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ANALYSIS OF THE EFFECT EVAPORATOR FAN ROTATION VARIATIONS ON AIR BLAST FREEZER PERFORMANCE FOR FREEZING MANGO PUREE

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Abstract. Mangoes are the main commodity in Indramayu Regency, but they are easily damaged after harvesting due to improper mango processing. One solution to overcome this problem is to process mangoes into puree. This process requires freezing technology such as an air blast freezer machine. The evaporator fan functions to prevent blocking of the evaporator fins and distribute cold air so that the room temperature reaches -18˚C. This research aims to determine the effect of variations in evaporator fan rotation on the performance of the air blast freezer system. Data are taken every 10 minutes until the mango puree reaches the set point temperature. Three experiments were conducted with evaporator fan speeds set to low (1800 RPM), medium (2200 RPM), and high (2600 RPM). Based on the tests that have been carried out, the system performance at low fan rotation produces an actual Coefficient of Performance (COP) of 1.9 with an efficiency of 41% and electricity costs of IDR 462,900. Medium fan rotation produces an actual COP of 2.0 with an efficiency of 43% and electricity costs of IDR 469,380. High fan rotation produces an actual COP of 2.1 with an efficiency of 45%. This research shows how variations in fan speed affect the COP, system efficiency, and operational costs, therefore the results of this research contribute to the development of energy efficient and economical cooling technology, especially for tropical-based food preservation applications such as fruit puree mango.

Keywords : Mango, Puree, Air Blast Freezer, Fan, Performance.

1. INTRODUCTION

Mango fruit is a fruit that contains various vitamins and minerals. One of the problems faced in developing mango fruit is that it is easily damaged, so its shelf life is relatively short. This causes high post-harvest yield losses during the main harvest and causes the selling price of mangoes to decline. Preserving mango puree is important because mangoes have a short shelf life due to their high water content, and are susceptible to post-harvest damage. The transformation of mango into puree allows the product to last longer and can be used as a raw material for the food industry [1]. So that consumers can still enjoy mangoes outside of the harvest season, there needs to be a process for processing mangoes into puree. The shelf life of mango puree really depends on the storage temperature. From the research that has been carried out, the longest estimated shelf life is for puree pasteurized at a temperature of 65 °C with a storage temperature of 7 °C, namely 11.2 months. The shortest estimated shelf life was obtained for puree stored at a temperature of 30 °C, namely 0.95 – 1.1 month [2].

Processing mango puree will definitely require cooling system technology such as an Air Blast Freezer machine. The fast-freezing method (Air Blast Freezer) was chosen because the fast cooling process can help prevent the growth of microorganisms during post-harvest mango processing more effectively than the regular freezing method. This system uses a fan to distribute cold air efficiently, ensuring a homogeneous temperature across the product surface. In addition, fast freezing with an air blast freezer preserves the texture, color and nutrition of mango puree better than the slow freezing method, which can cause cell damage. Other methods, such as static freezing or using liquid nitrogen, do not provide adequate air circulation, which can lead to the formation of large ice crystals, damaging the product structure [3].

The function of the fan is to distribute the cold air produced by the evaporator throughout the room. The use of fans is intended to ensure that the room and product temperatures reach the target temperature, namely -18 ˚C. The rate of air flow entering the evaporator greatly influences the system performance (coefficient of performance) in the refrigeration system [4]. The problem above is to determine the performance of an air blast freezer system when using three variations of evaporator fan, namely low, medium and high.

2. METHODS

The stages of conducting the research were carried out based on the flowchart shown in Figure 1. At the data collection stage, the author will take data from the refrigeration system at the point of condenser in and out temperature (˚C), evaporator in and out temperature (˚C), suction and exhaust pressure (psi), product temperature (˚C), and cabin temperature (˚C). Meanwhile, environmental conditions during testing were adjusted to the average temperature of Indramayu Regency during the day, namely 33 °C. Then data are collected every 10 minutes until the mango puree reaches a temperature of -18 °C. The data analysis stage was obtained from the results of data collection by calculating engine performance and comparing engine performance between air blast freezer systems using variations in low, medium and high evaporator fan rotation. The fan speed variations were selected based on significant differences in Air Blast Freezer (ABF) system performance. 1800 RPM (low) is a representation of energy saving conditions with slow air distribution. 2200 RPM (medium) represents a balanced speed that aims to optimize energy efficiency and cooling performance. 2600 RPM (high), which is the maximum speed for fast air distribution and even freezing in a short time. The selection of the RPM value is based on the voltage output setting via the dimmer and adjusted to the evaporator fan capacity.

