Drying effects of vacuum far-infrared on aquilaria malaccensis leaves

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Abstract. Vacuum far-infrared radiation is an advanced drying technique that has the unique characteristics of energy transfer mechanism. In vacuum drying, the moisture evaporates at lower temperature while in infrared drying, the energy is absorbed directly which save a considerable amount of energy. The combination of the two would results in the time savings and enhancement of product quality. The effects of vacuum far-infrared drying on colour changes, elements and moisture content removal of Aquilaria Malaccensis’ leaves were investigated. The parameter of the experiments were set to be temperature of 40, 50 and 60 °C, pressure of 0.6 and 0.8 bar, and a residence time of 120 minutes. The drying process reaches its optimum condition at temperature of 50°C and pressure of 0.6 bar, where the colour changes of the leaves, moisture content removal and elemental analyzer showed the best result of all six runs. The optimum drying conditions are recommended for further researches of the leaves.

1. Introduction
Aquilaria Malaccensis is a species of plant in the Thymelaeaceae family found primarily in Bangladesh, India, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, and Thailand [1]. This species is of particular economic interest as it is the principal source of gaharu, one of the most highly valuable forest products currently traded internationally. The leaves of this species is believed to have a healing effects towards mild headaches and fever in some of the old and rural cultures that can be found from other natural herbs [2]. The many practices of agarwood has made the sustainable production of its kind become a major concern to prevent extinction [3]. The management in plantations of Aquilaria is recently established and it is foreseen that such plantings will deliver an alternative source of agarwood and lessen the harvesting pressures on its wild stands.

As of late, far-infrared (FIR) vacuum drying has been utilized as an advanced drying system because of various focal points. The uniqueness of using a vacuum far-infrared is that it lowers the pressure of the system and relatively reducing the operating temperature which in turns help in saving energy [4, 5]. Contrasted with other drying routines, FIR vacuum drying has a short drying time, simple establishment, high vitality proficiency, quick reaction of warming and drying and low capital expense [6]. The effectiveness of far-infrared (FIR) as a drying techniques onto the Aquilaria Subintegra leaves has discovered the potential FIR in preserving the antioxidant activity from the dried leaves extract [7].
Aquilaria Malaccensis has been known as one type of the popular and rare agarwood in the world. There are various types of active ingredients in almost every parts of the plant, including the leaves. The active ingredients extracted from the plant are used widely around the world. With its endangered population and long time to replanting, it is crucial to enhance its usage and preserve the active ingredients [8]. The leaves, often regards as waste or useless, are useful when treated and preserved accordingly. The aim of this study is to investigate the effects of vacuum far-infrared drying on Aquilaria Malaccensis’ leaves, specifically on the colour changes, moisture content removal, and the elemental analysis of the leaves under VFIR conditions.

2. Methodology

2.1. Materials
Fresh leaves of Aquilaria Malaccensis were collected from a farm located in Jalan Kebun, Shah Alam prior to start this experiment. Particularly uniform size of Aquilaria Malaccensis’ leaves with 3-5 cm in width and 6-10 cm in length that are matured and free from diseases were chosen to be used throughout the experiment. There were two batches of leaves collected which were in November and December of 2015, both came from the same farm and tree.

2.2. Collection of aquilaria malaccensis’ leaves
The collected Aquilaria Malaccensis’ leaves were cleaned by rinsing with running tap water, wiped dried with cleaned tissues to remove the impurities before let dried at room temperature in a laboratory. The cleaned leaves were then stored in a refrigerator at a temperature of 22°C and were ready for experimental procedures.

2.3. Experimental procedures
Six experimental run were selected, each with different parameters, to investigate the effect of VFIR drying on the leaves. The pilot scaled VFIR dryer used was fabricated by Nucleus Scientific & Instruments. The chamber inside the dryer was fitted with 3 FIR heat sources on three levels of the chamber. Temperature of the chamber is controlled using a system controller while the pressure is controlled using a vacuum pump. A set of temperature of 40, 50 and 60 °C while pressure of 0.6 and 0.8 bar were selected as the parameters in this experiment.

A handful amount of cleaned Aquilaria Malaccensis’ leaves were taken for each run, placed on the tray inside the VFIR, five pieces almost identical leaves were chosen randomly to be placed on the weighing balance and be used as sample for the colour changes analysis as well as elemental analysis before and after each run. Each run was performed for 120 minutes so that the leaves were well-dried in a fixed residence time.

