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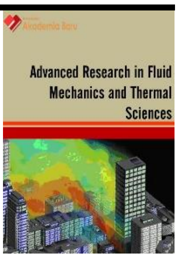

Combination System of Spray Dryer and Low Evaporator Temperature Refrigeration for Drying Vitamine B1

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ABSTRACT

This study explores a combination of spray drying and refrigeration systems on production of vitamin B1, which is known to be heat-sensitive. It analyzes the effect of drying air temperature on vitamin B1 levels and notes the related influence on production levels. In addition to temperature, productivity is influenced by moisture and drying airflow rates. In this study, air temperatures were set at 80, 110, and 140^{o}C. Air humidity variations were carried out by changing the humidifier's outlet air temperature to 10, 15, and 20^{o}C. The airflow rate varied at 150, 300, and 450 lpm. High Performance Liquid Chromatography (HPLC) testing methods was used to test the level of damage to vitamin B1 products. By setting the temperature of air passing through the evaporator at 10^{o}C, the drying temperature at 140^{o}C, and airflow rate at 450 lpm, damage to vitamin B1 can be minimized by 7.69%. The drying productivity with the refrigeration system is even 3 times larger than the result of the drying productivity with conventional methode. These results indicate that the combination of spray drying and refrigeration systems with low evaporator temperatures can have a significant positive impact on the production quality of vitamin B1.

Keywords:
Vitamin B1, Heat – sensitive Material, Evaporation Temperature, Refrigeration System, Spray Dryer

1. Introduction

The spray drier is a drying technology used to produce pharmaceutical drugs [1] by converting the liquid material into small powdered particles [2]. The technology uses drying air temperatures above 100°C [2-7].

Air dryers with a high temperature reduce the water content in the material. The higher the air temperature in the drying chamber, the faster the material dries [3]. Due to high operating temperatures, this spray dryer technology cannot be used on heat-sensitive materials [8,9]. The ideal drying air temperature for heat-sensitive materials is in the temperature range 50-60°C [10] or 60 –

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80°C [11]; at that temperature, the produced powder will not be damaged by thermal degradation [11]. However, when compared with the use of other drying technology, such as dye-sensitized solar cells based, this technique takes a longer time to reach a temperature of 50°C ± 2°C, ie more than 200 hours [12]. Vitamin B1 (thiamine) is one example of a material that is sensitive to heat. Vitamin B1 is stable at 100°C for a few hours, but if there is air moisture increase, vitamin B1 will be damaged quickly [13].

According to the Directorate of Nutrition Ministry of Health [14], low levels of vitamin B1 are contained in food sources, such as green beans (0.47 µg), carrots (0.04 µg), and tomatoes (60 µg).

Vitamin B1 is a co-factor of several enzymes essential that play a role in the synthesis of hemoglobin in metabolic processes [15,16]. Vitamin B1 can be developed through enzyme biosynthesis that act an effective new antimicrobial/antibiotic agent for treatment of infectious diseases [17], such as tuberculosis, HIV/AIDS, cervical cancer, cataracts, glaucoma, and diabetes. Therefore, the production of Vitamin B1 is crucial and need to be investigate further.

Research on the drying of heat sensitive materials has been widely applied and has been reviewed above. From previous research has been known about various variables or parameters that affect the process of drying the material. Previous studies have found enough knowledge, but there are some important but untapped physical phenomena. The phenomenon is about the effects of drying the air temperature on vitamin B1 damage in the spray dryer process. In addition, the productivity of the spray dryer is of course influenced by the flow rate, humidity and drying air temperature. This phenomenon needs to be examined quantitatively. The improvement understanding of the phenomenon will provide important knowledge for the perfection of spray dryer technology, particularly for sensitive materials.

High quality of Vitamin B1 can be achieved at level of humidity and an air drying temperature below 100°C, however this methode tends to result is low quality production. In fact, drying can be performe at temperature if the drying air temperature is above 100°C, the quality of vitamin B1 products may be decreased. This study analyzed the effect of drying air temperature and dryer air on quality and quantity of vitamin B1 production. In this study vitamin B1 essence solutions were tested by using a combination of spray dryer and refrigeration systems with double condensers. While humidity is not discussed as a research parameter, however the moisture content of drying air is lower because of the effect of lowered drying air temperature in the refrigeration system.

