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Pulsed UV Integrated Infrared Dryer System for *Orthosiphon Stamineus Herb*.

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ABSTRACT

The drying system is an important part for food and herbs preservation. Therefore, an effective drying system are needed to ensure the increase the shelf life of the food and herb without degrade its good nutrient and bioactive compound. In this study, *Orthosiphon stamineus* herb was used to dry using an Infrared dryer and combination of Pulsed UV light treatment + Infrared drying. Infrared drying involves transferring heat by radiation from a hot source to a lower-temperature substance that has to be heated or dried, meanwhile the pulsed UV light is a non-thermal treatment. The temperature of the heated element determines the peak wavelength of the radiation. The objective of this study is to design an infrared dryer system and analyze the quality of the dried herb. The *Orthosiphon Stamineus* have been dried using a 200W Infrared dryer system at 60°C. Total phenolic compounds and antioxidant capacity were determined using the Folin-Ciocalteu method and the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity assay measured using a UV/VIS Spectrophotometer. A moisture analyzer was used to look at the changes in moisture content, and a colorimeter was used to look at the colour changes. The result showed that drying *Orthosiphon stamineus* by using an Infrared dryer and combination of Pulsed UV light treatment + Infrared drying under 60°C has significantly affected the herbal leaves quality in terms of moisture content, colour properties, Antioxidant capacity, and Total phenolic content.

1. Introduction

Orthosiphon stamineus Benth (commonly known as Misai Kucing plant) is among Southeast Asia's oldest and most widely used traditional medicinal herbs, native to Malaysia, Indonesia, Thailand, Vietnam, and surrounding countries. For culinary uses, the entire fresh plant (stem, leaves, and flowers) can be utilized. This medicinal plant belongs to the *Lamiaceae* family. After reproducing stem

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cuttings, this plant may reach a height of about 1.2 m, and the leaves can be harvested in 3–4 months. Rosmarinic acid (RA), quercetin, eupatorium, and sinensetin are the four major marker components in Misai Kucing extract (SEN). The therapeutic effects of these phenolic compounds include anticarcinogenic, antiallergic, antihypertensive, anti-inflammatory, antioxidant, and diuretic activities [1]. Drying is the oldest and most widely used method for preserving fruits, vegetables, herbal-based nutraceuticals and dietary supplements. However, due to physical, chemical, organoleptic, and nutritional changes, the high drying temperature can degrade the final product's quality [2]. The nutritional value of *Orthosiphon stamineus* was decreased due to heat degradation of bioactive substances, which has become a serious concern for the business [3]. Under comparable conditions, infrared heating has a number of benefits over traditional drying. In comparison to other drying processes, infrared radiation is quicker than convection [4].

Faced with rising public health awareness, food must concentrate on storing as many vitamins and other phytochemical compounds as possible. Temperature, climate, light, moisture content, water activity, pH, and food spoilage enzymes are all factors that affect the degradation of these bioactive compounds during food processing. In the same conditions, infrared heating has several benefits over traditional drying. In comparison to other drying methods, experiments have found that infrared radiation is quicker than convection. The energy of infrared radiation is transmitted from the heating element to the object, allowing the material to be heated more rapidly and uniformly while avoiding heating the environment. The irradiated surface evaporates significantly more water, reducing drying time by up to half. Because of these, infrared radiation was used in combination with other drying techniques. The drying process decreases the product's moisture content and water activity, reducing deterioration during shelf life, but it also increases the loss of bioactive compounds due to prolonged exposure to high temperatures [4-6]. Furthermore, low-temperature drying can increase product consistency, but the drying rate may be reduced due to the longer drying period [7]. The NIR region is much more productive for thicker body drying, while the FIR area is better for thinning layer drying, but long-term temperature exposure destroys nutrient mixtures [5-6]. Drying is the method of extracting water, and the long drying period can lead to a lot of nutrition loss [8].

The quality of herbal-based nutritional and dietary supplement products is intimately linked to the quality of the raw herbs used. The quality of herbs is influenced by a number of factors, one of which is drying. Herbal plants can be dried using either natural or artificial ways. The majority of Malaysian herbal growers today use natural drying as their normal procedure. However, because it employs heat and is operated in a confined chamber, the artificial approach delivers a faster drying rate and is more hygienic than the natural method [9]. Drying herbs limits microbial development and prevents certain biochemical changes, but the drying can also produce other changes that influence herb quality, such as changes in appearance and aroma caused by volatile losses or new volatile production as a result of oxidation or esterification processes [10]. However, following the drying process, certain improvements in food properties, such as discolouration, scent loss, textural changes, nutritional content, and physical appearance and form, have been noted, which may be attributed to high drying temperatures. Several studies have investigated the effects of various drying processes on the quality of herbs such as dill [11], lovage and parsley [12], coriander [13], mint [14], rosemary [15].

