YOUNG COCONUT WASTE AS GREENER DESICCANT ALTERNATIVE IN DESICCANT DEHUMIDIFIER

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Abstract: Due to tropical climate in Malaysia, humidity control becomes a challenge, hence dehumidifiers are designed to control the relative humidity in order to achieve the optimal thermal comfort. In existing desiccant dehumidifiers, the desiccants used are mostly hazardous to environment and people due to its property. Therefore, this research proposes young coconut waste as an alternative adsorbent for desiccant dehumidifier. The performance of the coconut coir is evaluated via dehumidifying duration of a 100 sqft room with initial relative humidity of 72%. The recorded data are compared to the same-sized desiccant filters from silica gel, calcium oxide and calcium sulphate. The RH Delta value demonstrates that the humidity adsorptivity performance rank is dominated by calcium sulphate (0.129), followed by young coconut waste (0.086), silica gel (0.086) and calcium oxide (0.043) in descending order. This indicates that young coconut waste is as competitive as silica gel, which is a common commercial desiccant. Moreover, young coconut waste has the lowest formaldehyde average emission that is 0.058 ppm compared to 0.06 ppm by calcium oxide. This exhibits that young coconut is not only competitive in terms of humidity adsorptivity, but also environment-friendly and is therefore very attractive to replace chemical desiccant in dehumidifier.

Keywords: Dehumidifier; Coconut coir; Solid Desiccant.

1.0 INTRODUCTION
In Malaysia, high humidity level acts as a trigger for the mold growth. It is synonym as the root cause of respiratory discomfort and allergies [1]. Dehumidifiers can be classified into two types that are desiccant and compressor dehumidifier. Desiccant dehumidifier is less bulky and have a consistent system or
performance despite changes in temperature. Conventional desiccant dehumidifier uses calcium chloride or calcium oxide to collect moisture from the air, but these chemicals are hazardous and carcinogenic substances, when are inhaled continuously by home occupants. In contrast to calcium chloride salts, silica gel is a safer dehumidifier desiccant that is incredibly effective at removing unwanted moisture from an environment. However, the disposal of silica gel is not an easy task, where silica gel waste should be packed in thick plastic bags or sealed drums. It also should be disposed by following the guidelines for chemical waste disposal. Besides calcium chloride, the most commonly used desiccant materials are lithium chloride, triethylene glycol, silica gels, aluminum silicates (zeolites or molecular sieves), aluminum oxides, lithium bromide solution, and lithium chloride solution. Every each of those have their own hazard to human health [2].

Desiccant is a hygroscopic substance that attracts the moisture due to vapor pressure difference. Desiccants can be classified into many ways e.g. solid or liquid, physisorption or chemisorption, natural or artificial, bio or rock based, composite and polymer-based desiccants etc [3]. Liquid desiccant is more efficient to dehumidify humid air with low-temperature regeneration heat, while the solid desiccant can effectively dehumidify drier air with higher temperature regeneration heat [4]. Many studies have been conducted on the properties of desiccant materials such as silica gel, alumina, carbon black, and polymers. They are common desiccants used in desiccant wheel dehumidification systems [5]. Silica gel displays an average ability to dehumidify air and a mediocre total amount of dehumidification for various levels of relative humidity. Polymer desiccant has been researched widely in recent years. If compared to silica gel in high humidity and low regenerated temperature environments, polymer desiccant displays a superior total amount of adsorption and higher transient adsorption rates [6].

Because most of these materials are expensive and hazardous, researchers are encouraged to search for new and more economical alternatives. The environmental impact of desiccants has also been studied. Replacing chemical desiccants, including silica gel and calcium sulphate, with natural fiber is a new and sustainable approach [7]. High-fiber agricultural wastes are potential desiccant candidates for use in desiccant dehumidification applications [8]. The feasibility of air humidity adsorption by dry coconut coirs and dry durian peels have been studied for applications in open-cycle air conditioning [9].

Specifically in Melaka, there is abundant young coconut waste due to famous local operated coconut shake businesses. The young coconut waste produces unpleasant smell to the surrounding and causes air pollution. This is very uncomfortable for residential area. Apart from that, the waste causes landfill problem due to its large size and fill the waste disposal site promptly. The disposal of the young coconut waste also involves transportation cost and if it is too large in quantity, it also involves disposal service cost. This waste can be converted into wealth by processing it into desiccant due to its humidity adsorptivity characteristic. By using the young coconut waste as an alternative desiccant filter in dehumidifier, the environmental problem and air pollution can be prevailed.

2.0 METHODOLOGY

2.1 Drying of Coconut Coir

The young coconut waste was collected from young coconut stalls in Melaka at several areas, mainly from Melaka Tengah region such as Batu Berendam and Bukit Katil. In order to get smaller grain size of material for the sieving and drying process, the young coconut waste was crushed in coconut crusher TC40, which uses impact cutting. The crushed raw material went through a pre-drying for 1 hour at temperature of 105°C to decrease the moisture content until the raw material can be sieved. The young coconut waste grain was manually sieved into less than or equal to 1mm size. Finally, the young coconut waste undergoes further drying process at temperature of 95 °C. The dried young coconut waste is then packed into a filter housing of size 41.5 x 41.5cm.
2.2 Determination of Dehumidification Performance of Young Coconut Coir

According to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) thermal comfort can be defined as “condition of mind which expresses satisfaction with the thermal environment” [10]. Field study was conducted basis of questionnaires and surveys for thermal comfort in Malaysia. Regression results temperature was 24.4°C with comfort zone range from 23.1°C to 25.6°C. More than 80% occupant felt comfort with relative humidity within range of 74% - 83% (humidity ratio 0.01324 - 0.016904 kg/kg). The standard indoor thermal comfort by Pusat Tenaga Malaysia (PTM) shows that temperature range is between 23°C and 26°C with relative humidity of 60% to 70% (humidity ratio 0.01052–0.01479 kg/kg) [11].

