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The effect of temperature on low temperature vacuum drying with induced nucleate boiling for stingless bees honey

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Abstract. Low Temperature Vacuum Drying (LTVD) with induced nucleate boiling is a new method that has been invented to reduce the water content of honey at a lower temperature without damaging the nutrient content of honey. The objective of this study is to investigate the effect of temperature on the dewatering rate by this LTVD method. The honey sample was placed in a pressure vessel and the air from the vessel was removed to create a vacuum condition. This experiment was conducted by using three different temperature which was 40 °C, 45 °C and 50 °C. The honey sample was dewatered for 5 minutes and each condition was repeated three times. The water content before and after the experiment was measured by a digital refractometer. Final water content decrease from 26.5 % to 25.1 % from temperature 40 °C to 50 °C. The dewatering rate increase from 0.14 %/min to 0.28 %/min when the temperature increase from 40 °C to 50 °C. The highest dewatering rate was obtained at 50 °C. However, considering the quality conservation of honey, it is suggested to apply a temperature of 45 °C to get a high dewatering rate while considering the quality of honey. It could be concluded that the temperature effect the final water content and dewatering rate of honey.

Keywords: LTVD; Nucleate Boiling; Dewatering; Stingless Bees Honey.

1. Introduction

Honey is a primary product of bees which is generally known as a natural remedy that obtains from flower nectar or honeydew. Stingless bees (Meliponini) is one of the bee species that can produce honey and play an important role in flower pollination. Stingless bees produce three main products such as honey, bee bread and propolis. Each product has its advantages that beneficial for its users. Stingless bees honey (SBH) is known for its high nutritious and therapeutic value. SBH also has stronger antioxidant properties compared to other honey types [1]. In recent years, SBH has been introduced to the public in Malaysia as a nutritious superfood rich with health benefits. The specialty of SBH is it has a unique taste which is a little sour and has a unique aroma that makes it different



from other honey. Nowadays, there was a lot of improvement in the development of meliponiculture (stingless bees keeping) technology, this includes bee bread dryer, propolis extractor, honey extractor and also honey dryer.

Water content is one of the parameters that determine the quality of honey. Honey with high water content tends to ferment easily. SBH has been reported contain higher water content, acidity, ash and HMF but low total sugar compared with honey from honey bees (*Apis Mellifera*) [2]. Honey spoilage is the main problem in storing SBH as it has high water content. To overcome this issue a drying process is required to reduce water content while preserving honey's nutritional content. Department of Standards Malaysia (2017) suggested that the water content of SBH should be kept below 22%. Since honey is known as heat sensitive material, the process should consume low temperature to drying honey. High dewatering temperatures could damage the nutrition content of honey. As reported by Tosi et al., heating led to a reduction in honey quality as the diastase activity decreases and hydroxymethylfurfural (HMF) content increases [3].

In order to lower the temperature for the drying process, the process should consume low pressure or vacuum condition to lower the boiling point of the material. This technique is well recognized as low temperature vacuum drying (LTVD). LTVD is commonly used to reduce the water content from heat sensitive materials such as food, pharmaceuticals and biological products [4]. There are various types of LTVD available including microwave vacuum drying, freeze-drying, vacuum evaporation, vacuum drying and spray drying. Microwave vacuum drying was able to enhance the reduction of water content honey, but the radiation emitted from the microwave can damage the nutrient content of honey [5]. While freeze-drying works by freezing the material and reduce the pressure surrounding it to sublimate the frozen water in the material [4]. However, this method is costly as it consumes a large amount of energy to freeze and dehydrated material [6]. Vacuum evaporation invented by Shinya et al., was able to dry the honey, but this method is very costly to operate [7]. Meanwhile, vacuum drying developed by Tabouret (1977) manages to reduce about 4 % of the water content of honey within 90 minutes at 68 °C [8]. However, the operating temperature was considered too high for drying honey. There is also spray-drying combine with LTVD, but this method can only producing a dry powder from a liquid and operation temperature was exceed the limit for drying honey [9]. Therefore, an LTVD with induced nucleate boiling has been developed to meet a requirement for drying honey without jeopardizing its nutritional content [10].

