Influence of Air Drying Parameters in Spray Drying performance for Water and Tomato Extracts with Low Energy Consumption

by Nanang Ruhyat

Influence of Air Drying Parameters in Spray Drying performance for Water and Tomato Extracts with Low Energy Consumption

E. A. Kosasih, N. Ruhyat

Applied Heat Transfer Laboratory, Department of Mechanical Engineering,

Universitas of Indonesia, 16424, Depok

Jawa Barat, Indonesia

kos.sri@gmail.com
nanangruhyat@yahoo.com

Abstract

In the spray drying process, if the drying temperature is too high, it can cause damage to heat-sensitive materials. Minimum Temperature tomatoes air-drying a solution of 4^0C higher than the water, where the water 36 ^{0}C, and 40 ^{0}C to a solution of tomato. However, if the temperature is too low, it can cause very slow production rate of drying products. Variations in the rate of material flow, air flow rate and drying air temperature is expected to efficiently drying material, in which the lowest damage to the product with the most efficient energy consumption in the spray dryer. And the lowest energy consumption is the use of a dehumidifier at a temperature of 10 °C, the temperature at 120 ° C, and air flow rate at 450 lpm. At high air flow, which is 450 lpm, use a dehumidifier to lower the specific energy consumption significant. This is especially the drying air temperature of 60 ° C, which is to air flow of 450 lpm, the specific energy consumption without dehumidifier is 2.4x107 J/kg and the dehumidifier (evaporator exit air temperature 10 ° C) and heat recovery condenser is 1.2x107 J/kg. Means there is a reduction in specific energy consumption amounted to 49.2%.The decline in specific energy consumption of 49.2% is very significant that for humid areas such as Indonesia's utilization of the evaporator and condenser for spray dryers are highly recommended, on the flow of air and maximum material flow.

Keyword : Air Drying Parameters, Spray Drying, Water, Tomato Extracts, Low Energy Consumption

1. Introduction

Spray drying method is one of most used technologies on food (Madhavi, D.L. et.,al. 1998), and drug manufacturing industry (Broadhead et al., 1992), and is used on optimal condition to obtain products in powder form (Fazaeli,M et. al., 2012) in the small size (Master, 1991). Spray drying are favorite technique to produce extraction powder of many kind of fruits (Renata V. Tonon et al., 2008). Spray drying are drying instrument that work by spraying the dispersion system in air flow that is dry and usually hot in drying chamber. However, this kind of drying technology still has lack of performances.

Constraints that exist in the current spray dryer is low efficiency and high drying air temperatures that can damage vitamins, protein and β-carotene on the material to be dried (Solval, Kevin M. et. Al., 2012). The high temperatures also damage the flavor, color, aroma and some other substances.

To lower the temperature of drying, the spray dryer combined with freeze drying using nitrogen (Wang et. Al., 2006) or in combination with a dehumidifier. In this study, spray drying will be combined with dehumidifier (considering the specific humidity of the air in Indonesia is high) so that the specific humidity of the drying air becomes low and resulting on high evaporation rate, thus the drying air temperature can be lowered. However dehumidifier from refrigeration system requires high energy that will reduce efficiency. To that end, the heat will be utilized from condenser to heat the drying air coming out of the evaporator (EA. Kosasih, N. Ruhyat, 2016).

Tomato (*Lycopersicum esculentum*) is a plant that is often used hortikula for processed food products and nutrition have a role in society. Tomato is a fruit that is relatively complete nutritional compositions containing these fruits also contain carotenoids that function as provitamin A and lycoppen forming, in a medium-size fresh tomatoes (100 grams) contains about 20 calories, 40 mg of vitamin C, vitamin A SI 1500, 0.06 mg (vitamin B1), iron 0.5 mg, 5 mg calcium, 94 g of water and others (Depkes RI, 2003). The levels of lycopene contained in tomatoes fresh ranged from 3.1 to 7.7 mg/100 g (Tonucci et. Al., 1995). Lycopene content in tomatoes that can be extracted is high enough for the product - health or cosmetic products given lycopene levels equivalent to 100 times the strength of vitamin E in preventing free radicals (Di Mascio et al., 1989). Tomatoes also contain useful substances that are sensitive to heat, so this research will be used as the material to be dried. Lycopene during spray drying process (one of the nutrient content in tomatoes) is affected by the air conditioning (temperature, air flow rate), the condition of materials (additives, material flow rate), and the velocity atomization (Masters, 1991). Degradation of lycopene increases with increasing temperature of air entering (Goula & Adamopoulos, 2006). During the process at a temperature of 80^0C there is no significant loss of lycopene, but at a temperature of 110^0C are missing 12% of lycopene (Zanoni, et.al., 1998).

