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Multi-Angle Swirling Fluidized Bed Drying Of Stingless Bees Pot-Pollen

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Abstract. Pot-pollen is another stingless bee product, a mixture of pollen, honey, and bee enzyme stored in cerumen pots. Pot-pollen is protein rich and have therapeutic properties. However, they contain high moisture rendering them susceptible to microbial and fungi growth which will lead to spoilage without proper storage. Conventional methods to remove moisture includes sun drying, oven drying, and food dehydrators. However, they can be unhygienic, reduce pot-pollen quality, and lengthy drying time. Swirling fluidized bed dryer (SFBD) is a promising alternative as they have rapid drying time without damaging the nutrients. The addition of multi-angle swirling distributor (MASD) has the potential to improve drying performance without additional energy input. The current study aim to investigate the drying performance of swirling fluidized bed dryer with multi-angle distributor. Raw pot-pollen is dried in a lab scale SFBD at 3.0 m/s using single angle and multi-angle swirling distributors, 6767, 6730, and 6745. The results shown that the multi-angle swirling distributors 6730 and 6745 improved the drying performance of SFBD, by 17.1 % and 6.5 %, respectively. The best drying performance is shown by the 6730 distributor. Thus, multi-angle SFBD is able to rapidly dry the heat-sensitive stingless bee pot-pollen and represented significant improvement from single angle SFBD.

1. Introduction

Sweet and tangy honey is what usually comes to mind when stingless bees are mentioned [1]. As an industry largely represented by its honey production, it has huge market potential, the projection stood at RM 3.03 billion in Malaysia alone [2]. In Malaysia, the popularity of stingless bees are due to its honey as a local alternative for authentic honey, as most honey in the market are reported to be fake [3]. On the other hand, lesser known products of stingless bees including propolis and pot-pollen (bee bread) [4]. Combination of these products from stingless bees can facilitate the industry to achieve its full potential.

Pot-pollen is a substance produced by stingless bees by mixing pollen collected from flowers, honey, and bee secretion, sealed to ferment in cerumen pots inside their hives [5]–[7] This wonderful concoction is another beneficial product from stingless bee containing exceptional levels of proteins[8]. They also contain all the essential amino acids [9], and antioxidants [10][11][12][13]. Pot-pollen also found to show antimicrobial properties[14] [15]. However, excessive heating when drying may result in depletion of their levels of beneficial composition. Eventhough pot-pollen are loaded with nutrients and therapeutic benefits, they are not usually harvested by beekeepers and sometimes they are simply thrown away by beekeepers to provide space for honey production inside stingless bee hives [16]. This is due to the difficulty in storage after harvesting pot-pollen. Raw pot-pollen need to be frozen to prevent microbes and fungi build up, leading to spoilage. Containing high moisture content, pot-pollen provides a favourable condition for microbes and fungi growth which can lead to spoilage. Thus, to prevent such occurrence, suitable drying method to remove moisture down to acceptable levels is essential.

The traditional method for drying is via sun drying. This method involves spreading out the raw product and exposing them under direct sunlight. This method is unhygienic as it exposes pot-pollen to contaminants. Besides, ultraviolet radiation from the sun and the heat can destroy beneficial pot-pollen contents. Alternatively, pot-pollen can be dried using oven or food dehydrator. Although they are more hygienic and cleaner, the heat can cause loss of nutrient, and these methods may take a long drying time [17]. Thus, a drying method which can rapidly dry stingless bee pot-pollen without harming its content is highly desirable.

Swirling fluidized bed dryer (SFBD) is a promising alternative to dry stingless bee pot-pollen. SFBD differs from conventional fluidized bed such that the fluidizing air inside the chamber is at an inclined angle to induce swirling motion [18]. This swirling motion and fluidization quality is affected by the inclination angle and ultimately can dictate how particles behave inside a SFBD [19]. Previously, SFBD has been shown to dry pot-pollen much more rapidly dried with minimal effect to their natural compositions, compared to conventional methods [7]. As temperature is the limiting factor for drying heat-sensitive materials, there is a need to explore different parameter configurations to enhance drying performance, sans heating. A prior study on pot-pollen drying using SFBD with 67° swirling angle has managed to increase the drying rate by increasing the superficial air velocity[20]. However, the energy consumption will also increase with increase in velocity. Thus, another suitable alternative need to be explored. A swirling distributor may be modified to employ a multi-angle configuration instead of a single swirling angle in previous studies. This multi-angle configuration may enhance drying performance without additional energy requirement as just the distributor design is altered. Hence, this study proposes adapting multi-angle swirling distributor in SFBD to enhance drying performance without increasing velocity. Thus, the aim of the current study is to investigate the drying performance of multi-angle swirling fluidized bed dryer for drying stingless bees pot-pollen.

