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Design and performance of a dehumidifier dryer and a solar-assisted dehumidifier dryer for flower drying

(Reka bentuk alat pengering penyahlembap dan alat pengering penyahlembap dibantu suria untuk pengeringan bunga)

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Key words: flower drying, solar drying, dehumidifier drying

Abstrak

Pembangunan terhadap alat pengering penyahlembap dan alat pengering penyahlembap dibantu suria telah dijalankan untuk meningkatkan kecekapan cara pengeringan gantung-dan-kering dan meningkatkan mutu bunga-bunga kering yang dihasilkan. Ujian dijalankan terhadap dua alat pengering yang telah direka bentuk untuk menilai prestasi dan kesesuaian dalam pengeluaran komersial bunga kering untuk karangan bunga. Alat pengering penyahlembap yang berkapasiti 81.5 kg/24 jam telah mengeringkan 4.8 kg daun basah daripada kelembapan 76% kepada 28% dalam masa 8 jam. Manakala alat pengering penyahlembap dibantu suria yang berkapasiti 18.5 kg/24 jam telah mengeringkan 3.8 kg daun basah daripada kelembapan 79% kepada 34% dalam masa 30 jam bagi tempoh 4 hari dengan jumlah tenaga suria harian antara 2 500 hingga 4 300 Wh/m^2. Alat-alat pengering tersebut adalah sesuai untuk digunakan bagi pengeluaran bunga kering.

Abstract

Work on the development of a dehumidifier dryer and a solar-assisted dehumidifier dryer were carried out to increase the efficiency of the hang-and-dry method of drying as well as improve the quality of dried flowers produced. Tests were carried out on the two experimental batch dryers that were designed to evaluate their performance and assess their suitability for commercial production of dried flowers. Results showed that the experimental dehumidifier dryer system equipped with a 81.5 kg/24 hours capacity dehumidifier unit was able to dry 4.8 kg of wet foliage from 76% wet basis to 28% in 8 hours. The solar dehumidifier dryer system, equipped with a 18.5 kg/24 hours capacity dehumidifier unit, managed to dry 3.8 kg of wet foliage from 79% to 34% in 30 hours over a period of 4 days with total daily solar radiation from 2 500 to 4 300 Wh/m^2. Both the dehumidifier dryer and the solar-assisted dehumidifier dryer are thus technically suitable for use in dried flower production.

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Introduction

In Malaysia, the import of dried flowers and foliages for bouquet arrangements is estimated at about RM3 million a year (Ooi 1999). However, local commercial production of dried flowers and foliage for use in bouquets and floral arrangements is negligible at present.

Drying is the most critical operation in the production of dried flowers. The most commonly used methods to produce dried flowers commercially include the freeze drying method and the hang-and-dry method.

The flowers are picked on a dry morning and artificially dried immediately inside a dark drying chamber at a low temperature of below 50 °C. This is to ensure that the quality of the flower in terms of minimal fading of colour and loss of fragrance is retained (Ooi 1998, 1999) and that it stays this way over a long period of time of at least 3–6 months. The freeze drying method is expensive and the flowers do not last under local ambient conditions. The hang-and-dry method is inefficient and produces low quality dried flowers (Ooi 1998, 1999).

In the conventional hang-and-dry method a drying-storage shed is constructed from partially enclosed corrugated zinc sheet side walls with a pitched zinc roof. Air movement around the hung bunches of foliage and flowers is provided using electric fans. With this design, the drying environment is not well sealed from light and the drying air condition fluctuates widely following the ambient air condition. The dried flowers produced are generally of poor quality.

The advantages of the dehumidifier dryer system over the conventional batch fuel fired dryer systems are (a) easily available energy supply, (b) no necessity for facilities for fuel handling and storage, (c) minimal risk of fire, (d) better quality dried products, (e) less product spoilage (e) faster drying, (f) more uniform dried product and (g) less environmental pollution.

The objectives of this study on the design, development and evaluation of a dehumidifier dryer and a solar-assisted dehumidifier dryer were to overcome the limitations and weaknesses of the conventional hang-and-dry method of drying and to improve the quality of dried flowers produced.