Hot air from the condenser is wasted in the condensation process and can be utilized. The temperature of hot air in the refrigeration system ranges from 40-50°C [18] and from 40-90°C [19].

2. Methodology

The materials used in this study are a vitamin B1 essence solution. The vitamin B1 essence weight was 15 g, and 285 g of maltodextrin was added to help the vitamin B1 avoid sticking to the drying chamber wall. Aquades were added at a volume of 1200 g as a solvent. The overall weight of the ingredients of the vitamin B1 solution was 1500 g.

The production capacity of the test equipment used is 3 lph for aqueous material testing and tested at dryer air temperature at 120°C. The parameter tests for vitamin B1 are shown in Table 1 and Table 2 below.

Table 1
Parameter test of productivity

Air temperature out of evaporation system(°C)	10, 15 and 20
Air flow rate (lpm) liter per minutes	150, 300, and 450
Temperature control on electric heater (°C)	90, 120, 140

Table 2
Parameter of vitamin B1 quality testing

Air temperature out of evaporation system(°C)	10
Air flow rate (lpm) liter per minutes	450
Temperature control on electric heater (°C)	80, 110, 140

The test parameters are parameters that determine the measurement result variable against vitamin B1 production and product damage.

The flow rate of the material being sprayed into the drying chamber has been conditioned that the material is in maximum dry condition or has been 100% dry. The spray liquid has been set at drying temperature (60, 90 and 120°C), dryer air flow rate 150, 300 and 450 lpm and certain moisture, so that the liquid material becomes dry. The productivity of the dry matter increases with the decrease of moisture at evaporation temperature, ie 10, 15 and 20°C.

The drying process of this material can be shown in Figure 1. Figure 1 illustrates the combination of systems in this study, the refrigeration system and the spray dryer system.

2.1 Refrigeration System

As seen in Figure 1. The refrigeration system used one unit of air conditioner with refrigerant R134a. This system consisted of a half- horse power (½ HP) hermetic compressor, two condensers, one evaporator, and one expansion valve. These two condenser are aranged in parallel.

The air from the surounding is suctioned by a blower with airflow rates that varied at 150, 300, and 450 lpm (1 lpm = 0.00002 kg/s) which measured by using a rotary flow meter (FM). The air flow from the blower to the evaporator. The evaporator acts as a humidifier and cooler.

The temperature of air through the evaporator was set to 10, 15, and 20°C (T_e) by adjusting the expansion valve to reach the temperature. These temperatures could not be precisely achieved; consequently, the air-specific humidity in the evaporation process could also not be consistently controlled. For each temperature drop that occurred, the relative air humidity (RH) was recorded.

The high-temperature dry air then flow to the electric heater in the spray dryer system. Then the drying air is heated in electric heater till reach desired temperature. Then it used to dry the material in the drying chamber of a spray dryer system.

2.2 Spray Dryer

An illustration of the spray drier can be seen in Figure 1. The vitamin B1 ingredients were prepared as a liquid. Using a peristaltic and a booster pump, the material was streamed toward a small atomizer hole in a vertically mounted pneumatic nozzle above the drying chamber. The peristaltic pump regulated the material flow rate (FFR) and was assisted by a booster pump that forced the incoming flow into the pneumatic nozzle atomizer hole. The pneumatic nozzle had a small pipe line for pressurized air coming from an air compressor that pressed and sprayed the liquid vitamin B1 essence into a granule that fell into the drying chamber. The pressure regulator (P) helped to adjust the amount of pressure provided by the air compressor in order to spray the liquid into a grain with a small-diameter. In the reinforcing chamber, the granules of material contacted the temperature-controlled hot air from the heater (T_{CH}). A transparent chamber held the material so the drying process could be observed. The material granules could be considered dry if the granules evaporated before attaching to the wall or after attaching and drying out. If the material adjacent to the wall of the dryer room appeared to flow, then the grains of material were still categorized as wet. By adjusting the material flow rate and drying airflow rate at the heater control temperature. When the water content of the material evaporated, the dried material would fall through the cyclone to the container under the dryer chamber.