Mukhopadhyay et.al used Pulsed light (PL) which has recently gained interest as a viable non-thermal technique for microbial decontamination of fresh fruits and vegetables. PL is a food processing and handling technology that has been authorized by the US Food and Pharmacy Administration (21CFR179.41). To inactivate germs on food surfaces, PL uses brief, strong pulses of broad-spectrum light spanning from UV to near-infrared (200–1100 nm). The germicidal action of PL light is mostly due to photochemical damage to microorganisms' deoxyribonucleic acid (DNA), which causes cell replication to be disrupted. Surface decontamination by PL may entail a photochemical, photothermal, and photophysical action in addition to photochemical. Several research has been published on the great potential of PL technology for pathogenic and spoilage microorganism inactivation, as well as its impact on shelf life and quality. As a result, a short-term or low-dose PL treatment combined with an active antibacterial sanitizing wash may be effective in controlling target microbes on produce [16]. However, there is no data on the Pulsed Uv Integrated Infrared Dryer System for Orthosiphon stamineus Herb. The objective of this research was to develop an infrared dryer system that would allow Orthosiphon stamineus leaves to be dried at the 60°C temperature and determine the quality of the herb before and after infrared drying and Pulsed UV treatment+ Infrared Drying.

2. Methodology

In this study, the oven dryer system is developed with the Infrared light and infrared with the Pulsed UV light. The results from both drying systems was recorded and compare based on the drying process of the *Orthosiphon stamineus* herb. After the drying process, the dried *Orthosiphon stamineus* herbs leaves was tested on the colour analysis, moisture content, total phenolic content (TPC) and total antioxidant activity (TAA). The overall process diagram is represented in Figure 1.