Materials and methods

The most important design requirement of the dryers is that the drying air temperature should not exceed 50 °C to ensure better flower shape retention and minimal colour loss (Ooi 1998, 1999).

Design and development of the dehumidifier dryer

The dehumidifier dryer consisted of a totally enclosed box measuring 3.05 m long x 1.22 m wide and 1.83 m high *(Figure 1* and *Plate 1*). The box was divided into a 2.02 m long x 1.35 m high drying chamber and a dehumidifier chamber in which a Munters PD15 dehumidifier was located. The unit was powered with a 0.64-kW compressor and a 0.18-kW fan. A 3-kW electric heater supplied hot air to the unit. The roof, floor and walls of the box were fabricated from 50 mm thick pre-laminated rigid polyurethane insulation sheets. A 0.15-m deep air duct allowed recirculation of air between the drying chamber and the dehumidifier chamber. Air circulation was provided by a 0.45 m diameter x 0.5 kW axial flow fan.

A plywood weighing platform placed over four load cells measured the total weight of the flowers during the drying process. The foliage and/or bunches of flowers were hung on a mild steel trolley rack placed over the platform. Moist air was drawn from the drying chamber into the dehumidifier chamber to reduce the humidity and reheated to provide dry warm air for drying.

Thermocouples were installed at various locations to measure the dry-bulb and wet-bulb temperatures of the re-

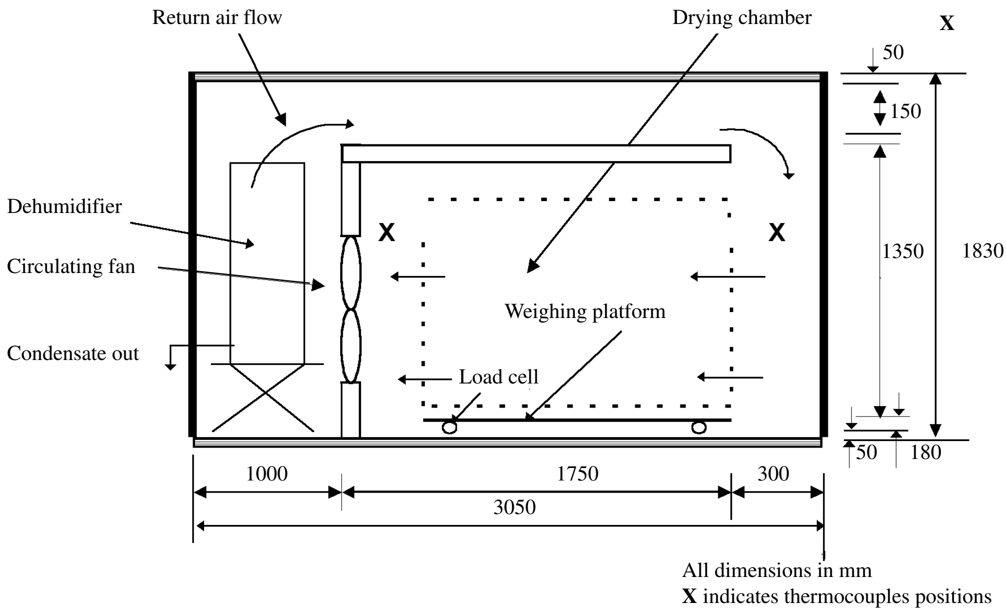

Figure 1. Sectional view of the dehumidifier dryer

Plate 1. The dehumidifier dryer

Plate 2. The solar-assisted dehumidifier dryer

circulating air as it flowed through the dryer. Ambient air conditions were also monitored. A hole was provided at the bottom corner of the dehumidifier chamber to allow water that condensed at the dehumidifier unit to be drained out and weighed at specific intervals.