In this project, the dehumidification performance of coconut coir is tested and analyzed. The results are compared to a few other chemical desiccants, that are calcium sulphate, calcium oxide and silica gel. In the study, the capability of humidity adsorptivity of every desiccant is observed. The experiment is conducted in a 100 sqft room. Figure 1 shows the dehumidifier simulator used to collect the data of dehumidification period of each filters. The simulator is designed according to a real desiccant dehumidifier concept. The initial room humidity air is sucked into the dehumidifier through the inlet. The moisture in the inlet air is mixed by a propeller, so that the humid air is distributed evenly before being adsorbed by the desiccant filter. The dehumidified air is then blown out into occupant’s room via an outlet fan. Once the desiccant achieve 50% of moisture level, the heater with blower is turned on to dry and regenerate the desiccant to its dry state, so that it can be reused to adsorb moisture. To ensure the system working continuously in a cycle, water vapour adsorbed must be driven out from the desiccant material (regeneration) via heating so that it can be dried enough to adsorb water vapour in the next cycle. The hot air and moisture from the heater blower is sucked out to the outside room through an exhaust fan.

The relative humidity of the room is observed for 2 hours using coconut coir, silica gel, calcium oxide and calcium sulphate simultaneously as the desiccant filter for the dehumidifier. The data are recorded at room temperature at 23°C. The room is conditioned by an air-conditioner. Theoretically, desiccants capable to adsorb moisture more effectively with decrease in temperature.

2.3 Emission Test for Formaldehyde

Chemical substances used as desiccant in desiccant dehumidifier can emit various kinds of hazardous substances when heated including formaldehyde that have an impact on indoor air quality and can be harmful to human health. Many countries have established mandatory or voluntary rating systems to control emissions of formaldehyde. In 2010, the World Health Organization (WHO) established an indoor air quality guideline for short- and long-term exposures to formaldehyde (FA) of 0.1 mg/m(3) (0.08 ppm) for all 30-min periods at lifelong exposure [12].
Formaldemeter htV-m is used to measure the amount of formaldehyde emitted by the desiccants when heated to approximately 70°C (uncontrollable heater temperature). The readings are recorded for each desiccant filters at 15 minutes, 30 minutes and 45 minutes during the heat application on the desiccants (regeneration process).

3.0 RESULTS AND DISCUSSION

From results in Figure 2, it can be extracted that young coconut waste follows the same pattern as calcium sulphate in humidity adsorption. However, calcium sulphate shows higher rate of adsorptivity compared to other desiccants. At certain points of every desiccant, the relative humidity became higher than their 15 minute-previous point. These points occur most probably just before the regeneration process, whereby the related desiccants were unable to continue adsorbing humidity until the humidity is removed from them. Since the graphs in Figure 2 are hard to be interpreted to get the actual humidity adsorption performance of every desiccant, difference of relative humidity (RH) between every point and its previous adjacent point or known as RH Delta was calculated and accumulated. The RH Delta average of every desiccant was then calculated and is depicted in Figure 3.

The average of RH Delta in Figure 3 illustrates that the humidity adsorptivity performance rank is dominated by calcium sulphate, followed by young coconut waste and silica gel and the last place goes to calcium oxide. This shows that young coconut waste has a quite good performance and as competitive as silica gel and even better than calcium oxide. This also indicates that young coconut waste is a good desiccant and qualified to be utilized in a desiccant dehumidifier.
The desiccant from young coconut waste is further tested in terms of its formaldehyde emission. The result is to be compared with other chemical desiccants. Figure 4 demonstrates the formaldehyde emission for every increasing 15 minute-duration. Silica gel and calcium sulphate do obviously show the increasing trend of formaldehyde in parts per million (ppm) outlet air. However, calcium oxide demonstrates the opposing behavior, most probably due to formaldehyde elimination caused by chemical reaction of calcium oxide and formaldehyde. Whereas, young coconut waste shows some reduction of formaldehyde at the first 30 minutes of experiment and back addition at minute 45. This is most probably due to the cellulosic structure of the young coconut waste.

To see the formaldehyde emission contribution of every desiccant more clearly, the average formaldehyde in ppm for the whole 45 minute-duration was calculated for every desiccant and is depicted in Figure 5. From the Figure 5, young coconut exhibits the lowest
formaldehyde emission compared to other chemical desiccants. This indicates that young coconut waste is favorable as desiccant as it is more environment and human health friendly.

![Formaldehyde Emission During Desiccant Regeneration](image1)

**Figure 4.** Formaldehyde Emission During Desiccant Regeneration (Heating Process) in ppm vs Duration

![Average Formaldehyde Emission vs Desiccants](image2)

**Figure 5.** Average Formaldehyde Emission in ppm vs Desiccants

### 4.0 CONCLUSION

From the result data, there are several findings that can be listed out as following:

1. Calcium sulphate, young coconut waste, silica gel and calcium oxide exhibit the humidity
adsorptivity in descending order.

2. Young coconut waste humidity adsorptivity is as competitive as silica gel’s, allowing it to be a new organic desiccant to replace the existing commercial chemical desiccants.

3. Young coconut waste shows the lowest formaldehyde emission, which is 0.58 ppm in average in 45-minute duration.

4. Young coconut waste is not only as competitive as other chemical desiccants in terms of humidity adsorptivity, but it also the most human health friendly as it has the lowest formaldehyde emission at outlet air; therefore the most favorable desiccant among other chemical desiccants.

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