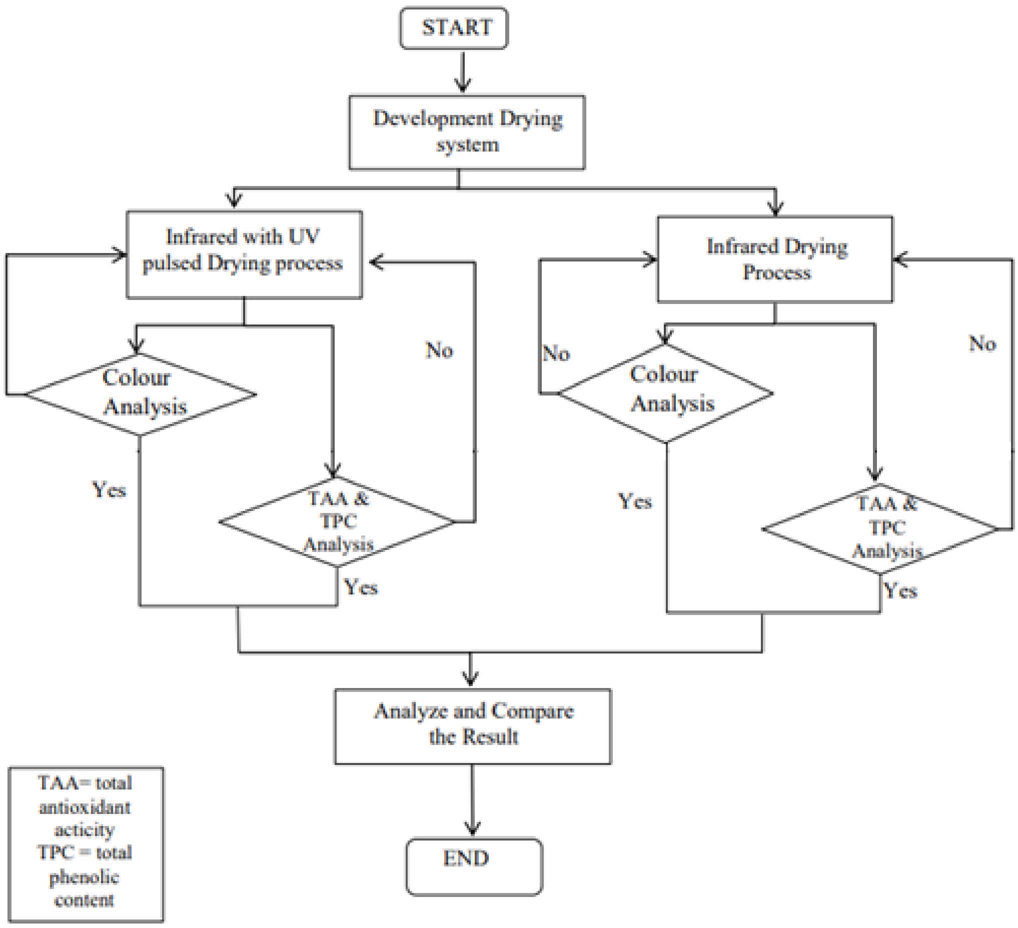

Fig. 1. Overall process diagram

2.1 Development of Infrared Dryer System

The objective of this study is to create an infrared drying system. The original oven's drying system was altered. Figure 2 shows the development of the dryer system by the placement of the infrared lamp and SHT31 sensor. The oven has a capacity of 25 litres. The oven's heater was replaced with an infrared lamp. (200W) and medium infrared wave. The inner temperature and humidity level of the drying system are measured with the GY-SHT31-D sensor. This module's average accuracy is ±2 %RH (relative humidity) and ±0.3°C (for temperature).

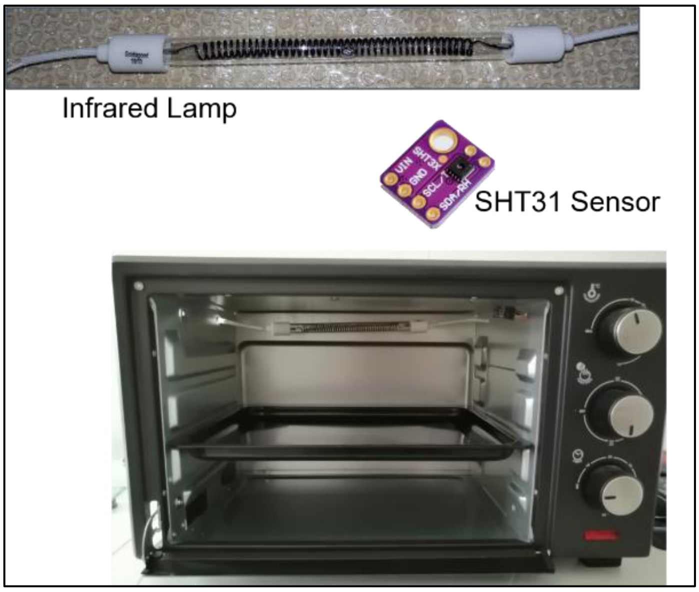

Fig. 2. The development of the dryer system by the placement of the infrared lamp and SHT31 sensor

Figure 3 shows an understandable diagram about the connection of the circuit in this study. The AC solid state relay was used to manage the input current to the oven to keep the highest temperature within the infrared heat limitations. The Arduino board's solid-state digital output was used to turn on and off the infrared lamp. The Arduino board and signal delivered power and ground to the SHT31 sensor, which is linearly proportional to the temperature, via the Arduino Uno analogue input. Figure 3 shows the development of the dryer system by the placement of the infrared lamp and SHT31 sensor.

