside [14, 22]. This way the water content becomes more even. In this tempering process, heat loss should be avoided so that there is no temperature difference between the inside and outside. The combination of drying and tempering is called intermittent drying. In this way, the use of intermittent drying methods can prevent protein denaturation and minimize chlorophyll reduction.

4. Conclusions

The effect of temperature and intermittent drying on moisture content, energy efficiency and chlorophyll content have been evaluated. The result showed that moisture content of intermittent drying is better than continuous drying at various temperatures, this is because during the intermittent tempering process, free water in the middle of the *Moringa Oleifera* leaves diffuses to the surface which will then diffuse into the environment when the drying process continues. The drying efficiency using the intermittent method reached 18,75% - 96,69%, reducing the drying energy required. Using the intermittent drying method with has been proven to be able to prevent protein denaturation thereby maintaining the chlorophyll content in *Moringa Oleifera* leaves.

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