Drying Characteristics of Katuwelbatu (*Solonum virginianum* L.) during Heat-Pump Drying

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Abstract - This study was conducted to evaluate the drying characteristic of different parts of Katuwelbatu (*Solonum virginianum* L.) in a heat-pump drying (HPD) system. A HPD system of 0.62 kW was used to evaluate the drying characteristics of *Katuwelbatu* plant parts. The HPD system was established in 2.9 m × 2.85 m × 3.6 m dehumidified room. The performance of the HPD system was evaluated through the Moisture Extraction Rate (MER) and Specific Moisture Extraction (SMER) rate. A load cell-based weighing scale was designed to measure the weight loss of *Katuwelbatu* during drying and data were recorded. The roots, stem, leaves, and berry of *Katuwelbatu* plant were placed in the HPD system and the drying rates were obtained. MER and SMER value of the evaluated HPD system were0.18 kg-water/h and 0.52 kg water/kWh respectively. During 30 h of drying time in HPD system, the moisture content of leaves and stems were reduced from 83.0% to 4.0% (w.b). and 83.0% to 5.0% (w.b.) simultaneously. The moisture content of berries was reduced from 77.6 % to 46% w.b. during 96 h of drying time in HPD system. The results indicated that the required final moisture content of *Katuwelbatu* plant materials can be effectively obtained through established HPD system. Further studies are required to analyze the quality of the *Katuwelbatu* plant materials dried in HPD system.

Key words: Heat-pump drying, *Katuwelbatu*, dehumidification

1 Introduction

Katuwelbatu (*Solanum virginianum* L.) plant is a prickly herb which has spines on whole plant. The fruits are edible globularand berries, leaves are spiny and elliptical or ovate, flowers are blue and appear in cymes or sometimes solitary, and stems appear green when young and brownish when matured. Among the phytoconstituents in *Katuwelbatu*, the major constituents are alkaloid (Rane, *et al.*, 2014). Every part of the plant has various medicinal uses: i.e. an expectorant, a treatment for cough, asthma, fever, and heart diseases (Taur and Patil, 2011).

Drying, process of moisture removal due to simultaneous heat and mass transfer (Ertekin and Yaldiz, 2004) is a common method of medicinal plant preservation. Drying is an energy intensive process which causes 30% to 50% of the total costs in medicinal plant production (Qaas and Schiele 2001). Low drying temperatures between 30°C and 50°C are recommended (Müller and Heindl, 2006) to protect sensitive active ingredients in medicinal plants, but the decelerated drying processes cause a low capacity of drying installations. Drying is also a large expense (30% to 50% of the total costs) in medicinal plant production (Müller, 2007) due to high investment and energy costs.

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Strommen et al. (2002) reported that HPD consumes 60 – 80% less energy than that consumed by other dryers for the same drying temperature. The principal advantages of heat pump dryers emerge from the ability of heat pumps to recover energy from the exhaust and their ability to control independently the drying air temperature and humidity (Prasertsan, et at., 1996). Many researchers have acknowledged the importance of heat pump dryers in producing a range of precise drying conditions to dry a wide range of products and improve their quality (Prasertsan and Saen-saby, 1998, Adapa, Sokhansanj and Schoenau, 2002, Alves-Filho, 2002).

Application of heat-pump drying technique to the medicinal plant industry would be advantageous to improve the quality of the dried product and to reduce the energy consumption. Therefore, the objective of this study was to determine the drying characteristics of *Katuwelbatu* plant materials in a heat pump drying system.

2 Materials and Methods

2.1 Installation of HPD System

This research was carried out at the Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka. A HPD system (Figure 1) consists of condenser, compressor, evaporator, capillary expansion device, drying chamber, weighing scale, and control unit was installed in a 2.9 x 2.85 x 3.6 m room. Drying characteristics of *Katuwelbatu* in this HPD system was studied.

Metal housing was placed to direct the air from evaporator to condenser to facilitate air circulation of the system. The condensed water at the evaporator was collected into measuring can outside the room through a pipe connected to the evaporator. Arduino based control system was developed to control the working cycle of HPD system by tuning ON and OFF the power supply to the evaporator and compressor. The HPD system was operated as 15 min ON time and 5 min OFF time.