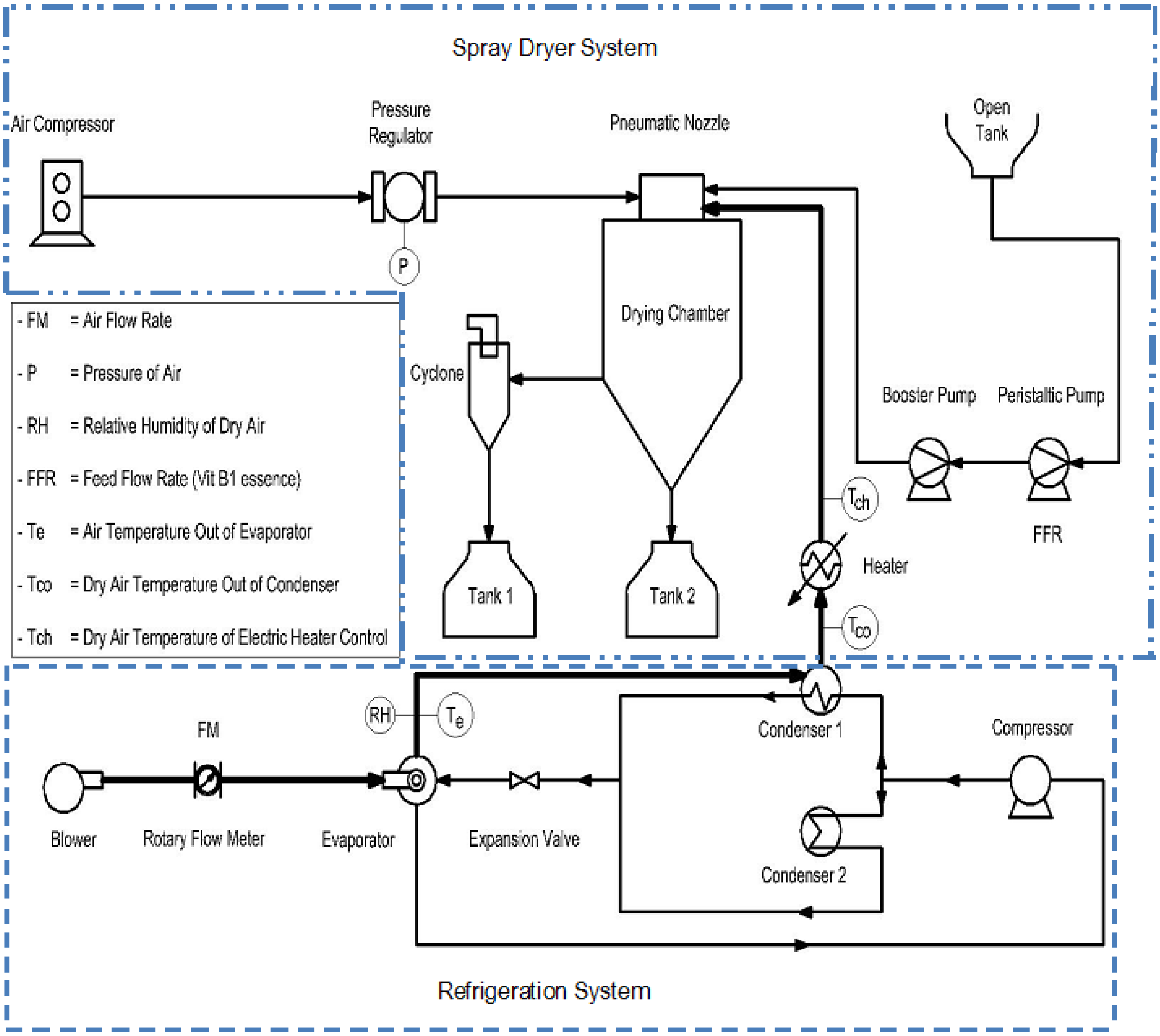

Fig. 1. Schematic diagram of the experimental system

Vitamin B1 products were collected, including products right next to the drying chamber walls and cyclone walls. They were tested with High Performance Liquid Chromatography (HPLC) testing methods was used to test the level of damage to vitamin B1 products.

3. Results

The influence of specific air humidity and airflow rate (in g H_2O/kg dry water) to feed flow rate (litres per hour) at drying air temperature (litres per minute) is shown in Figures 2, 3, 4 and 5 below.