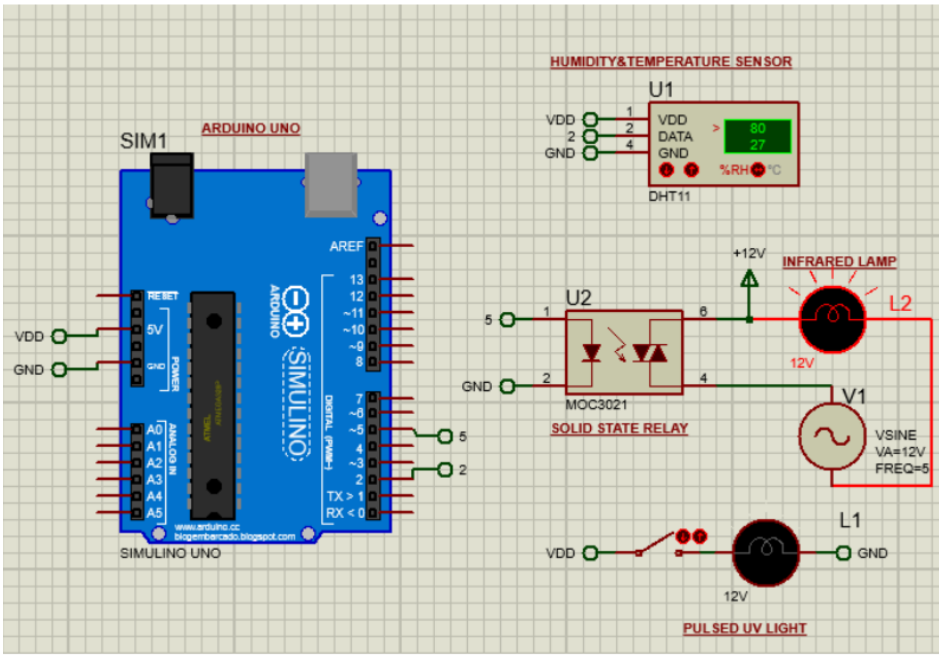

Fig. 3. The development of the dryer system by the placement of the infrared lamp and SHT31 sensor
* The DHT11 sensor that has been illustrated in the figure above is used for the reason of the SHT31 sensor is not available in Proteus software

2.2 Stimulation Coding

For the stimulation coding, Arduino IDE software was used. The coding was build using the concept of Proportional Integrated Derivatives (PID) and Pulsed Width Modulation (PWM). The coding has integrated with SHT31 coding, the important libraries. The setpoint and gain values are set in order form to make the temperature to maintain.

2.3 Material and Method

The *Orthosiphon stamineus* plant are cultivated at Agrotechnology Research Station, Universiti Malaysia Perlis, Sg. Chucuh, Perlis, Malaysia. The plants were grown from cuttings and cared for in accordance with the majority of Malaysian growers' practices. The fresh leaves were collected, washed, and rinsed at the time between 8:00 and 9:00 a.m. The leaves were then quickly peeled from the twigs in preparation for drying. A moisture analyzer was used to determine the initial and final moisture content of the fresh leaves and dried leaves. The samples of 20g of *Orthosiphon stamineus* leaves were dried by using an infrared dryer at 60°C. As for the combination of Pulsed UV light treatment + Infrared drying, the herbs have been placed under the Pulsed UV light for 5secs treatment and then dried using Infrared Dryer. The samples were replicated three times and the results were recorded.

2.4 Sample Preparation

100ml distilled water was used to extract 1 g of dried herbal leaves and fresh leaves for 4 hours at 40°C using a shaker water bath (Thermolab, Germany). The extracted solution was filtered using Whatman No. 1 filter paper before being packed in bottles and kept in the freezer (- 20°C) prior for the analysis.

2.5 Moisture Content Analysis

The moisture content of the 1g dried and fresh sample was measured using an MS-70 moisture analyzer (A&D, Japan).

2.6 Determination of Colour

A Minolta CR-400 chroma metre was used to determine the colour properties of all stored samples. In the CIELAB system, the D65 illuminant and CIE 1964 Supplementary Standard Observer were used to calculate calorimetric data (1986). The calorimetric or chromaticity coordinates define the colour properties of samples: clarity (L*), red/green colour component (a*), and blue/yellow colour component (b*). Clarity (L*= 0 black and L* = 100 colourless), a red/green colour component (a*>0 red and a*0 green), and a blue/yellow colour component (b*>0 yellow and b*0 blue) are all represented by the coordinateL*. The total colour difference (E) was calculated using Eq. (1),

$$\Delta E = \sqrt{[(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2]} \quad (1)$$

where L_0, a_0 and b_0 are the Initial values for the fresh leaves colour before drying.

2.7 Total Phenolic Content (TPC) Analysis

The total phenolic content (TPC) was analysed based on modified method of Wahyono et al. [17]. The 200µl of *Follin-Ciocalteu* reagent (FCR) and 200µl of extract solution were combined with 1.58 ml distilled water and vigorously agitated for 4 minutes before 1 ml of 20% sodium carbonate was added. In a dark setting, the mixed solution was left to react for 2 hours. The total phenolic content was determined using a UV/VIS spectrophotometer (Shimadzu, Japan) with an absorbance reading of 760nm. The concentration of total phenolic content was measured in caffeic acid equivalents, with caffeic acid as the standard (CAE).