Nucleate boiling is a phase in which bubbles nucleate, grow and depart from the heated surface. This type of boiling is the most desirable for the chemical process due to the high heat rates. The performance of LTVD with induced nucleate boiling could be affected by temperature. As reported by Kretavičius et al., heating honey below 50 °C does not affect the enzyme activity in honey [11]. Therefore, to prevent degradation of the honey quality, it should be heated at temperatures below 50 °C. From the literature review, there is no study reported on the effect of temperature at range 40 °C, 45 °C and 50 °C on LTVD with induced nucleate boiling dewatering honey. Therefore, the objective of this study is to investigate the effect of temperature on the dewatering rate of SBH.

2. Materials and methods

SBH sample used in this experiment was obtained from a farm at Padang Terap, Kedah, Malaysia and stored in bottles. Figure 1 shows an experimental setup that has been developed to dewatering 200 g of honey. 200 g of honey sample was placed in a pressure vessel that was connected with a vacuum pump to create a vacuum condition. A pressure gauge was used to monitor the pressure inside the vessel. A stainless steel tube was used as a heating element that transfers heat to dry the honey sample inside the vessel. For heating the honey sample, water inside the water tank was heated until obtaining the required temperature and the water pump was used to transfer hot water from the water tank to stainless steel inside the vessel then flow inside the water tank again. Temperature inlet, outlet and honey were monitored by using thermocouples. Three different temperatures were conducted which were 40 °C, 45 °C and 50 °C to investigate the effect of temperature on the dewatering rate of honey. The pressure was set at -96 kPa for every experiment. The initial and final water content of honey was

measured by using the digital refractometer ATAGO. The honey sample was dewatered for 5 minutes and the process was repeated 3 times for each temperature. The dewatering rate was determined by using Equation 1:

$$\eta_D = \frac{\Delta W_h}{t} \quad (1)$$

where η_D is dewatering rate [%/min], ΔW_h is the changes in water content [%] and t is the time take for the dewatering process [min].