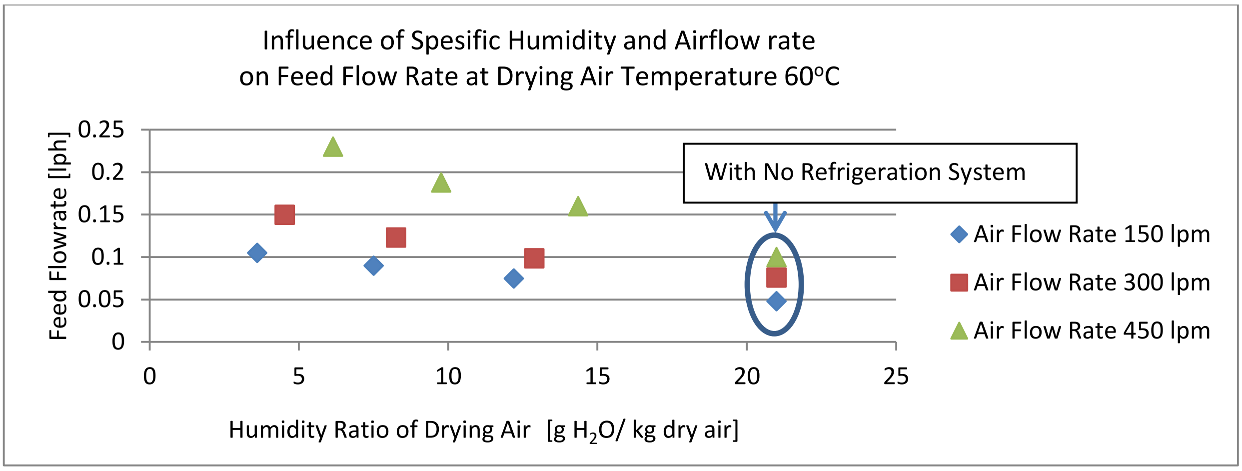

Fig. 2. Relation of specific air humidity and airflow rate to the material flow rate at the drying temperature of 60°C

Figures 2, 3 and 4 shows that drying air temperatures coming out of the evaporator are tested at 10, 15, and 20°C and airflow rates of 150, 300, and 450 lpm.

Figure 2 shows that at an airflow rate of 150 lpm, Air-specific humidity lowers from 3.6 to 21 g of air/ kg of dry air. Evaporator is able to make the drying air humidity low, so that the rate of evaporation to be increased because of the air entering the drying chamber has been in dry conditions. At the material flow rate, there is an increase in the capacity of vitamin B1 products, from 0.07 to 0.10 lph. The increased material flow rate requires a large dryer airflow rate. The same holds true for airflow rates of 300 and 450 lpm. At an airflow rate of 450 lpm, the material flow rate increases to 40%.

At an airflow rate of 450 lpm, the drying productivity with the refrigeration system is even 2.3 times or equal to 130% greater than the drying productivity if without using refrigeration system.

Figures 3 and 4 show the largest production capacity of vitamin B1 occurs at a drying temperature of 120°C and an airflow rate of 450 lpm, which is 0.55 lph. This is an increase of 59% over the lowest vitamin B1 production capacity, which occurs at a drying temperature of 120°C and an airflow rate of 450 lpm, with a material flow rate of 0.35 lph.