2.4. Colour measurement
For colour changes analysis, the leaves’ colour was measured using a Konica Minolta Chromameter (B8208418). Each of the five selected leaves were measured of their colour using the chromameter before and after each run were performed, with all five leaves were analyzed at the same spot for both before and after each run, in order to get the most accurate results. Hunter scale values of L, a, and b were used where L=0 for black, L=100 for white, a<0 for green, a> for red, b<0 for blue, and b>0 for yellow. Chroma (C), which indicate the colour intensity, was calculated as below:

\[ C = a^2 + b^2 \]  

The hue angle (h) from 0 or 360° indicates a red hue and 90, 180, and 270° indicate yellow, green, and blue hues, respectively. The h value was calculated as below:

\[ h = \tan^{-1} \frac{b}{a} \]  

2.5. Moisture content removal
For the moisture content removal of the leaves after drying, data were collected from the weighing balance installed within the VFIR dryer itself and the weight of the five leaves placed upon the balance were taken before the dryer is turned on and after 120 minutes of drying. The difference in weight would indicate the total moisture loss of the five leaves from the drying process.

2.6. Elemental analysis

The elemental analysis of the leaves before and after the drying process were conducted using a Thermo Fisher Scientific Flash EA 1112 elemental analyser. The leaves that need to be analysed were ground until the size of almost powder because the elemental analyser can only analysed sample that is in very little size.

Twelve samples were analysed prior to six experimental run with two samples each. The results were given in the percentage concentration of nitrogen, carbon, and hydrogen atoms in the sample, where comparison between the composition in before and after drying were made.

3. Results and discussion

3.1. Effect of VFIR drying on the colour changes of the leaves

The effect of VFIR drying on Aquilaria Malaccensis’ leaves were investigate in terms of the colour changes of the leaves after it has been dried using the chromameter. Fresh Aquilaria Malaccensis’s leaves have a green and slightly yellow colour before it turned into dark yellow after it has been dried. Colour is an important physicochemical property. The impact of VFIR drying conditions on colour parameters of L, C and h of dried Aquilaria Malaccensis’ leaves were examined and results are shown in Table 1. Aquilaria Malaccensis’ leaves dried at 60°C and 0.6bar (run 6) had the highest L value which is 42.93, while Aquilaria Malaccensis’ leaves dried at 60°C and 0.8bar (run 5) had the highest C value, 19.69. The h value indicated that all dried Aquilaria Malaccensis’ leaves were yellow and slightly green. The results obtained from this experiment follows the previous study in the increment of values, except the hue angle. This may be due to the fact that the type of leaves used is different.

| Run | Variable | T (°C) | P (bar) | Lightness | Chroma | Hue Angle |
|-----|----------|--------|---------|-----------|--------|-----------|
|     |          | Before | After   | % Difference | Before | After | % Difference | Before | After | % Difference |
| 1   | 40       | 35.24  | 39.34   | 11.62      | 16.33  | 17.36 | 6.29        | 43.68  | 66.69 | 52.67      |
| 2   | 40       | 34.94  | 39.94   | 14.30      | 16.64  | 17.67 | 6.16        | 48.02  | 66.04 | 37.54      |
| 3   | 50       | 36.32  | 41.84   | 15.22      | 18.79  | 19.10 | 1.64        | 47.53  | 71.23 | 49.86      |
| 4   | 50       | 35.21  | 40.63   | 15.41      | 15.24  | 18.15 | 19.11       | 44.61  | 67.53 | 51.36      |
| 5   | 60       | 35.28  | 41.86   | 18.64      | 17.37  | 19.69 | 13.34       | 49.26  | 73.48 | 49.17      |
| 6   | 60       | 36.05  | 42.93   | 19.10      | 17.86  | 18.90 | 5.79        | 45.93  | 72.32 | 57.44      |

From the Table 1, it can be seen that run 4 (50°C and 0.6 bar) shows a high percentage differences of the total three categories namely lightness (L), chroma (C) and hue angle (h). On the contrary, run 2 (40°C and 0.6 bar) shows the lowest total percentage of differences. This is due to the lower temperature and greater vacuum has been achieved.

In previous study using Miang leaves [9], the optimum temperature was found to be at 65°C and 0.53 bar for the drying of Miang leaves with the lightness and chroma of the leaves increased after the drying process, but the hue angle only had a minor increment. The results obtained from the experiment follows the previous study in the increment of values, except the hue angle. This may be due to the fact that the type of leaves used is different.

3.2. Effect of VFIR drying on the moisture content removal of the leaves
The drying process of the leaves using VFIR dryer has caused some weight loss of the leaves after the drying and this is due to the moisture loss inside the leaves itself. In any drying process, moisture content inside the sample will be lost and it is the sole purpose of drying process to be conducted on any sample. Drying of leaves were conducted to ensure moisture loss and preserved the ingredients inside the leaves. For this experiment, the moisture content removal of the five leaves placed on the weighing balance were determined and tabulated in Table 2.