2.1 Research Design

A process or stage of working on a final project that starts from start to finish. The following is a diagram of the stages of work in the final project research.

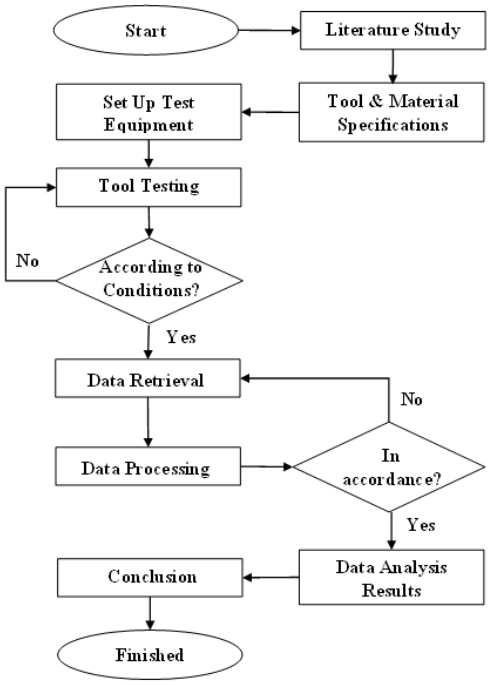


Figure 1. Research Flow Chart

2.2 Set Up Test Equipment

The test equipment used in this research includes a 2 PK refrigeration compressor and an upright chiller evaporator, which is equipped with an evaporator fan. The evaporator has been modified for low temperature operation by adding several components, including a hot gas pipe from the discharge line. This pipe channels hot steam to melt the ice and prevent blockages in the evaporator coil, with manual control via a push button. The hot gas will work for 2 minutes after the cooling time lasts for 60 minutes. Three fans in front of the evaporator which function to increase the air flow rate in the evaporator. The cooling room uses an iron plate and sandwich panel structure with a thickness of 5 cm and dimensions of 1 x 1.5 x 1 m. Table 1 shows the component specifications used in this research.