2.8 Total Antioxidant Activity (TAA) Determination

The antioxidant capacity of the extracts was evaluated using the modified DPPH method as published by Akowuah [18]. About 2 ml of 2,2-diphenyl-1-picrylhydrazyl (DPPH) was combined with 200 µl aliquots of samples. Methanol was used to mark up the mixture to 3 ml. The mixed solution was allowed to react a room temperature for 1 hour. The control was also prepared. After 1 hour, the absorbance value was determined using a UV/VIS spectrophotometer (Shimadzu, Japan) at λ=517nm. The antioxidant capacity of samples was determined by utilising the Eq. (2),

$$\text{FRSA} = \left[\frac{(A_c - A_S)}{A_c}\right] \text{x } 100; \quad (2)$$

where A=Control absorbance, B=Sample absorbance

3. Results

The experiment was carried out to study the effect of Pulsed UV Integrated Infrared Dryer System on *Orthosiphon stamineus* leaves quality at 60℃. The samples were dried and the changing on *Orthosiphon stamineus* dried leaves quality (total phenolic content, antioxidant activity, moisture content, and overall colour difference) were analysed. The infrared drying and the combination of Pulsed UV light treatment + Infrared drying experiment was carried out in triplicate.

3.1 Moisture Content

The changes of moisture content on *Orthosipho statmineus* infrared dried leaves and Pulsed UV light+ Infrared dried leaves have been compared with fresh leaves were plotted in the graph as shown in Figure 4.

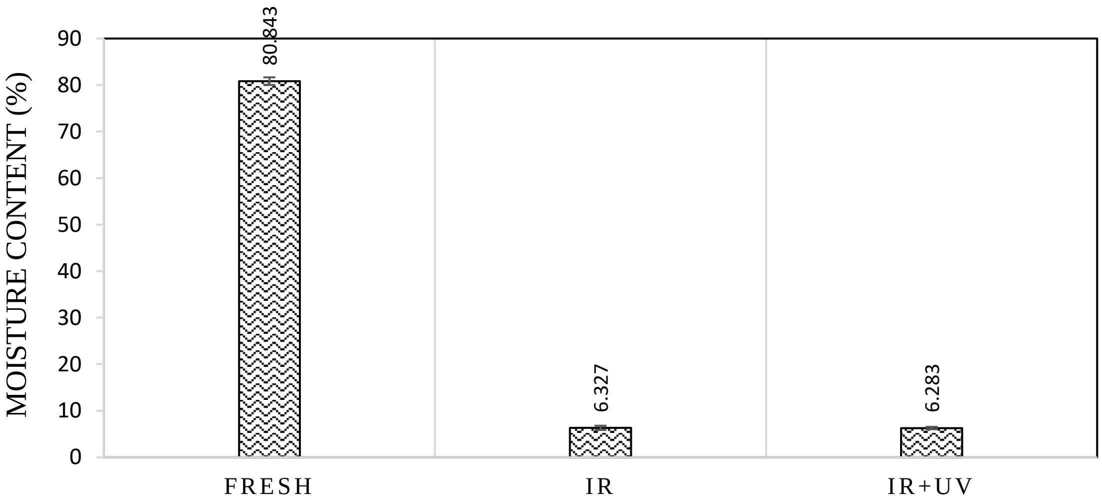

Fig. 4. The changes of moisture content after the infrared drying and Pulsed UV light + Infrared drying process under 60°C for 120 and 195 minutes
*The Pulsed UV light treatment has been carried out before the Infrared drying

The results show that there was a huge change in moisture content after infrared drying and the Pulsed UV light + Infrared drying process under 60℃. The drying time which took to dry the 20g of fresh *Orthosiphon stamineus* leaves is 195 minutes for infrared drying. As for Pulsed UV light + Infrared drying, it took for 120 minutes. The comparison of moisture content of fresh leaves was 80.84% and reduced to 6.33% after the infrared drying process for 195 minutes and for Pulsed UV light + Infrared drying, it was decreased to 6.29% at 60°C for 120 minutes. The Pulsed UV light + Infrared drying can save up to 75 minute to achieve the drying quality and showing a better drying rate in comparison with infrared drying. The drying was discovered to be an important component that aims to reduce moisture content, avoid enzymatic and microbiological activity, and therefore preserve the product to lengthen shelf life [19].