Design and development of the solar-assisted dehumidifier dryer

The 3.0 m long x 1.22 m wide x 1.3 m high solar-assisted dehumidifier dryer has sides and bottom constructed from 50 mm thick rigid polyurethane slabs laminated both sides with galvanised steel panels *(Figure 2* and *Plate 2)*. The top of the box is covered with a 4-mm thick glass giving an upper exposed surface area of 3.6 m^2. The glass is fixed at an inclination of 7°. The box is positioned facing South along the North-South direction. The solar heat collector placed about 0.15 m below the glass is made of corrugated galvanized iron sheet painted black to increase its absorptivity. The box consisted of two compartments. The drying chamber had a capacity of 1.1 m^3. A 0.825-kW White-Westinghouse dehumidifier unit (WD395N8 model) was placed in the

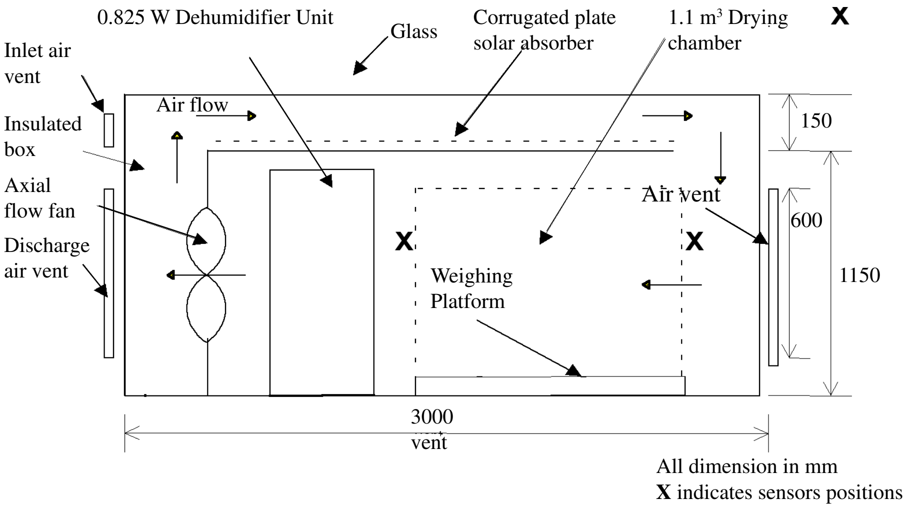

Figure 2. Sectional view of the solar-assisted dehumidifier dryer

chamber. Air circulation was achieved via the 30-mm diameter axial flow fan that gave an air flow of up to 2 000 m^3/h. A mild steel rack was constructed in the drying chamber to hang the flower and foliage bunches.

Vaisala 50Y sensors, connected to PS 5/12 power supply of Datataker 605, were used to measure the temperature and relative humidity of the re-circulating air at various locations within the drying system as well as the ambient conditions. The total incident solar radiation was measured using a SolData photoelectric pyranometer connected to the Datataker 605. Celtron load cells located under a weighing platform in the drying chamber measured the total weight of the flowers during the drying process. The condensed water from the dehumidifier unit was drained out and weighed.

After bleaching and washing, the foliage were tied in small bunches and placed on the trolley rack in a soaking wet condition and allowed to drip dry for about 1–2 hours before loading into the mild steel rack on top of the loading/weighing platform. The dehumidifier unit was set to operate at 45% RH and 40 °C. The dryer box doors were then shut and the dehumidifier unit and blower started. Air temperatures and weight of condensed water from the dehumidifier unit were recorded at one hourly interval.

Results

Performance of the dehumidifier dryer

The total weight of the wet foliage after drip-drying was 4.8 kg. The moisture content of the foliage measured using the oven-dry method was 76% wet basis (wb). The temperature and relative humidity of the air at the outlet of the drying chamber was about the same as those at the inlet of the dehumidifier unit compartment. After the dehumidifier unit was switched on the air was heated up steadily from 48–55 °C. The corresponding relative humidity of the dehumidified air was steadily reduced from 55% to 32% RH. The weight of water removed from the foliage, based on the load-cell/platform readings showed the amount of water removed decreased from 1.2 kg after the first hour of drying to less than 0.01 kg after 8 hours of drying. The drying rate decreased exponentially after the second hour of drying. The total weight of the foliage after the drying was 1.6 kg and the moisture content at the end of the test was measured at 28% wb which was considered sufficient for the dried flower industry *(Figure 3)*.