Spray drying is one of the techniques used in the food industry are involved in the processing to obtain pollen powder like fruit, dried fruit into powder has many benefits and better economic potential by making the powder it will reduce the volume and packaging, as well as easy handling and transportation (Mujumdar, 2006).

2. Materials and methods

In the drying process , there are several factors that can affect the results of drying , such as hot air temperature ,fuel flow rate , air flow rate , humidity and ratio of additives to the material . Schema tool for research (which has been and will be done) can be seen in Figure 1 . Water drying technology and tomato juice in this study using spray drying contained in the heat transfer laboratory, University of Indonesia . This study is part of the manufacture of spray drying (with dehumidifier) for heat sensitive materials that are energy efficient which can be applied in the field of food and medicine. The purpose of a study is to want to see the effect of adding a dehumidifier (to lower the specific humidity of air conditioning) the minimum temperature drying of materials water and water mix tomatoes with maltrodextrin . In subsequent studies will be seen also influence heat recovery condenser to the specific energy consumption. Thus the spray drying becomes effective (for heat sensitive materials) and more efficient with Low Energy Consumption .

Ripe tomato juice should be prepared first. Selected tomatoes with red color uniformity, then washed clean after the blender without adding water with a cloth and squeezed to get the juice to be tested according to the parameters - parameters that have been defined, namely:

Variations in water testing:

1. Pure water
2. Dryer air dew point: 10, 17, 23, and 28 [°C]
2. The flow of material: 0.005 dan 0.0025 [liter/menit]
3. Air flow rate is: 17, 24, 30, 35 [m^3/h]
4. Pneumatic air pressure at the nozzle: 2 [bar]
5. Specific humidity of air entering 0.00763 dan 0.01213 ($kg/kg_{dry\ air}$)
6. The air humidity is varied by way of varying the spray-drying air temperature coming out of the evaporator. Variations in air temperature of the evaporator out is: 20°C, 15°C and 10°C.
7. Variation of temperature of air conditioning (heating lisrtik outgoing or incoming drying chamber) is: 60°C, 90°C and 120°C.

Variations testing tomato water mixture with maltodextrin (25%):

1. Dryer air dew point: 10, 17 [°C]
2. Material flow: 0,18 and 0,42 [l / h] 0.005 dan 0.0025 [liter/menit]
3. Air flow rate is: 17, 24, 30, 35 (m^3/h)
4. Pneumatic air pressure at the nozzle: 2 [bar]
5. Specific humidity of air entering 0.00763 dan 0.01213 ($kg/kg_{dry\ air}$)
6. The air humidity is varied by way of varying the spray-drying air temperature coming out of the evaporator. Variations in air temperature of the evaporator out is: 20°C, 15°C and 10°C.
7. Variation of temperature of air conditioning (heating lisrtik outgoing or incoming drying chamber) is: 60°C, 90°C and 120°C.

This study aims to determine of the drying air of optimum temperature can be achieved in a solution of tomato with the addition of 25% maltodextrin and water levels, and then compared and analyzed by using a spray dryer with dehumidification system.