3.2 Colour Properties

Physical appearance and total colour change (E) are important physical properties to visually assess the dehydrated product because consumers make their first judgement on food quality based on appearance. Due to an abnormal colour or significant change in physical appearance, customers may reject the product [20]. Currently, drying causes dehydration of the product, resulting in the Maillard reaction (non-enzymatic browning), pigment degradation, and enzymatic browning. The Figure 5 shows the difference of colour from fresh leaves to dried leaves. The changes of colour properties by infrared drying and Pulsed UV light+ Infrared drying at 60°C for 120 and 195 minutes are represented in Table 1.

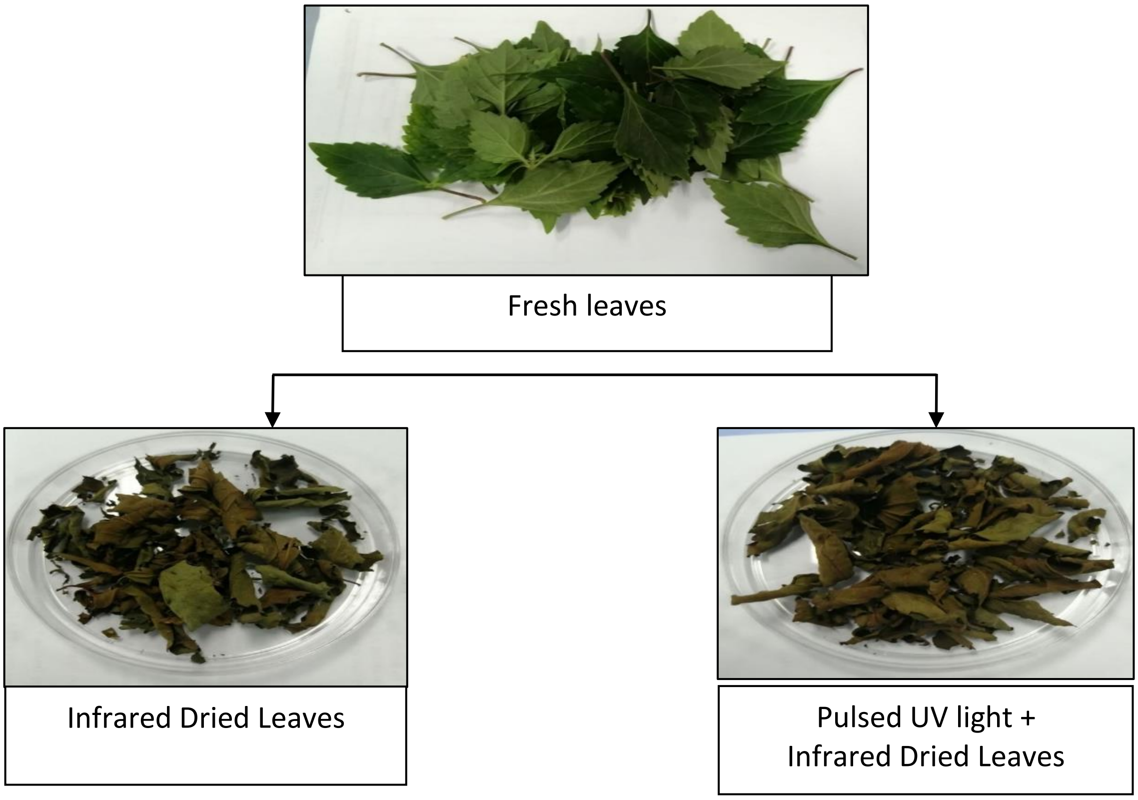

Fig. 5. The visual appearance of *Orthosiphon stamineus* fresh leaves and dried leaves under

The 60°C for 120 and 195 minutes in Infrared Dryer and Pulsed UV light + Infrared dryer. The positive value of L* and b* were referred to as lightness and yellowness. The negative value of a* was referred to as the greenness of the sample's colour. The obtained results showed that there were significant changes of L*, a* and b* during the Infrared Dryer and Pulsed UV light + Infrared dryer at 60°C.