2. Methodology

Pot-pollen samples used in this study is obtained from a stingless bee farm in Binjai, Kemaman, Malaysia. The pot-pollen are collected from hives of *Heterotrigona itama* species, one the common species reared in Malaysia. Raw pot-pollen is harvested intact within cerumen pots to avoid mixing with pot-honey. Prior to drying experiment, pot-pollen is cleaned and removed from their pots and stored at -10 °C. Pot-pollen drying experiment is conducted using a lab scale SFBD at Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan, Malaysia. Figure 1 below shows the schematics of the lab scale SFBD setup for the drying experiment.

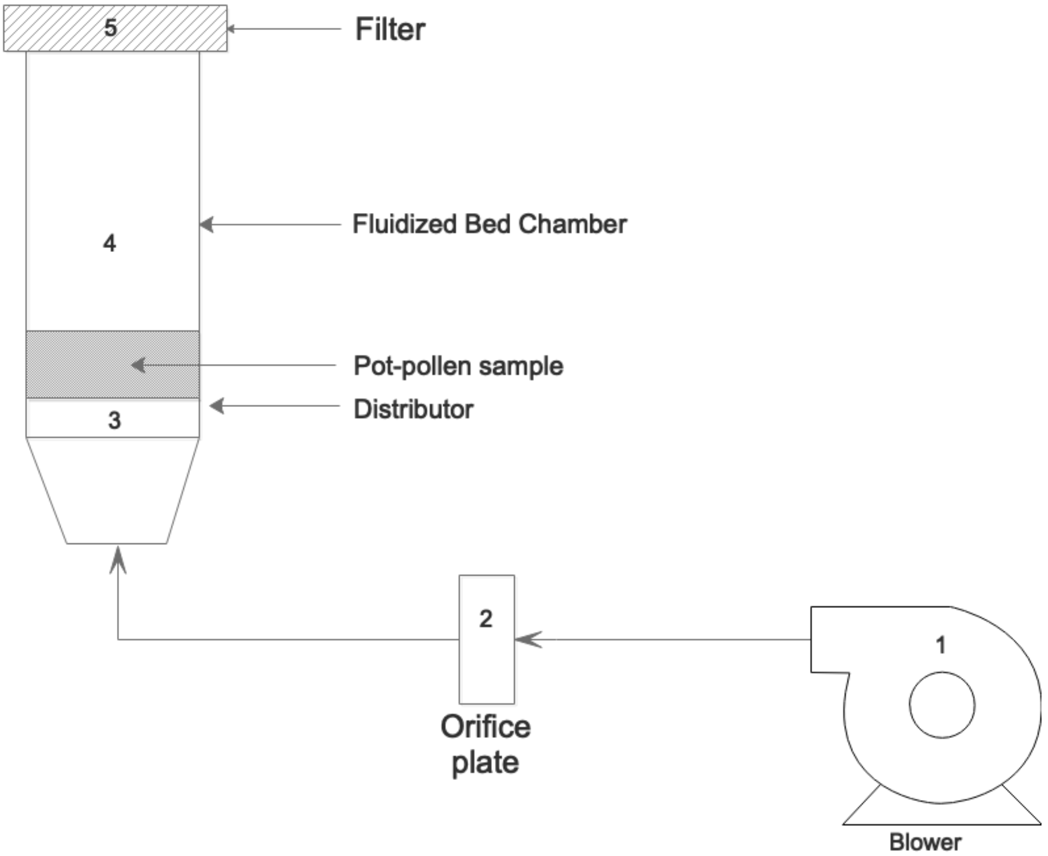

Figure 1: Schematics of swirling fluidized bed dryer (SFBD)

The setup consists of 1) a centrifugal blower, which provides the fluidizing air in the study, attached to a motor speed controller, to control the inlet air velocity, 2) an orifice plate, connected to a manometer for velocity measurement, 3) a swirling air distributor for inducing swirling motion of inlet air, 4) a drying chamber where the pot-pollen sample will be dried, and 5) a filter to prevent sample escaping the chamber. The drying chamber has the outer and inner diameters of 50 mm and 43.75 mm, respectively. Three swirling air distributors with different single angle and multi-angle combinations are used in the current study as illustrated in Figure 2. The angle combinations used for this study are 67°+ 67°, 67°+ 30° and 67°+ 45°, and denoted as 6767, 6730, and 6745 distributors, respectively. The distributors are designed such that the first and second angle are in alternate configurations. It can be seen from the figure the vertical and horizontal slots are set according to first angle, and the alternating sequence, in between first angle slots, the second angle slots as shown in Figure 2.