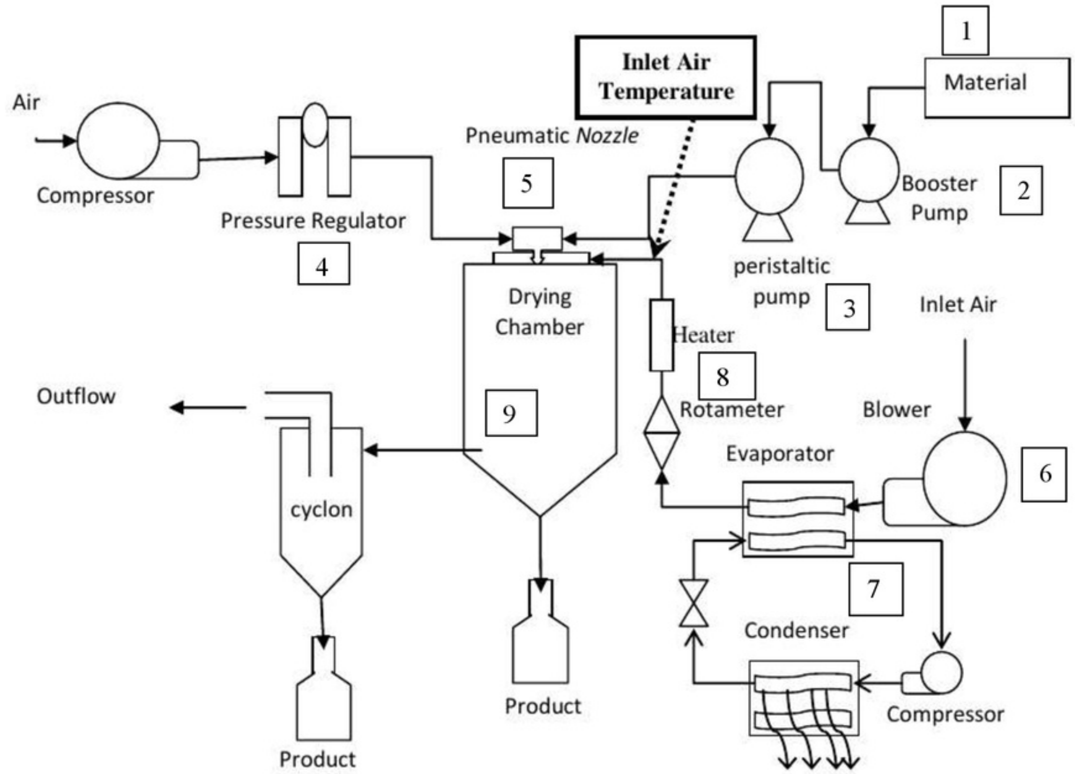

FIGURE 1. Schematic Spray Dryer

1. Liquid product containers

   Prepared products are water and filtered tomato juice with added fillers and 25% maltodextrin.

2. Booster pump

   Is the flow of product to the feeder apparatus peristaltic pump.

3. Peristaltic pump.

   Is a means of regulating the flow rate of the product forwarded to the nozzle of the drying chamber.

4. Air Pressure Regulator

   As the air pressure regulator for pneumatic nozzle

5. Pneumatic nozzle

   Pneumatic nozzle as an atomizer, fluid is sprayed through a nozzle in the direction of air flow (from above) or the so-called co-current

6. Air blower

   As a provider of environmental air is introduced into the system for drying medium

7. Dehumidifier

   Air conditioning tools to produce dry air as the drying medium

8. Air heaters and electric panels

Means to heat the dry air in order to lower the humidity, electrical panels show the hot air that passes through the air heaterDrying chamber, cyclone and powder reservoir

9. Drying chamber, cyclone and powder reservoir

   Occurs as a heat transfer from the air to the surface of the droplets (spray) material and vapor mass transfer from the surface of the droplets into the air in the drying chamber, then dried products brought into the cyclone due to the centrifugal force the products fall into the container through the downcomer.

3. Results and discussions

Temperature minimum of air drying for a solution of tomatoes is higher than the water, at the water is 36 ^{0}C, and is 40^{0}C to a solution of tomato that occurs in the air flow rate of 35 m^3/h, humidity specific 0.00763 kg/kg dry air, as well as the feed flow rate of 0.0025 liters/min. There is a relationship between the heightened discharge of materials and specific humidity of the air with the high temperature drying air minimum but the lower air flow.

The higher air flow rate, the minimum temperature air drying vanishingly small is the faster the drying process as well. The higher the feed flow rate of material, the higher the minimum temperature of the drying air. This is because the feed flow rate of materials that produce large droplets were great as well, so that the energy needed for drying the larger (Tonon et al., 2008), in addition to the time required for drying becomes longer.

Moisture content clearly influenced by the drying temperature, where the higher the drying air temperature drying process faster and easier to dry material.

In specific humidity, if specific humidity air is getting low, then the moisture content which is brought inside the air gets a little. So the air capability to bind moisture in the material higher, this causes the energy required for the drying process is getting smaller. Here, dry air to be high (kg / kg $_{\text{dry air}}$).

For air flow rate are getting bigger, the mass flow rate of air is large, too, so for the same heat energy required to dry the material, the temperature can be smaller.