Table 1
The changes of colour properties on the samples of *Orthosiphon stamineus* dried herbal leaves under 60°C and fresh leaves

Colour Properties	Fresh Leaves	Infrared	Pulsed UV+ Infrared
L*	46.36±1.1	43.80±2.0	44.23±1.07
a*	-4.34±0.35	0.82±0.75	1.43±0.21
b*	6.58±4.02	3.48±0.71	3.05±0.51

*Means (n=3) with different letters in a single column are significantly different at the 95 % confidence level

The changes in the lightness L* value significantly decreased around 46.36 to 43.80 for infrared drying and as for Pulsed UV light+ Infrared, it decreased slightly more than Infrared drying which is 44.23 between the fresh leaves. The a* value significantly reduced to 0.82 for Infrared and as for the Pulsed UV light drying it was 1.43 from -4. 34 which shows that it did not maintain the greenness of the leaves. The b* value significantly decreased from 6.58 to 3.48 for Infrared drying and as for the Pulsed UV light Infrared drying it reduced even more which is 3.05. The total colour difference after the infrared drying (IR) and Pulsed UV light drying (UV+IR) at 60℃ for 120 and 195 minutes are 26.25 for IR and 29.89 for UV+IR which is the colours that are similar are more common than those that are dissimilar [21].

3.3 Antioxidant Capacity

The antioxidant capacity and total phenolic content of *Orthosiphon stamineus* dried herbal leaves are two important quality indicators [22]. The changes in antioxidant capacity and total phenolic content during the two methods of drying are tabulated in Table 2.

Table 2
The changes of Antioxidant and Total Phenolic Content with samples of *Orthosiphon stamineus* fresh leaves and infrared dried leaves under 60℃

Sample	DPPH (%)	TPC (ppm)
Fresh	56.01±12.79	48.089±10.47
Infrared Drying	81.51±5.05	73.11±7.14
Pulsed UV light+ Infrared	67.36±8.80	65.07±11.01

Based on the results in Table 2, the antioxidant capacity of the dried leaves significantly increased from 56.01±12.79% fresh leaves to 81.51±5.05 % and as for the Pulsed UV light+ Infrared, it also increased to 67.36±8.80%. As for the result of the total phenolic content of the *Orthosiphon stamineus* leaves which have been dried using infrared drying and Pulsed UV light+ Infrared under 60℃ shows a significant increase from fresh leaves 48.089±10.47 ppm to 73.11±7.14ppm for Infrared Drying and 65.07±11.01 ppmfor Pulsed UV light+ Infrared. The content of total phenolic compounds in dried *Orthosiphon stamineus* changed as infrared power increased, indicating that infrared power had a favourable influence on total phenolic compounds and antioxidant capacity. This behaviour might be attributed in part to higher temperatures and radiation, which meant a short drying period, which could result in a rapid decrease in moisture content and limit total phenolic component breakdown. In contrast, the increase in total phenolic compounds and antioxidant capacity in the dried *Orthosiphon stamineus* with increasing infrared power was likely produced by the fact that infrared rays have the potential to break down covalent bonds and unleash antioxidants, which has been discovered in other studies [23]. By the combination of Pulsed UV light+ Infrared drying the results shows that it produces low quality compared to the infrared drying.

4. Conclusions

The drying of the herbal plant can be done by either natural or artificial methods. The usage of the traditional drying method provides a lesser drying rate compare to the artificial drying method. Besides, during the storage of dried *Orthosiphon stamineus* material, the moisture content of the dried leaves has to be controlled. High drying temperature would increase the loss of bioactive compounds. Therefore, the artificial drying method was used to reduce the moisture content and maintain the drying temperature. In this study, Pulsed UV Integrated Infrared Dryer System has been successfully developed by replacing the oven's radiator with an infrared lamp and drying the *Orthosiphon stamineus* leaves under 60℃. The reading of temperature and humidity level has been tested by using the SHT31 sensor while the temperature control has been maintained by PID coding using Arduino IDE software. It was observed that the Pulsed UV Integrated Infrared Dryer System in terms of moisture content, colour properties, total phenolic content and antioxidant have been significantly affected. As for the infrared drying, the antioxidant capacity and total phenolic content was increased, while for the Pulsed UV light treatment + Infrared drying, the antioxidant capacity and total phenolic content was increased compared with the fresh leaves but less than the infrared drying result. For both drying methods, the colour properties were decreased compared to the fresh leaves. As a conclusion, the study found that the Pulsed UV Integrated Infrared Dryer System was an effective method for the *Orthosiphon stamineus herb* drying to maintain its quality in term of colour, TPC and TAA, and reduce the drying time.

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