For the drying experiment, a 6767 swirling distributor is installed at the inlet of the drying chamber. The motor speed controller is set such that the velocity of the fluidizing air is at 3 m/s. The setup is run without sample for around 10 minutes prior to experiment to achieve steady state. A pot-pollen sample of 25 g is weighed and placed inside the drying chamber. The sample is weighed at 5 minutes interval for 60 minutes. Then, the experiment is repeated with the 67°+30° and 67°+45° swirling distributors. Figure 3 provides the graphical drying procedures.

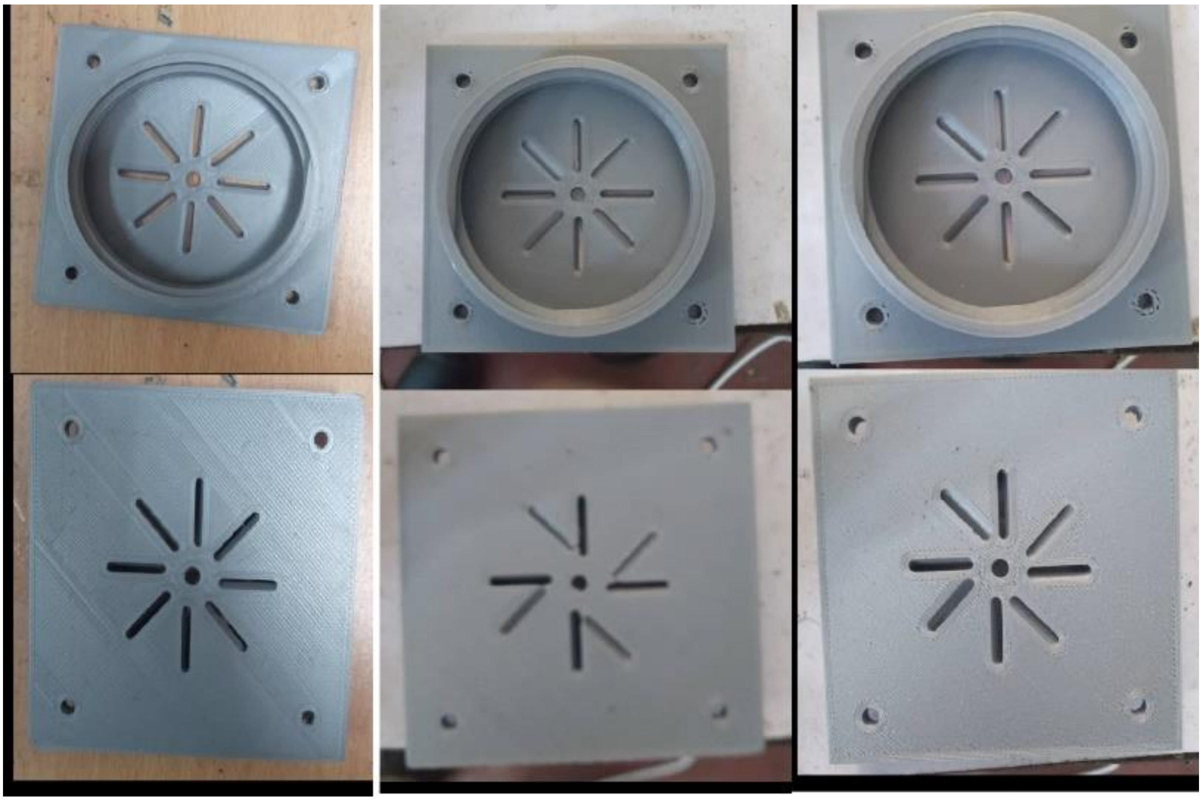

Figure 2: From left to right, swirling distributors with single and multi-angles configurations of 67°+ 67°, 67°+ 30°, and 67°+ 45°