To reducing the air flow rate, it is likely that most of the air entering the drying chamber is derived from recycled air that comes from the bottom of the drying chamber due to the back flow. So that will affect the trajectory of droplets of material. For small droplets that tend to gravitate towards the wall, for a large droplet will back up before finally dry and for droplets that are going to stick to the wall before it evaporates completely (Goula & Adamopoulos, 2004). This is why the product does not dry. Based on the graph optimum drying conditions occur in the air flow 0.01m3 / s, specific humidity of 0.00763 kg / kg, debit material 0.0025liter / min.

For pure water and a solution of tomato with the addition of 25 percent maltodextrin shown in the following graph.

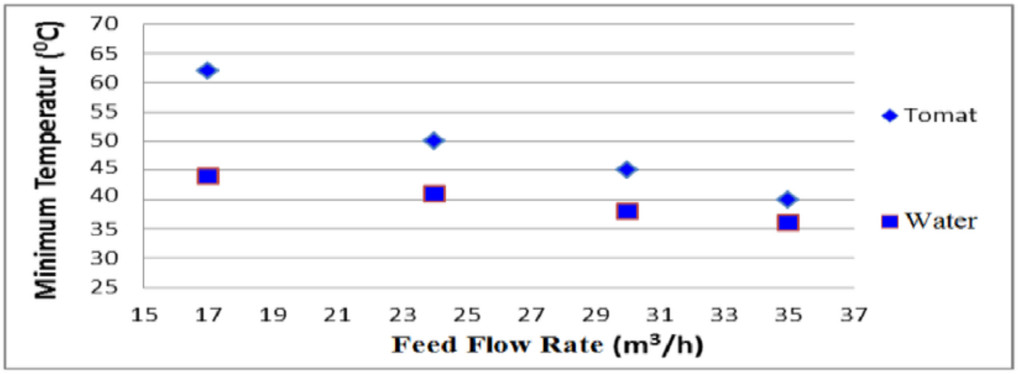

FIGURE 2. Comparison of Tomato solusion with water by feed flow rate of 0.0025 (l / min) and Specific Humidity 0.00763 (kg / kg $_{dry\ air}$)

At a feed flow rate of material 0.0025 liters / min and specific humidity of 0.00763 kg / kg $_{dry\ air}$, there is a difference between the drying air temperature of pure water with tomatoes ranged from 4 ^{0}C to 18 ^{0}C. The highest difference in water flow rate of 17 m^3/h, which is between the temperature of 44 ^{0}C to water, with temperture 62 ^{0}C for tomatoes. While the lowest difference occurs in the air flow 35 m^3/h, which is between the temperature of 36 ^{0}C to water, with a temperature of 40 ^{0}C for tomatoes.

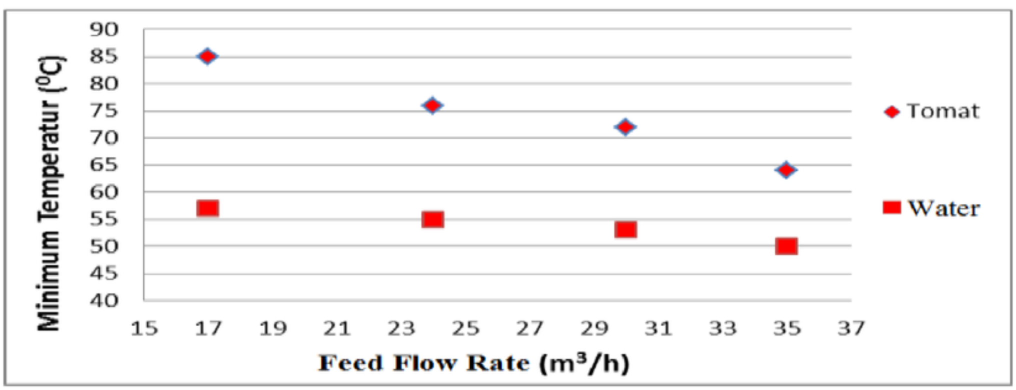

FIGURE 3. Comparison of Tomato solusion with water by feed flow rate of 0.005 (l / min) and Specific Humidity 0.00763 (kg / kg $_{dry\ air}$)

In the case for the material discharge 0005 liters / minute and specific humidity of 0.00763 kg / kg $_{dry\ water}$, drying air temperature difference between pure water with tomatoes ranging from 14^{0}C to 28^{0}C. The highest difference occurs in the air flow 17 m^3/h which is between the temperature of 57^{0}C to water, with 85^{0}C for tomatoes, while the lowest difference occurs in the air flow 35 m^3/h, which is between the water temperature to 50^{0}C, the 64^{0}C for tomatoes.