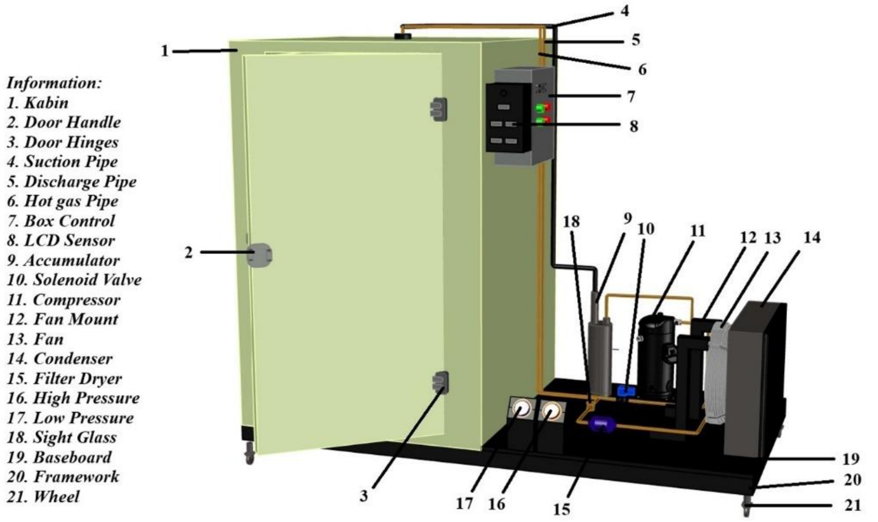
Table 1. Component Specifications

No	Component	Quantity	Unit	Information
1	Compressor	1	Unit	Hermetic 2 PK
2	Condensor	1	Unit	Air cooled
3	Capillary tube	200	cm	Diameter 0,7
4	Evaporator	1	Unit	Air cooled
5	Fan Evaporator	3	Unit	Axial fan
6	Ampere pliers	1	Unit	Model 2007R
7	Thermometer	5	Unit	Elitech
8	Digital Thermostat	1	Unit	Model Elitech STC 8080HX
9	Pressure gauge	2	Unit	Model HC-OG-3.8
10	Manifold gauge	1	Unit	R-404A
11	Vacum pump	1	Unit	Power 1/8 HP
12	Dimmer	1	Unit	Model SCR2000W
13	Tachometer	1	Unit	Model DT2234
14	Refrigerant	1	Can	R-404A Chemours

2.3 Tool testing

The composition of the air blast freezer system components for freezing mango puree is arranged according to figure 2. A compressor (1) will work on the refrigerant by pumping refrigerant throughout the system, so that the refrigerant has high pressure and temperature, the high pressure refrigerant will flow to the condenser (2) because the condenser temperature is higher than the ambient temperature, the refrigerant heat will be released through the condenser pipe walls into the surrounding environment. A filter dryer (3) is used to filter dirt in a system so that the dirt does not circulate with the refrigerant which could potentially cause congestion in the system. Capillary pipe (5) is used to reduce the pressure in a system so that the refrigerant temperature is lower than the temperature of the room to be cooled. Evaporator (6) is used as a heat absorber in the cabin. A cabin has the function of storing research materials carried out. An evaporator fan is used as an aid in distributing cold air produced by the evaporator (6) into the cabin.

An accumulator (7) is used to hold liquid refrigerant to ensure that the refrigerant entering the compressor (1) has a gas phase. The hot gas defrosts solenoid valve (8) functions if a vapor compression system wants to utilize hot vapor refrigerant from the compressor (1) to help melt the frost contained in the evaporator (6).



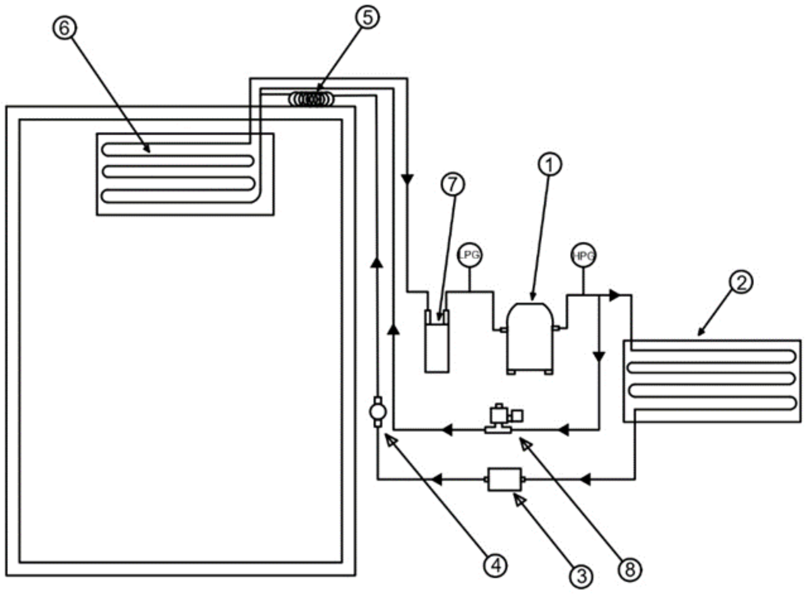


Figure 2. Air Blast Freezer Installation Scheme

Information:

1. Compressor
2. Condensor
3. Filter Dryer
4. Sight Glass
5. Capillary tube
6. Evaporator
7. Accumulator
8. Solenoid Valve