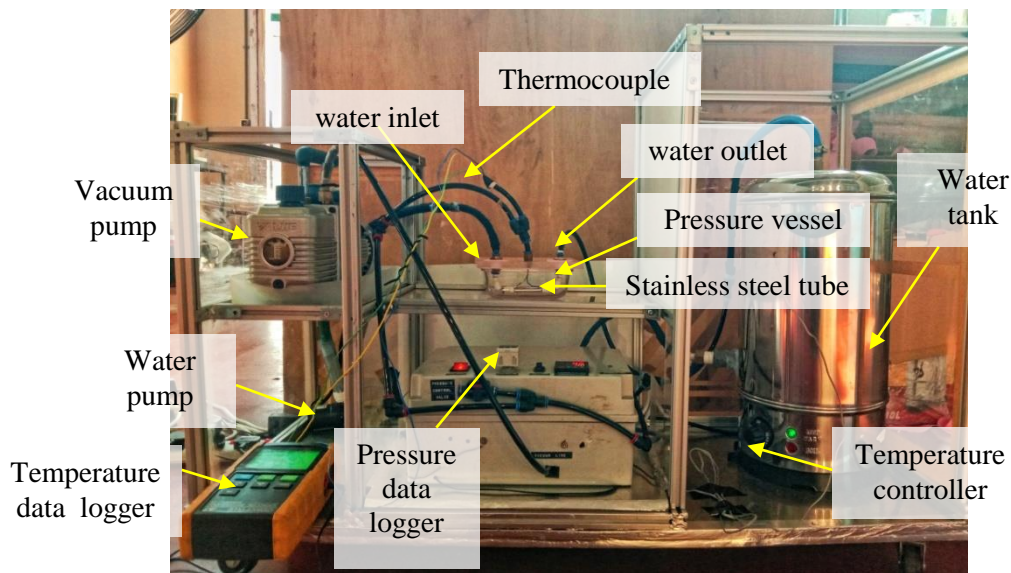


Figure 1. Experiment setup

3. Result and discussion

Figure 2 shows the graph of the average water content of SBH for each temperature after the dewatering process for 5 minutes. While Figure 3 shows the dewatering rate for each dewatering temperature. It shows the highest reduction of water content was at 50 °C which was reduced from 26.5 % to 25.1 %. As the result at temperature 50 °C could obtain the highest dewatering rate than others which was 0.28 %/min. However, it is not suitable for honey to be heated at 50 °C because it could overshoot and exceed the temperature limit for drying honey that can damage the nutrient content of honey. The lowest reduction of water content and dewatering rate was at temperature 40 °C which was only reduced by 0.7 % from initial water content and the dewatering rate was 0.14 %/min. While dewatering at temperature 45 °C was able to reduce from 26.5 % to 25.8 % water content after 5 minutes and the dewatering rate was around 0.16 %/min. The same trend also was observed by Ramli et al., higher dewatering temperature resulted in a much faster water removal rate [12]. The water content decreases faster at higher temperatures due to the increases in temperature difference between the sample and the heating element [13].

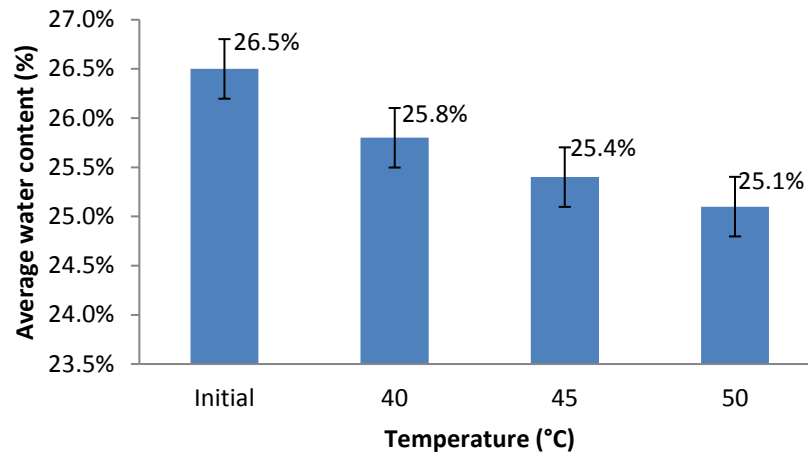


Figure 2. The average water content of SBH after the dewatering process

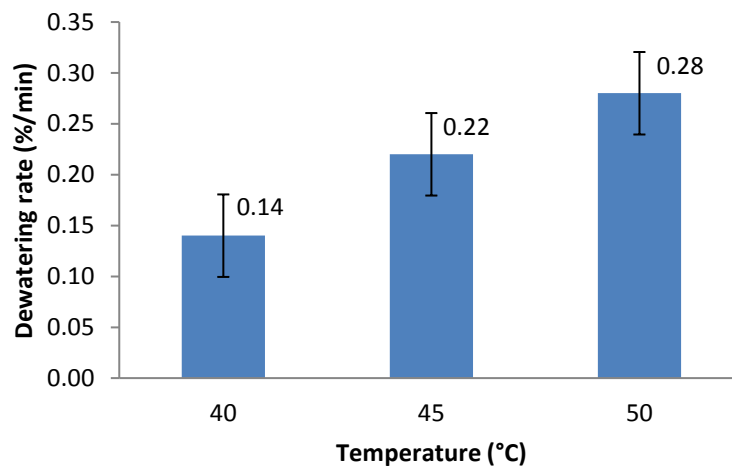


Figure 3. Dewatering rate for each dewatering temperature

From the result, the dewatering rate at 45 °C in this experiment was slightly higher from the previous study by Ramli et al., [12] which also uses LTVD with induce nucleate boiling method to reduce the water content of honey below 20 %. The dewatering rate at 45 °C from the previous study was around 0.2 %/min while in this experiment was 0.22 %/min. This different result due to the initial water content of honey which was the initial water content used in the previous study was around 26 % while in this experiment was around 26.5 % which was also slightly higher than the previous study. Dewatering rate higher at higher water content due to the evaporation of the remaining free water content [14]. At lower water content higher energy was needed to evaporate the bound water make the dewatering rate decrease.

Figure 4 shows the dewatering rate from the present study and other methods. The dehumidifier invented by Paysen shows the lowest dewatering rate which is approximately 0.00033 %/min. This method can reduce 0.6 % water content of 57 tonnes of honey in 30 hours [15]. Tabouret reduces the water content of honey with low pressure vacuum and the dewatering rate was about 0.044 %/min at 68 °C [8]. However, the dewatering temperature used is considered too high for dewatering honey.