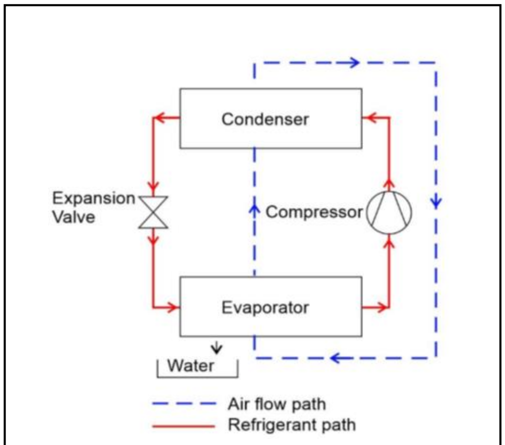

Fig. 1. Schematic diagram of HPD system

A load cell-based weighing scale was developed to measure the weight of *Katuwelbatu* samples during drying process. Three trays were placed on wooden board and three load cells were connected to the trays. The output data of load cell amplifiers were acquired by Arduino based electronic circuit system which was programmed using C language. The circuit was connected to a computer and the output data of the program were recorded using a data logger (RS232 COM ports data logger).

2.2 Evaluation of HPD system

Specific Moisture Extraction Rate (SMER) and Moisture Extraction Rate (MER) were used as performance indicators of HPD system. SMER is defined as the amount of water evaporated per unit energy measured by kg-water/kWh (Fayose and Huan, 2016). MER is the dehumidification quantity per unit time measured by kg-water/h (Liu *et al.,* 2018).

The temperature and relative humidity of the HPD system was measured using a digital RH and thermometer (Yamato Scientific Co. Ltd., Humidex YH12, Japan) and RH meter (CH-AZMT09-RH/TIM) before placing the samples. DHT22 (Aosong Electrical Co. Ltd., AM2302, China) sensor was used to acquire RH and temperature data during the HPD process. The data were recorded using Arduino microcontroller.

The current and voltage consumed by the HPD system was measured using clip-on meter (Fluke 375 True RMS, Netherland). The energy consumption of the HPD system was calculated and presented in kilo-watt hours.

2.3 Evaluation of drying characteristics of *Katuwelbatu* plant parts

The drying characteristics of *Katuwelbatu* plant parts (stems, leaves and berries) were studied in this experiment. The samples were obtained from local market and the initial moisture content of stems, leaves and berries of *Katuwelbatu* were 83±0.94%, 82±1.22% and 78±1.03% w.b. simultaneously. The samples were spread on the trays placed in the HPD system. The weight was measured by load-cell based weighting scale and the moisture content (w.b.) was calculated. The moisture removed from the product was assumed to be equal to the weight reduction at each time interval.

The drying rates of stems leaves and berries of *Katuwelbatu* were calculated and tabulated. The drying characteristic curves were obtained using these data.

3 Results and Discussion

3.1 Evaluation of the HPD system

SMER and MER performance indicators were used to test the performance of the established HPD system. *Katuwelbatu* stems, leaves and berries were tested and drying characteristic curves were obtained. The initial RH and temperature in the drying room were 86% and 26ºC respectively.

Figure 2 shows the RH and temperature variations in HPD system before placing the samples. RH and temperature were recorded for 24 h. RH of HPD system was reduced with time. The refrigerant in the evaporator absorbed the heat energy from the heated moist air and condensed the moisture. Therefore, RH in the HPD system was reduced. The temperature of the HPD system was increased from 26ºC to 30ºC within 15 h. The refrigerant transferred the heat energy in the condenser to the low moist air. Therefore, the temperature of the low moist air increased. The RH in the HPD system reached 32% and did not show a significant difference with time. The low moist heated air passing the evaporator could not reach the dew point temperature.