Testing is carried out by conducting experiments to obtain the desired system conditions. To get the desired temperature, several experiments were carried out. The experiment begins with a running test in an uncontrolled engine condition and by filling the refrigerant based on the pressure and current listed on the nameplate. From the experiments carried out, the temperature values at the inlet and outlet of the evaporator gradually became the same, as a result of this a blockage occurred in the evaporator component. Then the refrigerant is reduced with reference to the R404A refrigerant table, the refrigerant is filled with a pressure of 30 psi on the low pressure side. To overcome the blockage on the evaporator, hot gas defrost is carried out. This defrost time is based on the blocking condition of the evaporator component or is set manually by pressing the push button. When the push button is pressed, solenoid valve 1 (defrost) works. When and how long the defrost works, experiments are carried out by visually observing the condition of the evaporator. From these observations, it was found that the cooling time was 60 minutes, then defrosting for approximately 2 minutes. Determining the cooling time and defrost time incorrectly will affect the system, such as the compressor shutting down because the pressure is too low or the compressor shutting down because it overheats.

2.4 Data Retrieval

The steps taken after testing the system include collecting data, which will later be analyzed. This was done to determine the comparison of the air blast freezer machine with variations in rotation of the evaporator fan. The data that will be taken is the temperature of the mango puree. Before data collection, due to the unavailability of mango puree products in the required amount, 5 kg of mango puree was used. To meet the load requirement of 50 kg, bottled water in packaging was added as a substitute for mango puree.

In initial conditions, the product has a temperature of 27 – 30 °C. Data collection was carried out until the mango puree temperature reached -18 °C. The data collection process was carried out in 3 different experiments. The first data collection was carried out by varying the evaporator fan rotation low, with an rpm value set at 1800. The second data collection was carried out by varying the medium evaporator fan rotation, with an rpm value set at 2200. The third data collection was carried out by varying the evaporator fan rotation high, with the rpm value is set at 2600 rpm. The existing data was obtained from careful and direct observations. Required data includes discharge pressure, suction pressure, temperatures for the evaporator (in and out), condenser (in and out), cabin temperature, voltage, and current.

3. RESULTS AND DISCUSSION

Based on the results of data collection, data processing was carried out using the P-H diagram of R-32 refrigerant. Based on the results of the P-H diagram plot, the enthalphi value for each measurement variable is obtained and then the calculation is carried out using the following equation:

Compression work

$$qw = h2 - h1 \quad (1)$$

$$Qe = m \times qw \quad (2)$$

Heat release in the condenser

$$qc = h2 - h3 \quad (3)$$

$$Qc = m \times qc \quad (4)$$

Evaporation process

$$qe = h1 - h4 \quad (5)$$

$$Qe = m \times qce \quad (6)$$

COP calculation

$$COPcarnot = \frac{T\ evaporasi}{T\ kondensasi - T\ evaporasi} \quad (7)$$

$$COPaktual = \frac{h1 - h4}{h2 - h1} \quad (8)$$

Efficiency Calculations

$$\eta = \frac{COPaktual}{COPcarnot} \times 100\% \quad (9)$$

From the calculation process using the equation above, tables and graphs are obtained regarding the influence of fan speed variations on the performance parameters of the air blast freezer. Table 2 shows the calculation results for various fan variations at 300 minutes.

Table 2. Fan Variation Calculation Results

Variasi Fan	qw (kJ/kg)	qc (kJ/kg)	qe (kJ/kg)	COP aktual	COP carnot	Efisiensi (%)	Temp. Kabin (˚C)
Low	53	155	102	1,9	5	38	-2
Medium	52	154	102	1,9	5	39	-4
High	50	153	103	2	4,5	45	-6

3.1 Effect of Fan Variations on Compression Performance

Based on the graph in Figure 3, it explains that compression work using the 300th minute low evaporator fan research method has a qw value of 53 kJ/kg, while compression work using the 300th minute medium evaporator fan research method has a qw value of 52 kJ/kg , as well as for compression work using the 300th minute high evaporator fan research method, it has a qw value of 50 kJ/kg. This shows that the low evaporator fan research method has the largest qw or compression work value compared to the medium evaporator fan and high evaporator fan research methods. This is because the low evaporator fan research method has a large evaporation work value compared to the medium evaporator fan and high evaporator fan research methods. In this air blast freezer system there is a defrost system, which occurs when the system works once every 60 minutes which causes a temporary increase in temperature in the evaporator, thus affecting the graph of the compression process.