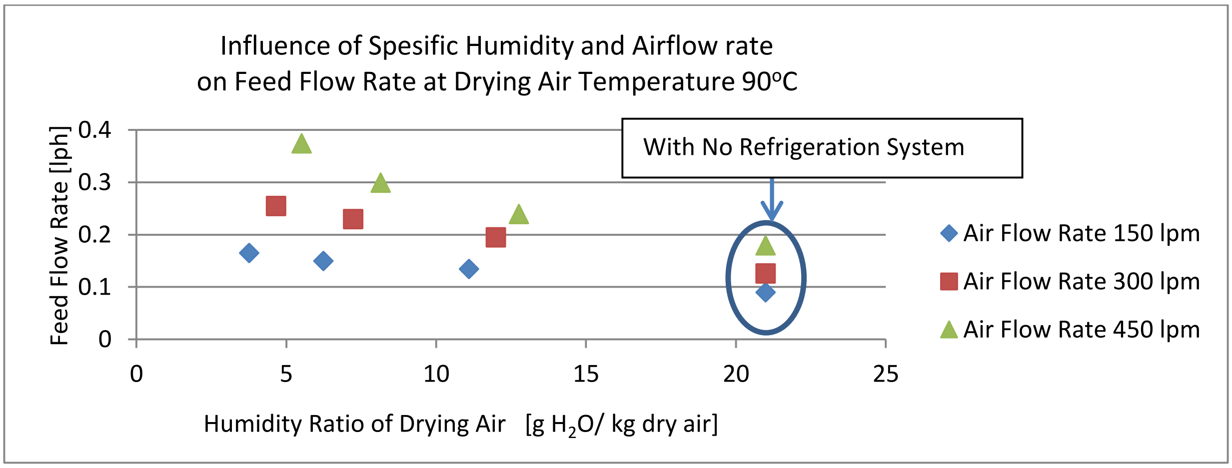

Fig. 3. Relation of specific air humidity and airflow rate to the material flow rate at the drying temperature of 90°C

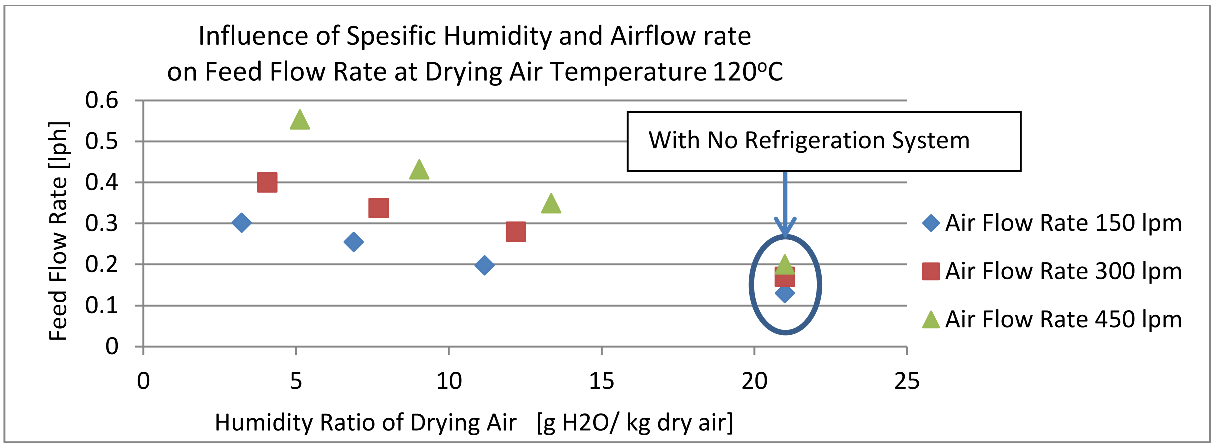

Fig. 4. Relation of specific air humidity and airflow rate to the material flow rate at the drying temperature of 120°C.

A large dryer flow rate can carry more water vapor, so the drying process will be faster. The dryer air temperature is directly proportional to the material flow rate. High airflow rates can shorten the product drying times.

Low air-specific humidity can also speed up the drying process. The material flow rate is inversely proportional to the specific air humidity passing through the evaporator. Products with low moisture levels in this study occur at RH 65% with moisture dry air used, which is 5 g H_2O/kg dry air. The highest productivity occurs in dry conditions because the moisture in the product is decreased.

At an airflow rate of 450 lpm, Figure 5 show the drying capacity at adrying air temperature of 60°C (with refrigeration, humidity ratio of 6.147 g H_2O/kg dry air is equal to the drying capacity at a drying air temperature of 120°C (without refrigeration, humidity ratio of 21 g H_2O/kg dry air), which is 0.2 lph.