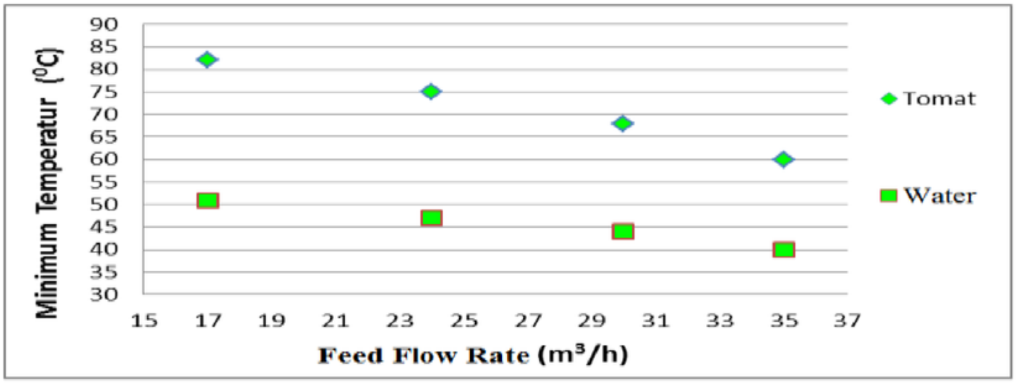

FIGURE 4. Comparison of Tomato solusion with water by feed flow rate of 0.0025 (l/min) and Specific Humidity 0.01213 (kg/kg $_{dry\ air}$)

At a flow rate of material 0.0025 liters / min and specific humidity of 0.01213 kg/kg $_{dry\ air}$, there is a difference between the temperature of the drying air temperature between pure water with tomato range of 20 ^{0}C to 31 ^{0}C. The highest difference occurs in the discharge of air at 0005 m^3/s, which is between the water temperature to 51^{0}C, and 82^{0}C in a solution of tomatoes. while the lowest difference occurs at a flow rate of air at 0,01 m^3/s, where the water temperature to 40^{0}C, and 60^{0}C for tomatoes.

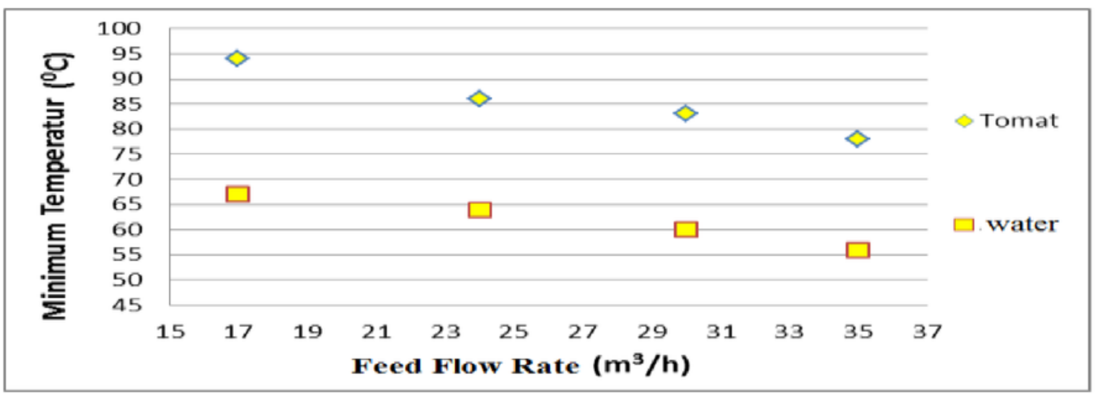

FIGURE 5. Comparison of Tomato solusion with water by feed flow rate of 0.005 (l/min) and Specific Humidity 0.01213 (kg/kg $_{dry\ air}$)

While the feed flow rate at 0005 liters / minute and specific humidity of 0.01213 kg / kg $_{dry\ air}$, there is a range of drying air temperature difference between pure water with a solution of tomatoes ranging from 22^{0}C to 27^{0}C. The difference was highest in air flow rate at 17 m^3/ h, which is between the temperature of 67^{0}C to water, with 94^{0}C for tomatoes, while the difference lowest in air flow rate at 35 m^3/h, which is between the temperature of 56^{0}C to water, with 78^{0}C for tomatoes, as well as the air flow rate at 24

m^3/h, a temperature of 64^0C to water, with 86^0C for tomatoes.