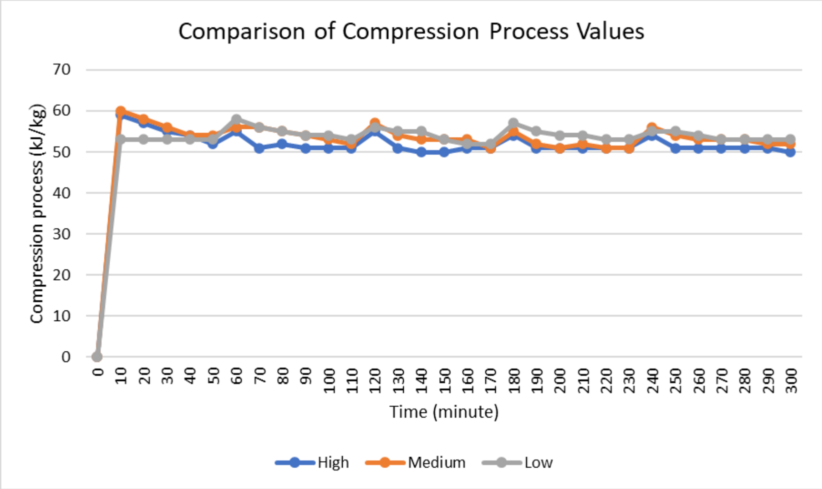


Figure 3. Comparison of Compression Work Values (qw) on Fan Variations

3.2. Effect of Fan Variations on Condensation Performance

Based on the graph in Figure 4, it explains that condenser work using the 300th minute low evaporator fan research method has a qc value of 155 kJ/kg, while condenser work using the 300th minute medium evaporator fan research method has a qc value of 154 kJ/kg , as well as for condenser work using the 300th minute high evaporator fan research method, it has a qc value of 153 kJ/kg. This shows that the low evaporator fan research method has the greatest qc or condenser work value compared to the medium evaporator fan and high evaporator fan research methods. This is because the heat capacity removed is smaller compared to the medium evaporator fan and high evaporator fan research methods. In this air blast freezer system there is a defrost system, which occurs when the system works once every 60 minutes which causes a temporary increase in temperature in the evaporator, thus affecting the graph of the condensation process.

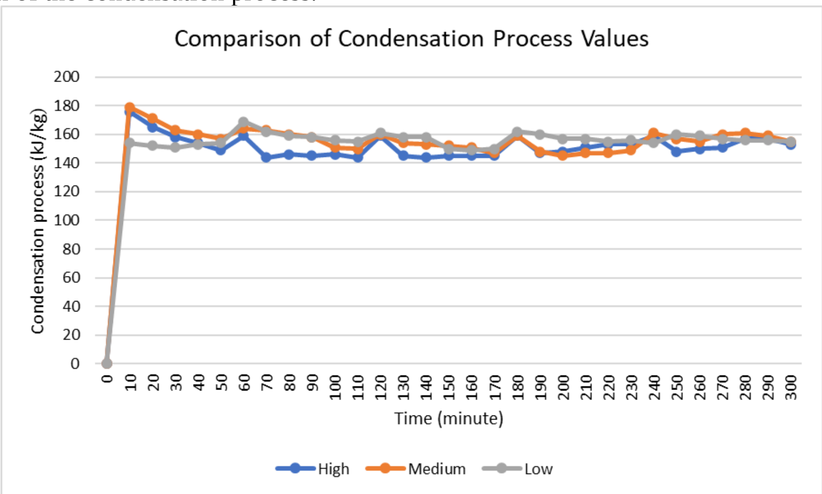


Figure 4. Comparison of Condensation Work Values (qc) on Fan Variations

3.3 Effect of Fan Variations on Evaporation Performance

Based on the graph in Figure 5, it explains that the evaporator work using the low evaporator fan research method at the 300th minute has a qe value of 102 kJ/kg, while the evaporator work using the medium evaporator fan research method at the 300th minute has a qe value of 102 kJ/kg. , as well as for evaporator work using the 300th minute high evaporator fan research method, the qe value is 103 kJ/kg. This shows that the low evaporator fan research method has the largest qe or evaporator work value compared to the medium evaporator fan and high evaporator fan research methods. This is because using a low fan has the effect of holding the air in contact with the evaporator longer so that more heat is absorbed compared to medium and high. In this air blast freezer system there is a defrost system, which occurs when the system works once every 60 minutes which causes a temporary increase in temperature in the evaporator, thus affecting the graph of the evaporation process.