Performance of the solar-assisted dehumidifier dryer

The initial total weight of the wet foliage was 3.8 kg and its moisture content was 79% wb. At the commencement of drying process, the dryer was operated as an aerator to remove surface moisture from the flowers and foliage. Ambient air was heated up as it was drawn over the solar collector. The hot air was then circulated through the drying chamber and exhausted into the atmosphere without switching on the dehumidifier unit. When the surfaces of the flower and foliage appeared dry, the inlet and outlet vents of the dryer box were closed and the dehumidifier unit was switched on.

The aeration process (with solar drying) to remove the surface water took about 2 hours. Solar-assisted dehumidifier drying was carried out. The dehumidifier unit and the blower were turned off after 8 hours of drying. The weight of water removed from the foliage after the first 8 hours was 1.1 kg. The total solar radiation incident during this period was very low, about 2 453 Wh/m^2. An average day would result in about 4 500 Wh/m^2 (Ong 1999). The next two days were sunnier with total solar radiation of about 4 334 and 3 833 Wh/m^2 respectively. Drying test was continued until the fourth day. The total weight of the foliage after drying was 1.2 kg and its moisture content was 34% wb *(Figure 3).*

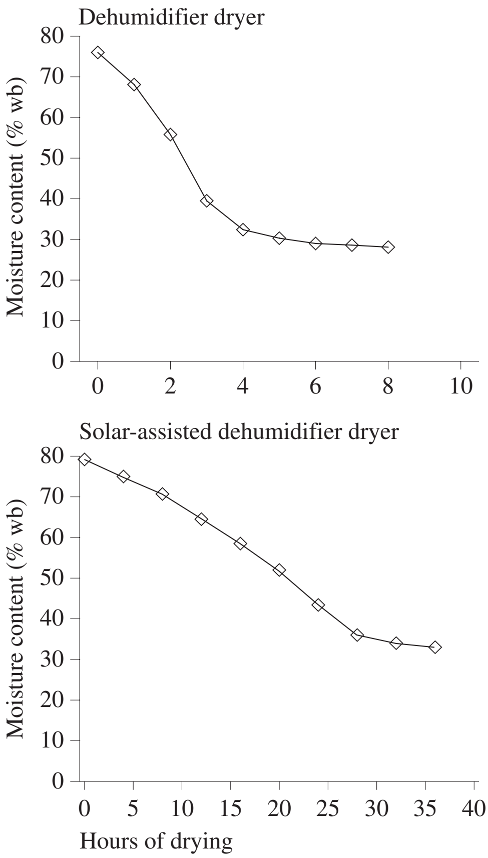

Figure 3. Foliage drying curves of dehumidifier dryer and solar-assisted dehumidifier dryer

Discussion

The results above showed that the dehumidifier dryer equipped with a 81.5 kg/24 hours capacity dehumidifier unit was able to dry 4.8 kg of wet foliage from 76% wb to 28% in 8 hours. The solar-assisted dehumidifier dryer with a 18.5 kg/24 hours capacity dehumidifier unit managed to dry 3.8 kg of wet foliage from 79% to 34% in 30 hours over the 4 days. The total daily solar radiation over the 4 days varied from 2 500 to 4 300 Wh/m^2. Technically, both the dehumidifier dryer design concept and the solar-assisted dehumidifier dryer design concept are suitable for use in the design of commercial dryers for flower drying.

Further research work is suggested to incorporate the solar-assisted dehumidifier dryer design concept into the design of a pilot-scale dryer-storage kiln for commercial production of dried flowers.

Conclusion

The dehumidifier dryer and the solar dehumidifier dryer has been successfully developed for drying of flowers and foliages. The dehumidifier dryer could dry 4.8 kg of wet foliage from 76% wet basis to 28% in 8 hours while the solar-assisted dehumidifier dryer could dry 3.8 kg of wet foliage from 79% to 34% in 30 hours over a period of 4 days with total daily solar radiation from 2 500 to 4 300 Wh/m^2.

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