The highest percentage of moisture content removal among the six run is run 5 using 60°C and 0.8 bar with 8.55% loss. The trend of the moisture content removal keeps on increasing until run 5, which shows a little decrement of only 0.09% in run 6. This may be of the factor that at run 5 (60°C and 0.8 bar), it is the optimum temperature and pressure for drying Aquilaria Malaccensis’ leaves which explains why at run 6 (60°C and 0.6 bar), a decrease in the pressure did not increase the percentage of moisture content removal of the leaves.

In a study of carrot’s drying using VFIR dryer [3], an increase in the temperature from 70 to 80°C does not showed a promising results and thus conclude that for each type of sample, the increase of temperature does not always mean the moisture content removal will be better.

### Table 2. Effect of VFIR drying on the moisture content removal of Aquilaria Malaccensis’ leaves

| Run | Variable | Responses | Weight of leaves | % Difference |
|-----|----------|-----------|-----------------|--------------|
|     | T (°C)   | P (bar)   | Before          | After        |
|     | 1        | 40        | 0.8             | 29.84        | 28.63        | 4.05 |
| 1   | 2        | 40        | 0.6             | 30.19        | 28.84        | 4.47 |
| 2   | 3        | 50        | 0.8             | 30.05        | 27.82        | 7.42 |
| 3   | 4        | 50        | 0.6             | 30.64        | 28.04        | 8.49 |
| 4   | 5        | 60        | 0.8             | 29.34        | 26.83        | 8.55 |
| 5   | 6        | 60        | 0.6             | 29.78        | 27.26        | 8.46 |

### 3.3. Effect of VFIR drying on the elemental composition of the leaves

The purpose of analyzing the elemental composition of the fresh and dried Aquilaria Malaccensis’ leaves was to compare the composition of nitrogen, carbon and hydrogen inside the leaves before and after it was dried using the VFIR dryer. The results of the analysis are tabulated in Table 3 below.

The process of drying requires heat and along the way, oxygen will be used in the process, making oxygen atoms and molecules less available inside the sample [10]. This explains why the composition of nitrogen, carbon and hydrogen increased after the drying process has stopped, because of the depletion of oxygen molecules. There may be other atoms that are presents in the sample but this experiment only covers the composition of nitrogen, carbon and hydrogen.

### Table 3. Effect of VFIR drying on the elemental composition of Aquilaria Malaccensis’ leaves

| Run | Variable | Nitrogen | Carbon | Hydrogen |
|-----|----------|----------|--------|----------|
|     | T (°C)   | Before   | After  | % Difference | Before | After  | % Difference | Before | After  | % Difference |
|     | P (bar)  | Nitrogen | Carbon | Hydrogen |
| 1   | 40       | 0.8      | 2.04   | 2.11 | 3.43 | 36.39 | 41.92 | 15.20 | 6.18 | 6.32 | 2.27 |
| 2   | 40       | 0.6      | 1.98   | 2.06 | 4.04 | 37.44 | 41.77 | 11.57 | 5.99 | 6.28 | 4.84 |
| 3   | 50       | 0.8      | 1.86   | 1.96 | 5.38 | 36.68 | 42.53 | 15.95 | 6.52 | 6.65 | 1.99 |
| 4   | 50       | 0.6      | 2.01   | 2.19 | 8.96 | 32.48 | 42.05 | 29.46 | 6.20 | 6.40 | 3.23 |
| 5   | 60       | 0.8      | 1.93   | 2.06 | 6.74 | 34.62 | 42.15 | 21.75 | 6.27 | 6.58 | 4.94 |
| 6   | 60       | 0.6      | 1.87   | 2.04 | 9.09 | 35.37 | 43.21 | 22.17 | 6.19 | 6.41 | 3.55 |

As shown in the Table 3, run 5 (50°C and 0.6 bar) obtained the highest percentage differences of all three elements among the six while run 2 continues to obtain the least percentage differences. This
shows that the drying process is most effectively conducted at temperature 50°C and pressure of 0.6 bar.

4. Conclusion
The effects of VFIR drying on the *Aquilaria Malaccensis*’s leaves were investigated on three different aspects namely; colour changes, moisture content removal and elemental analysis of the leaves before and after drying. All the data and observations throughout the experiment has pointed out that the best drying conditions for the *Aquilaria Malaccensis*’s leaves are at temperature of 50°C and pressure of 0.6 bar. This is to ensure that the leaves are well-dried and the active ingredients inside it could be preserve for future uses and researches. At this condition, the moisture content removal although not at the highest among all 6 runs came in closed second with 8.49% difference, just 0.06% behind the highest moisture content removal, while the colour changes and elemental composition both showed the best results.

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