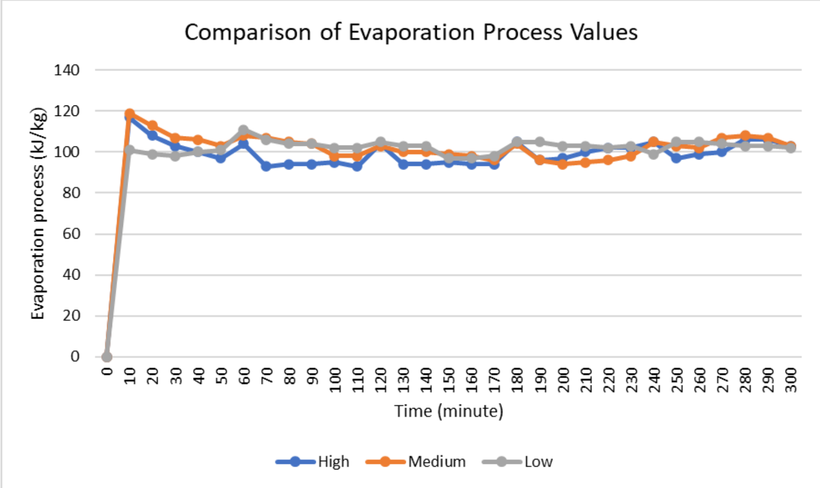


Figure 5. Comparison of Evaporation Work Values (qe) in Fan Variations

3.4 Effect of Fan Variations on Cabin Temperature

Based on the graph in Figure 6, it explains that the cabin temperature using the 300th minute low evaporator fan research method reached a temperature of –2˚C, while the cabin temperature using the 300th minute medium evaporator fan research method reached a temperature of -4˚C, as well as for the The cabin using the 300th minute high evaporator fan research method reaches a temperature of -6˚C. This shows that by using variations in high evaporator fan rotation, the cabin temperature decreases more quickly compared to variations in low evaporator fan rotation and medium evaporator fan rotation. This is because by varying the high evaporator fan rotation, the cold air distribution process is more evenly distributed more quickly. In this air blast freezer system there is a defrost system, which occurs when the system works once every 60 minutes which causes a temporary increase in temperature in the evaporator, thus affecting the cabin temperature graph.