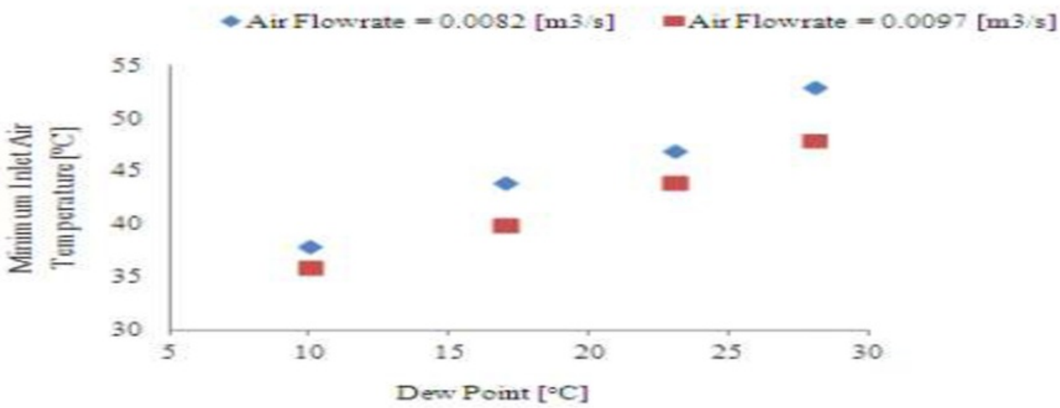

FIGURE 6. Water with debit 0,18 [l / h]

These graphs show the corresponding minimum temperature is down to the increase of air flow rate and the decrease of air dew point. The decrease of dew point (ie by using a dehumidifier evaporator) could decrease drying air temperature to 20 °C, whereas the increase in air flow rate only lose a maximum of 8 ºC.

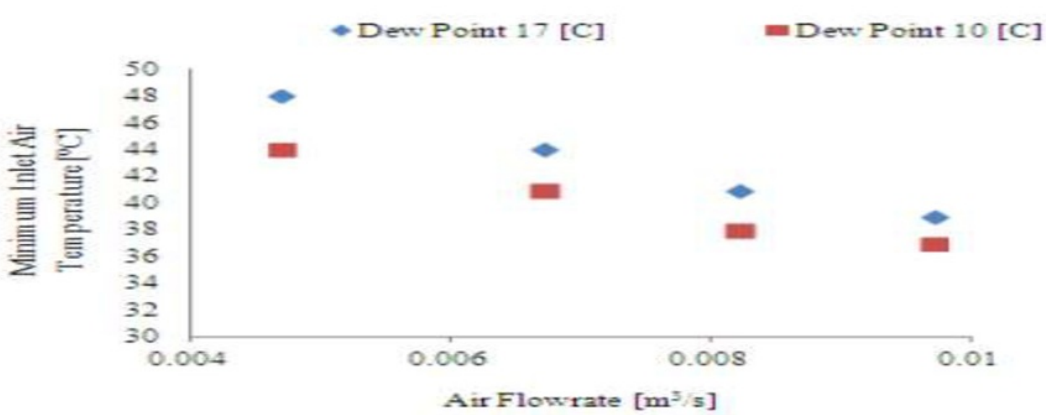

FIGURE 7. A mixture of water and tomato maltodextrin 25% with debit 0,18 [l / h]