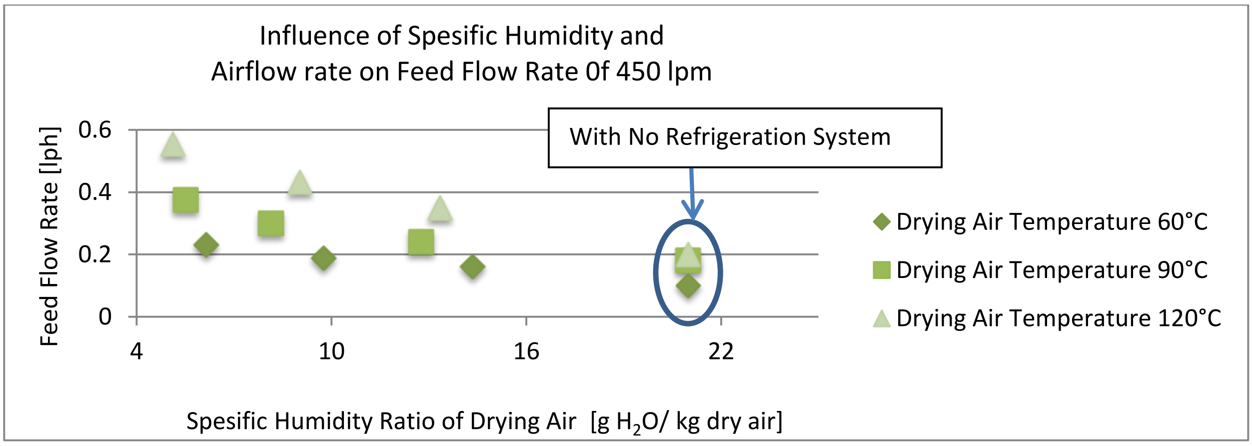

Fig. 5. Relation of specific air humidity and material flow rate at the airflow rate of 450 lpm.

The drying productivity at a drying air temperature of 120°C, at an air flow rate of 450 lpm (with refrigeration) even becomes 3 times the drying productivity at a drying air temperature of 120°C, at an airflow rate of 450 lpm (without refrigeration), the material flow rate increases to 178%. Table 3 shows the results of vitamin B1 testing on drying temperature variations.

Table 3
Level of vitamin B1 damage from tomatoes corresponding to the drying temperature

Sample No.	Matrix	Test mark (mg/100g)	Vitamin B1 Damage (%)
405.41505	Raw Material Vitamin B1 & Maltodekstrin	5729.54	0
405.41507	Raw Material Vitamin B1 & Maltodekstrin (80°C)	5639.42	0.78
405.41506	Raw Material Vitamin B1 & Maltodekstrin (110°C)	5331.97	3.47
405.41508	Raw Material Vitamin B1 & Maltodekstrin (140°C)	4848.48	7. 69

Use to set temperature out of evaporators on 10°C, with specific humidity in 5 g H_2O/kg dry air and the rate of flow of air maximum, which namely 450 lpm. The damage vitamins B1 interminate much different with air was dried. By the use of air which is dried up, productivity of Vitamins B1 is more stable. The influence of temperature is significantly to damage because the moisture levels of vitamins B1 dry air used are relatively stable, which namely 5 g H_2O/ kg dry air. This is in line with the Olsen's opinion where decreasing from changes in water moisture must be kept stable, because vitamin B1 will be quickly disrepair [13].

Vitamin B1 levels after the drying process were analyzed using the HPLC test method above, showing damage to vitamin B1 levels. Figure 5 illustrates the results of the analysis.

From Figure 6, it can be seen that the highest defect percentage in drying vitamin B1 occurs at 140°C, with vitamin B1 defects of 7.69%. This shows that the dehumidifier in the spray dryer system is able to maintain the drying temperature of vitamin B1 up to 140°C. At a temperature of 80°C, vitamin B1 defects occur at 0.78%. The drying air temperature for vitamin B1 can be increased above 140°C if a material flow rate increase greater than 59% is desired. Temperatures could also be set below 80°C, if less damage to the vitamin B1 content is desired. The critical temperature of vitamin B1 drying cannot be determined by this study because its lowest test temperature is 80°C.