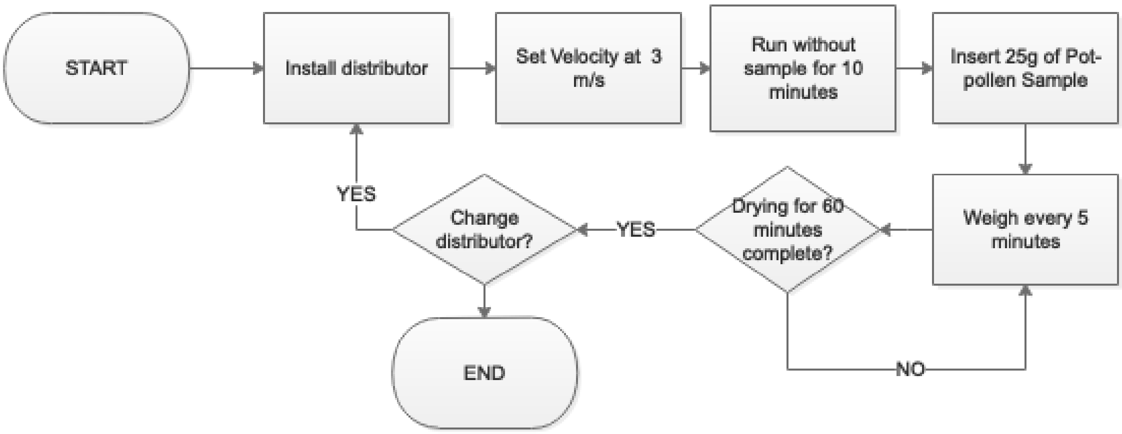

Figure 3: Stingless bees pot-pollen drying procedures in swirling fluidized bed dryer

Moisture content of pot-pollen is determined using a thermogravimetric method [16]. Then from the moisture content obtained, the moisture ratio can then be determined from the following equation [21]:

$$\boldsymbol{MR_t = \frac{MC_t - MC_e}{MC_i - MC_e}} \qquad (1)$$

where MR_t is the moisture ratio at any given time t, MC_t is the moisture content at time t, MC_i is the initial moisture content, and MC_e is the equilibrium moisture content. As MC_e is typicallyvery small, it can then be approximated to 0. Thus, the moisture ratio can then be simplified as shown below:

$$\boldsymbol{MR_t = \frac{MC_t}{MC_i}} \qquad (2)$$

From the moisture ratio obtained, the results can then be plotted against time to obtain the drying curves of each distributor configurations tested.

3. Results and Discussion

Figure 4 illustrates the drying curves of stingless bee pot-pollen in swirling fluidized bed dryer using different swirling angles including 67°+ 67°, 67°+ 30°, and 67°+ 45° swirling angles. These multi-angle distributors are denoted as 6767, 6730, and 6745, respectively. In general, all the drying curves resembles a typical drying process, where the drying is faster during initial stage and taper down in the latter stages. This behaviour can be attributed to surface drying is more dominant than internal drying in the earlier stage, while internal drying becomes major in the next stage [22]–[24]. In SFBD, air flow removes the moisture from the pot-pollen particle surface. Moisture contained inside the particle will travel towards the surface before being removed as well. The latter phenomenon have higher resistance which should explain the drying behaviour of stingless bees pot-pollen inside SFBD in the current study.