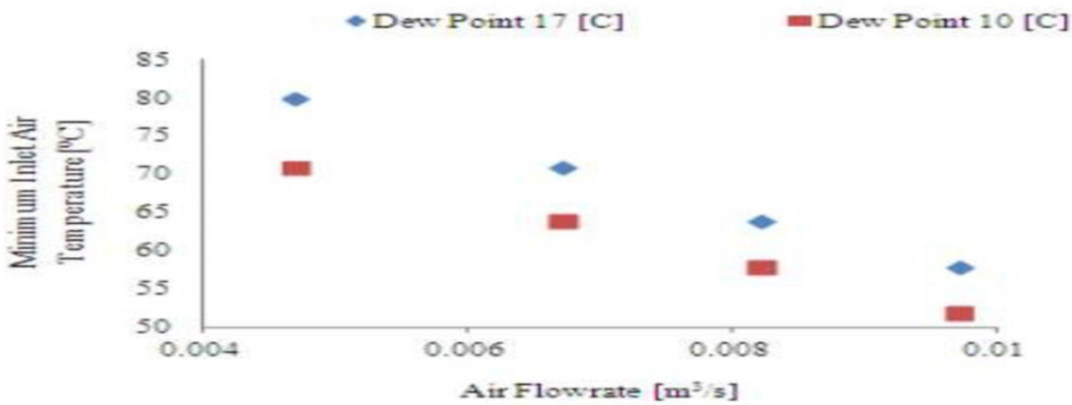

FIGURE 8. Mixed tomato water and maltodextrin 25% with debit 0,42 [l / h]

The present study on drying of water and tomato juice showed that the reduction in losses due to thermal degradation is a discharge can be done by raising or lowering the dew point of the air dryer. But raising the discharge air dryers can increase the specific energy consumption. Similarly, the use of refrigeration systems for dehumidification compressor also requires energy so that it can also increase energy consumption. But if energy is removed in the condenser dryers used to heat the air coming out of the evaporator heat consumption in the electric heater can be lowered so it may decrease overall energy consumption and the degradation products are low.

When the drying medium used is air, the temperature is the second most important role in drying. Where the water in the particle is pulled out in the form of water vapor and must be carried all by the air conditioning, otherwise it will cause a state of saturation on the surface of the particles that eventually it will slow the drying rate (Goula & Adamopoulos, 2010).

Specific Humidity Comparison With Specific Energy Consumption

Figure 9, 10 and 11 are graphs showing the relationship between the specific energy consumption of the specific humidity of the air entering the drying chamber with spray nozzles pressure variation material.

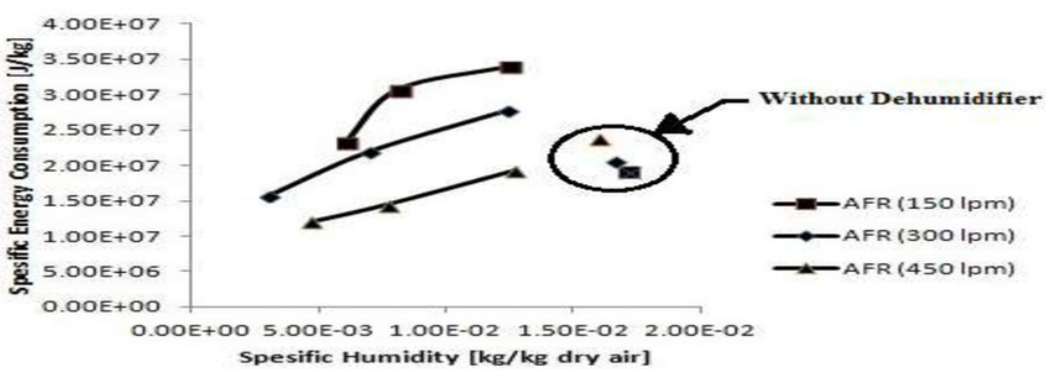

FIGURE 9. Graph relation to the Specific Energy Consumption Specific Humidity
at a temperature of 60°C and pressure nozzles 3 bar

Heater power will be smaller if the conditions of heated air will be passed to the condenser, in other words: the temperature of the air entering the drying chamber is desirable not only the power generated by the heater. Thus the power needed by the heater becomes smaller than without dehumidifier.

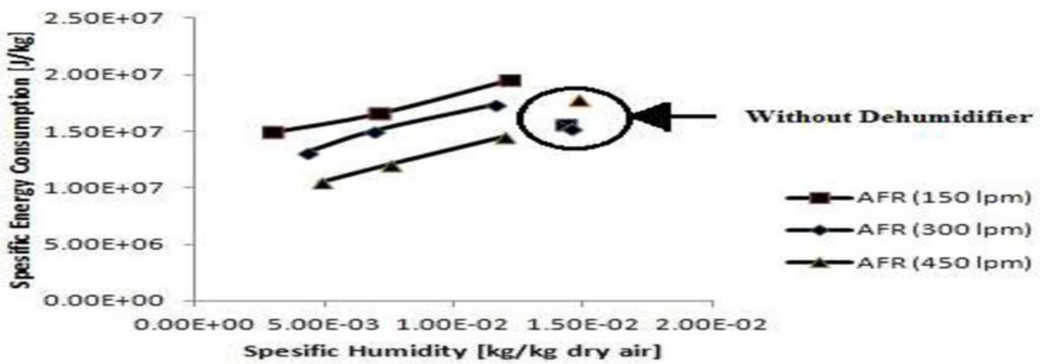

FIGURE 10. Graph relation to the Specific Energy Consumption Specific Humidity at a temperature of 90°C and pressure nozzles 3 bar