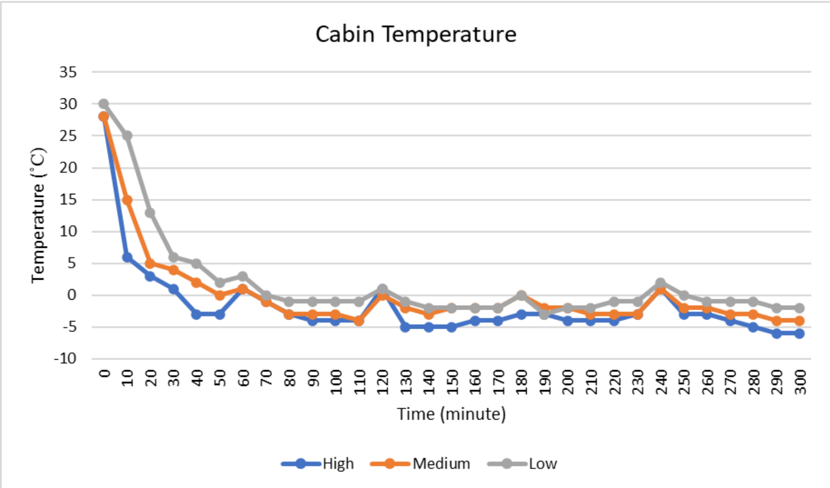


Figure 6. Cabin Temperature Comparison

3.5 Effect of Fan Variations on Actual COP Values

Based on the graph in Figure 7, it explains that the COPActual value using the 300th minute low evaporator fan research method has a COPActual value of 1.9. Meanwhile, the COPActual value using the 300th minute medium evaporator fan research method has a COPActual value of 1.9 and the COPActual value using the 300th minute high evaporator fan research method has a COPActual value of 2. This shows that with the evaporator fan research method high has the highest COPActual value compared to the low evaporator fan and medium evaporator fan research methods. This is because the high evaporator fan research method has a lower compression work value compared to the low evaporator fan and medium evaporator fan research methods.

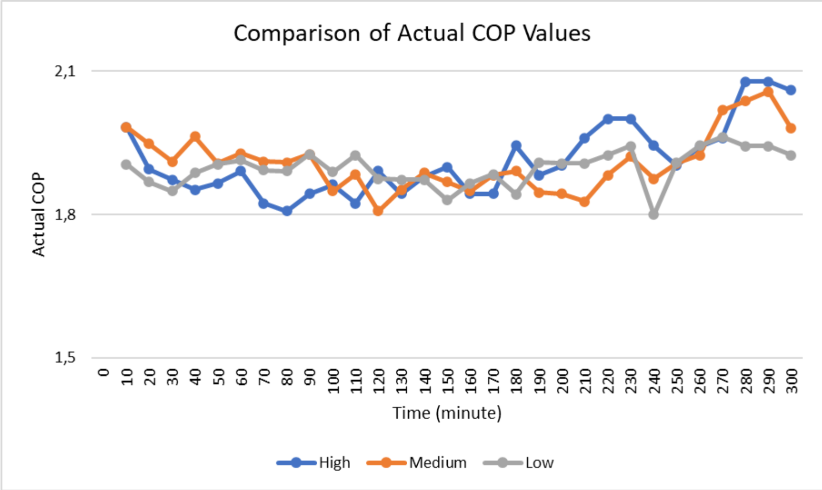


Figure 7. Comparison of Actual COP Values

3.6 Effect of Fan Variations on COP Carnot Values

Based on the graph in Figure 8, it explains that the COPCarnot value using the 300th minute low evaporator fan research method has a COPCarnot value of 5, while the COPCarnot value using the 300th minute medium evaporator fan research method has a COPCarnot value of 5, and for the COPCarnot value with The 300th minute high evaporator fan research method has a COPCarnot value of 4.5. This shows that the low evaporator fan and medium evaporator fan research methods have a higher COPCarnot value compared to the high evaporator fan research method. This is because the temperature in the evaporator is lower compared to the fan evaporator high research method. In this air blast freezer system there is a defrost system, which occurs when the system works once every 60 minutes which causes a temporary increase in temperature in the evaporator, thus affecting the graph on COPCarnot.