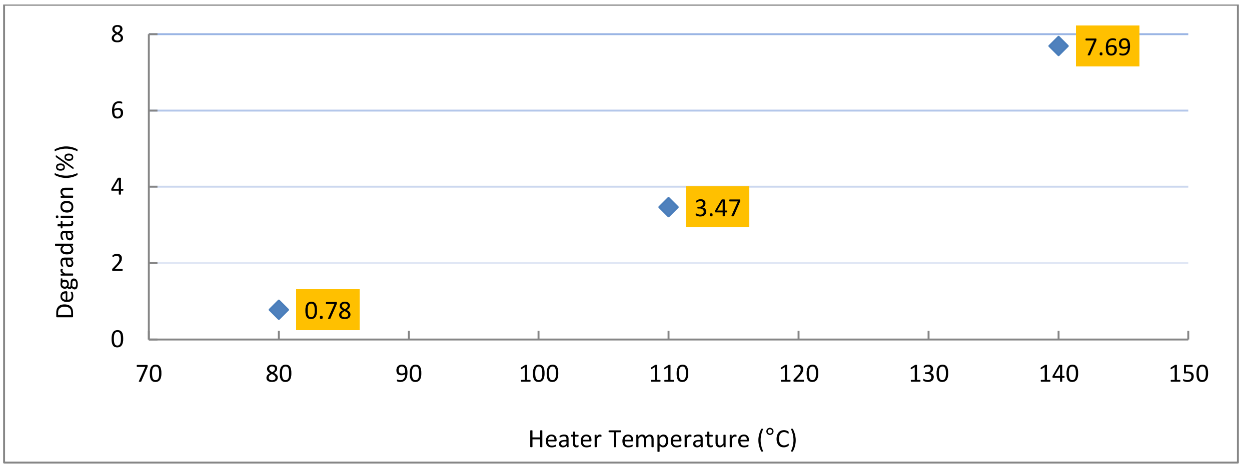

Fig. 6. Degradation of Vitamin B1 as a function result of the drying air temperature

The lowest production capacity of vitamin B1 occurs at a drying temperature of 60°C, with a low airflow rate of 150 lpm and evaporator temperatures of 20°C. The material flow rate reached, 0.02 lph, occurs at a specific air humidity of 5 g of dry air/kg of air with RH 83%.

The results of this study indicate that the combination of these systems can safely produce vitamin B1 at levels previously believed to damage heat-sensitive materials. Even at 140°C, the damage that occurs in vitamin B1 is only 7.69%, while it is expected that at 100°C, vitamin B1 will be damaged beyond repair [13]. This condition cannot be achieved without a refrigeration system. At a temperature of 120°C within 5 hours, without using the dual system, this will occur, vitamin B1 will be damaged entirely [20]. Other experiments conducted to obtain vegetable juice from Chinese cabbage, obtained by spray drying at outlet temperatures of 130°C, obtained a concentration of vitamin B1 lower than 6 mg/100 g [21]. This means a lot of failures at 130°C from using a spray dryer alone.

This study can support energy saving efforts, although refrigeration requires considerable compression shaft power consumption [22]. Specific energy consumption rate of 40% for the combination of spray dryer and refrigeration system by setting air temperature through evaporator at 10°C, drying temperature at 90°C, and airflow rate at 450 lpm [23]. This study may also be synergized with other studies. For example, air temperature in the condenser can be lowered below the ambient temperature [24], or pure refrigerant can be replaced with mixed coolant to facilitate low-temperature conditions without significant structural modification [22]. Then, the axial power savings required for the cooling cycle could be greater than 10.9%.

Waste heat energy from refrigeration systems with double condensers in this study can operate at low temperatures (60 – 90°C) which can be used directly to replace the drying role in an oven, microwave or smokehouse that operates at a temperature of 60°C [25]. A technique that can also be considered in the study of Polyphenol Pomegranate (Punica Granatum) Extracted for Meat [26] and can be developed to reduce or eliminate plant microbial cells that can develop in a greenhouse [27] by controlling humidity and operational temperature in sensitive materials temperature.

4. Conclusions

This study explores a combination of spray drying and refrigeration systems on production of vitamin B1, which is known to be heat-sensitive. It analyzes the effect of drying air temperature on vitamin B1 levels and notes the related influence on production levels.

This study conclude that vitamin B1 is very sensitive to humidity and is only stable under 100°C, which could be an obstacle if produced using a spray dryer. Combination of a spray dryer system and a refrigeration system have proved as simple method to increase Vitamin B1 production. Moreover, with this method Vitamin B1 can be minimized to 7.69% even at dryer air temperatures of 140°C, simultaneously with increased production of 59%. It can be observe that drying capacity with the refrigeration system is even 3 times or equal to 178% larger than the drying capacity without using refrigeration system. This research may be further developed by replacing the refrigerant or lowering the condenser temperatures below ambient temperatures.

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