The drying characteristics of different parts of fresh *Katuwelbatu* plant was evaluated. The moisture content of

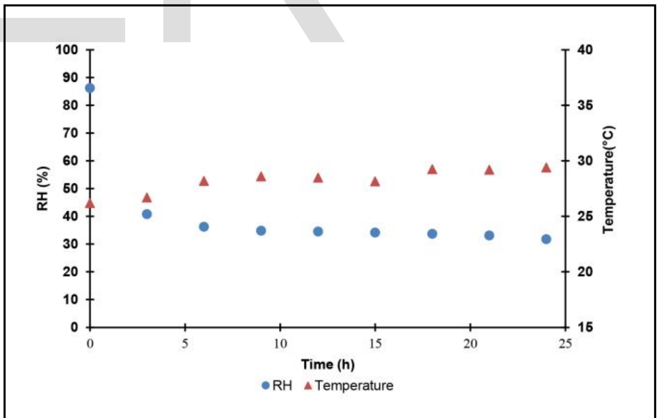

Fig. 2. RH and Temperature variation in the drying room

stems, leaves and berries of *Katuwelbatu* plant were measured in 3 h time intervals. Figure 3 shows the drying curves of stems, leaves and berries of *Katuwelbatu* plant. The initial moisture content of *Katuwelbatu* stems, leaves and berries were 83%, 82% and 78% w.b respectively in HPD system. The moisture content of *Katuwelbatu* stems and leaves were 5% w.b within 30 h and 10 h respectively in HPD system. The moisture content of fruits reached 57%, 48 h after HPD and was reduced up to 46% within 96 h in HPD. The industrial moisture requirement for *Katuwelbatu* fruits at storage condition is 10% w.b. Industry practices hot air drying (70ºC) for *Katuwelbatu* and the final moisture content of 10-12% (w.b) is achieved for 1000 kg of *Katuwelbtu* after 84

h. But the similar moisture content can be reached within 30 h in HPD system without deteriorating the color, texture and volatile compounds. In industrial drying operations, *Katuwelbatu* plant needs to be hanged in the barns. Handling of *Katuwelbatu* is difficult due to the thorny nature of the plant. Therefore, the labor consumption for industrial drying

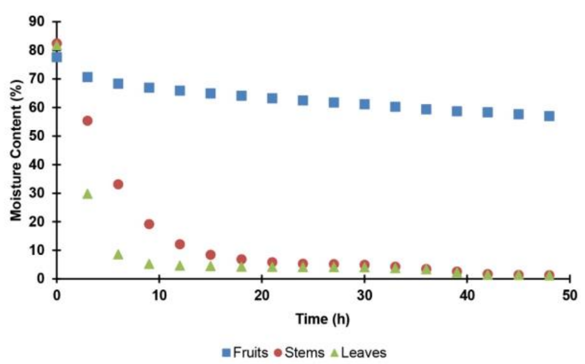

Fig. 3. Moisture content variation of the materials

of *Katuwelbatu* is high. The HPD system eliminates these problems.

The duty cycle of HPD system was 75%. Energy consumption per cycle of HPD system was 0.15 kWh. Total time per cycle was 20 minutes. Therefore, HPD system operated 3 cycles per hour. Hence the energy consumption of HPD system per hour was 0.462 kWh. The amount of water condensation was 0.23 kg/h. The calculated MER and SMER values were 0.18 kg-water/h and 0.52 kg-water/kWh, respectively. Achariyaviriya *et al.,* (2000) conducted heat pump drying for papaya glace at 50ºC and obtained MER and SMER values, 0.17 kg-water/h and 0.091 kg-water/kWh, respectively. The experimental results for HPD system indicated similar MER and SMER values for HPD as in literature.

4 Conclusions

This study concluded that heat pump drying technique is feasible for drying *Katuwelbatu* plant parts. The difficulty in material handling could be overcome through heat pump drying. The moisture content of fruits was reduced from 77.6% to 46% within 96 h. Moisture reduction of fruits takes long time of period to reach the required final moisture content of 10% due to case hardening. Therefore, as solution pretreatment application for fruit should be considered. Comparatively moisture content of leaves and stems were reduced from 83% to 4% and from 83% to 5% wet basis respectively within 30 h due to thin structure of the material. Further studies needed to be conducted to assess the quality of heat pump dried *Katuwelbatu* plant parts.

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