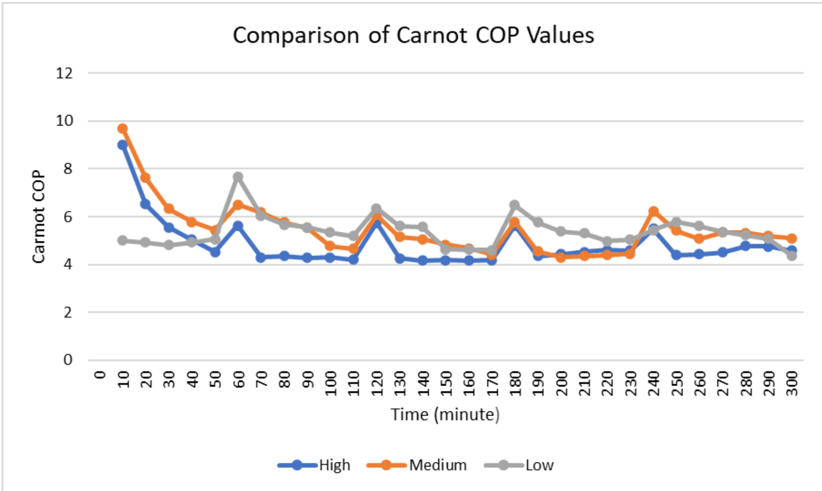


Figure 8. Comparison of Carnot COP Values

3.7 Effect of Fan Variations on Efficiency Values

Based on the graph in Figure 9, it explains that the efficiency value with the 300 minute low evaporator fan research method has an efficiency value of 38%, while the 300 minute medium evaporator fan research method has an efficiency value of 39%, as well as the high minute evaporator fan research method. The 300th has an efficiency value of 45%. This shows that the high evaporator fan research method has the highest efficiency value compared to the low evaporator fan and high evaporator fan research methods. This is because the high evaporator fan research method has a smaller Carnot COP value and the actual COP value is greater compared to the low evaporator fan and medium evaporator fan research methods.

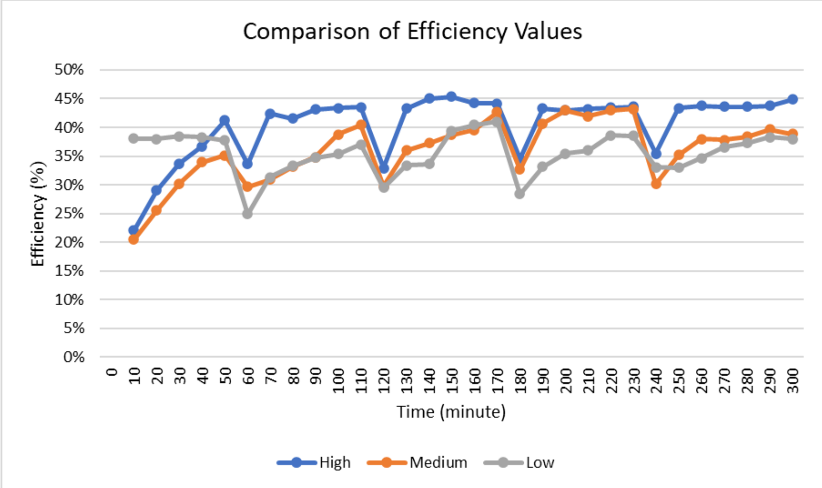


Figure 9. Comparison of Efficiency Values

4. CLOSING

4.1 Conclusion

Based on the results of the research carried out, it can be concluded that in the air blast freezer system, if the evaporator fan rotation is varied, it shows that.

1. For low evaporator fan rotation (1800 RPM), it shows that COPActual has the highest value of 1.9 and the lowest value of 1.8. Besides that, the highest COPCarnot value was 8.6 and the lowest value was 4.6. The highest efficiency achieved was around 41%, while the lowest efficiency reached a value of 22%. In the air blast freezer system, the average COPActual value was 1.9 and the average COPCarnot was 5.8 and the average efficiency value was around 34%.
2. For medium evaporator fan rotation (2200 RPM), it shows that COPActual has the highest value of 2.0 and the lowest value of 1.8. Besides that, the highest COPCarnot value was 9.6 and the lowest value was 4.2. The highest efficiency achieved was around 43%, while the lowest efficiency reached a value of 20%. In the air blast freezer system, the average COPActual value was 1.9 and the average COPCarnot was 5.4 and the average efficiency value was around 36%.
3. For high evaporator fan rotation (2600 RPM), it shows that COPActual has the highest value of 2.1 and the lowest value of 1.8. Besides that, the highest COPCarnot value was 8.9 and the lowest value was 4.1. The highest efficiency achieved was around 45%, while the lowest efficiency reached a value of 22%. In the air blast freezer system, the average COPActual value was 1.9 and the average COPCarnot was 5.1 and the average efficiency value was around 40%.
4. Based on the analysis that has been carried out, all variations of the evaporator fan rotation are not suitable for application in the air blast freezer system, because they do not meet the requirements for achieving a mango puree freezing temperature of -18 °C so they are not able to provide a solution to the problem of post-harvest mango fruit.

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