Meanwhile LTVD with induced nucleate boiling by Ramli et al., able to reduce the water content at the rate of 0.2 %/min at 45 °C which is 5 times faster than the dewatering rate achieved by Tabouret [12]. Meanwhile, the dewatering rate from the present study with the same dewatering temperatures was around 0.22 %/min which is showed an increment due to initial water content. Microwave vacuum drying shows the fastest drying method compare to others as the dewatering rate of this method is around 2.56 %/min [5]. However, this method cannot be considered as the best method because the radiation emitted from the microwave has the potential to damage the nutrient and quality content of the honey [16]. Thus, LTVD with induced nucleate is the better method for dewatering honey without causing damage to the nutrition content of honey compared to other methods.

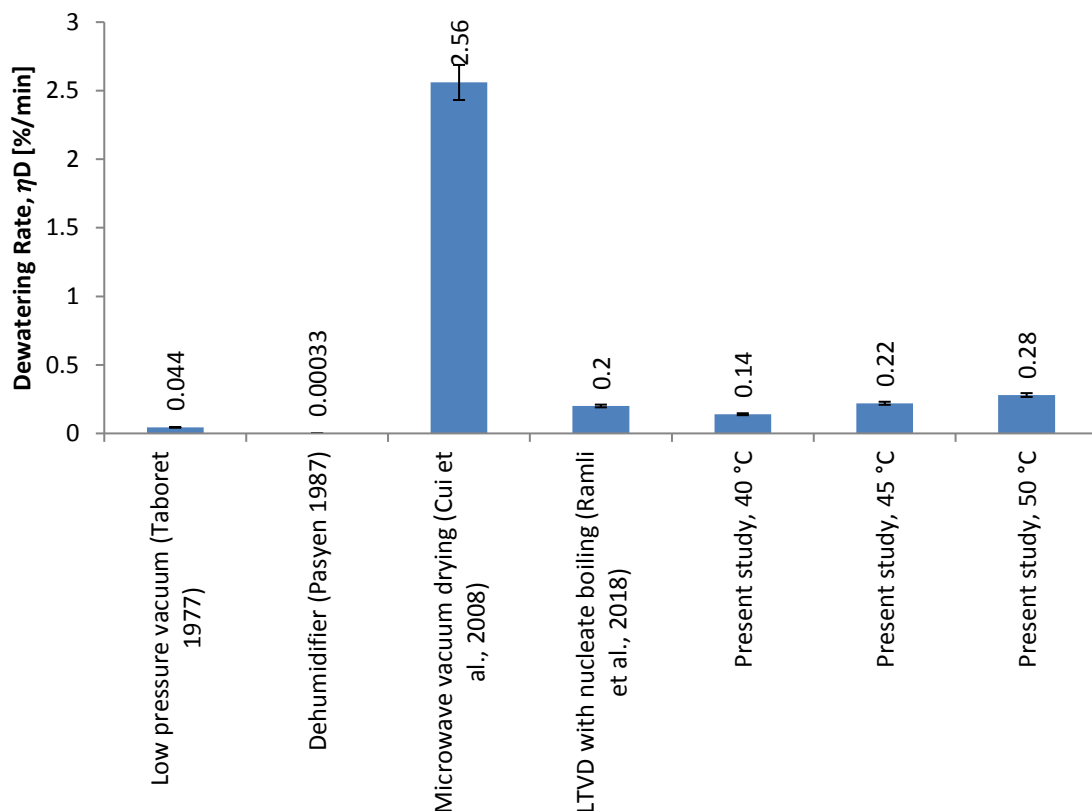


Figure 4 Comparison of the dewatering rate of the present study with other methods

4. Conclusion

The performance of LTVD with induced nucleate boiling increases as the dewatering temperature increase. From the range of 40 °C to 50 °C, the final water content of honey was decreased. Thus the dewatering rate increase as the water content decrease. The highest dewatering rate was at temperature 50 °C, but this temperature is not suitable for heating honey. Dewatering honey at 45 °C was highly recommended to minimize the deterioration of honey quality during the dewatering process.

Acknowledgments

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