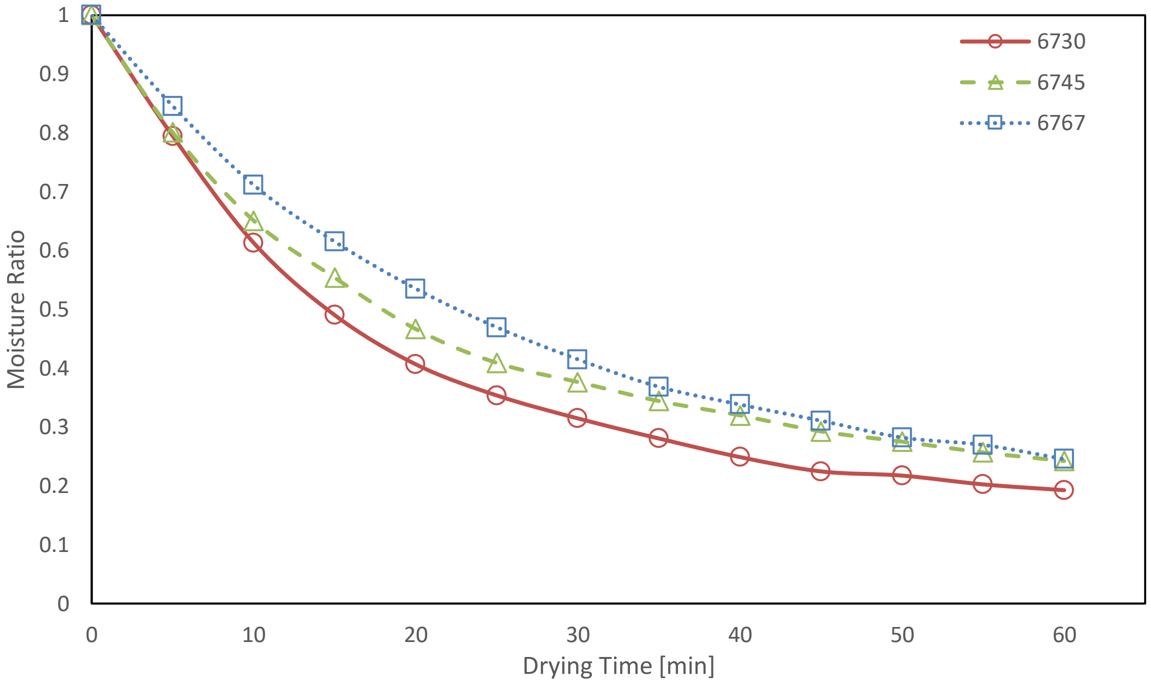

Figure 4: Drying curves of stingless bees pot-pollen in SFBD with single angle and multi angle distributors, 6767, 6730, and 6745.

In terms of drying rates, at the start of drying, the 6730 and 6745 shows very similar drying rates. Both distributors have faster drying compared to 6767. However, around 10 minutes mark, the drying curve of 6730 diverges as it start to exhibit higher drying performance compared to 6745 and 6767 distributors. This trend lasts until the end drying experiment. For 6745 distributor drying curve, the gap with 6767 distributor narrows as it approaches the end of drying experiment.

It can be observed that the multi-angle distributors have better drying performance compared to a singles angle distributor. The acute second angle addition have a positive impact towards drying rate especially in the first 30 minutes of the drying experiment. During this time, multi-angle distributors 6730 and 6745 managed to reduce moisture by 68.5 % and 62.3 %, respectively, compared to 58.5 % for the single angle distributor 6767. This represented as around 17.1 %, and 6.5 % improvement for the 6730 and 6745, respectively, over the single angle distributor. Overall, the 6730 distributor is shown to exhibit the best drying performance among all the distributors tested. The 6745 distributor came second as it is shown to have slightly higher drying performance compared to 6767. As the earlier region of drying curve represented mostly by surface drying, it may be deduced that multi-angle distributors managed to enhance the removal of moisture from the surface of pot-pollen particles. The combined angle managed to expand the paradigm of the swirling motion inside a SFBD. These trends may be explained due to more pot-pollen particles are being fluidized in swirling motion as multi-angle configurations cover wider range compared to single angle. In a single angle configuration, there are some regions with very low velocity incapable of fluidization of particle dubbed the “dead zones”. Improving the distributor configuration to reduce the area of “dead zones” will lead to improved drying performance. The multi-angle configuration eliminates the existence of “dead zones” in between the openings of the swirling distributors. Thus this explains the greater drying rates of multi-angle distributors compared to single-angle distributors. The secondary angle in the configuration performs better when set at 30° compared to 45°. This may be caused by the much wider range cover by 6730 compared to 6745 multi-angle swirling distributor as it “sweeps” pot-pollen particles at both lower and higher angles. Thus, it may be concluded that the multi-angle SFBD shown significant improvement over single angle SFBD, with 6730 has the best drying performance among all the distributors tested.

4. Conclusions

In this paper, stingless bees pot-pollen is dried in swirling fluidized bed dryer (SFBD) using single angle and multi-angle swirling distributors, namely 6767, 6730, and 6745, respectively. It was shown that all the swirling distributors managed to dry the stingless bees pot-pollen following typical drying curves. The multi-angle distributors 6730 and 6745 have better drying performance compared to the single angle distributor where 17.1 % and 6.5 % improvement, respectively, can be observed during the first 30 minutes of the drying experiment. The multi-angle distributor had shown the best drying performance among all the distributors tested. This may be attributed to the elimination of “dead zones” found when using single-angle distributors which enhance the drying rates due to increased particle fluidization. In conclusion, SFBD with 6730 multi-angle swirling distributor has potential to rapidly dry heat-sensitive materials such as stingless bees pot-pollen. The current study may be adapted for other heat-sensitive food materials with different particle sizes to explore SFBD suitability for drying other materials. The multi-angle swirling distributors may also be adapted to other fluidized bed applications such as mixing and combustion in future studies.

Declaration Of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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