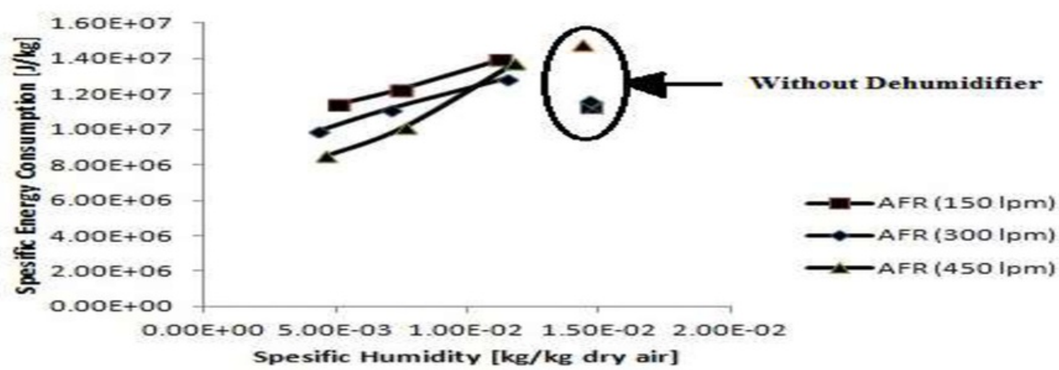

FIGURE 11. Graph relation to the Specific Energy Consumption Specific Humidity at a temperature of 120°C and pressure nozzles 3 bar

At the same air flow rate shows the specific energy consumption increases with increasing specific humidity. And with the increasing air flow rate, the more it will decrease the flow rate of feed material.

With the use of a dehumidifier, the specific energy consumption is not always smaller than in the high air flow rate (meaning also feed high material flow rate). At high air flow rate, which is at 450 lpm, use a dehumidifier to lower the specific energy consumption is significan.

This is especially the drying air temperature of 60 ° C, which is to air flow of 450 lpm, the specific energy consumption without dehumidifier is 2.4x107 J/kg and the dehumidifier (evaporator exit air temperature 10 ° C) and heat recovery condenser is 1.2x107 J/kg. Means there is a reduction in specific energy consumption amounted to 49,2 %.

The decline in specific energy consumption 49.2% is very significant that for humid areas such as in

Indonesia, the utilization of the evaporator (as dehumidifier air dryer) and condenser (as the air preheater dryer) to a spray dryer is highly recommended in the flow of air (hence flow of materials) that maximum. In the specific humidity is relatively high specific energy consumption tends to be high because the ratio of air flow rate at which material is evaporated, the power used, larger than the current specific humidity is relatively low. In the evaporator temperature is relatively low, the specific energy consumption are low because a larger condensation, thus becomes a lower RH.

4. Conclusion

Based on the analysis, it can be concluded as follows:

1. Raising the air discharge only lowers the air temperature at (maximum) 8 ^{0}C.
2. Utilization dehumidifier (evaporator refrigeration system (up to 10 ^{0}C dew point) can lower the drying temperature of 20 ^{0}C.
3. Minimum Temperature tomatoes air-drying a solution of 4^{0}C higher than the water, where the water 36 ^{0}C, and 40 ^{0}C to a solution of tomato. That happens at the air discharge 35 m^3/h, specific humidity of 0.00763 kg/kg $_{dry\ air}$, as well as the feed flow of materials 0.0025 liters / min.
4. The higher the discharge material, the higher the minimum temperature of the drying air. The higher the humidity, the higher the specific minimum temperature of air pengeringnya. The lower the flow of air, the higher the minimum air temperature pengeringnya. To obtain optimum drying air temperature then the parameters as:

a. Specific humidity is set at its lowest condition.

b. Air discharge is set at peak conditions.

c. Debit material is set at peak conditions.

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