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ANALYSIS OF HEAT TRANSFER EVAPORATION PROCESS FOR MAKING ANTS SUGAR MADE FROM FRESH RAW NEERA

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Abstract. Ant sugar is a powdered version of brown sugar and is often referred to as crystal sugar. It is called ant sugar because the shape of this sugar resembles that of ants nesting on the ground. The basic ingredients for making ant sugar are palm juice from coconut and palm trees (palm). In this study, the maximum temperature regulation is 140 ^{o}C and the pressure is 2 atm. The materials used in this study were coconut and sugar cane juice produced by farmers in Kokap Wates, Kulon Progo Regency. In the manufacture of ant sugar in the evaporation process the temperature of the material increases with increasing winding temperature and overtime. In the process of fresh neera evaporation, the value of heat transfer coefficient ranges between 20-22 (W / m^2.^{o}C). This shows that when the initial cooking for this concentration is needed more than 20 Watts to heat the material by 1 ^{o}C for an area of 1 m^2 of material. The value of heat transfer coefficient of turmeric neera beetween 17 - 25 (W / m^2.^{o}C).

1. Introduction

Nowadays, the consumption of sugar, especially granulated sugar is increasing rapidly year by year. This problem also needs to be supported by the sugar production from the industry to meet the needs of consumers for sugar; but in fact, the need for sugar cannot be fulfilled by the national sugar industry. [1] pointed out that the need of national sugar in Indonesia was as much as 3.2 million tons per year while the domestic production was around 2 million tons. It became a decrease for Indonesian as in 1975-1995, the national sugar production in Indonesia reached around 2.5 million tons.

The lack of sugar stock itself, encourages us to think of other alternatives of sugar whose ingredient is not from sugar cane, one of them is sugar made neera (crystal sugar). The national sugar diversification program which is based on crystal sugar will be even more effective if it is supported by the commitment build on community and government policy to develop "love palm sugar" culture and plan for a comprehensive, integrated and sustainable coconut sugar agro-industry program [2].

Ant sugar refers to powdered-brown sugar and is often known as crystal sugar. It is called crystal sugar since its shape represents the nest of ants living underground. The basic ingredients in making crystal sugar are the neera from coconut and palm trees. The weakness being faced now is there is no modern-process of making crystal sugar; however, most of crystal sugar are made conventionally by the processes of thickening and granules-making (crystallization) as well as drying. Many problems are still found in conventional process in which the process does not have any good hygiene standards, the process is done through batch system and the capacity of each batch is relatively low. Besides, conventional process also requires a long time and a lot of labor. Hence, it is very necessary to have a tool that is able to maximize the production process of crystal sugar [3].

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Evaporator is defined as a heat exchanger producing heat transfer from one fluid to another, in which the fluid is separated from one another by a wall or barrier that is passed by the heat. The heat transfer from one substance to another often occurs in the industry process. In most processes, the heat intake or expenditure is required in order to achieve and maintain the conditions needed during the process [4]. The first condition is to achieve the condition needed for the working process itself, for example if the process itself should be at a certain temperature, this temperature must be reached by the heat intake or expenditure. The second condition is to maintain the condition needed for the operation of the process, found in the work of exothermic and endothermic. Besides chemical changes, this situation also becomes natural workmanship at the same time. It was became the reason to conduct this research in order to obtain an alternative of granulated sugar through crystal sugar made of coconut juice or neera [5].

2. Literature Review

Literature review that will be used for this research are

2.1 Coconut neera

Neera refers to liquid tapped from the male flower of palm tree. This liquid contains between 10-15% of sugar. Neera can be processed into soft or alcoholic drinks, palm syrup, palm sugar and nata de arenga. This coconut neera is easily fermented as it contains very-active wild yeast. When neera is late cooked, it usually turns into cloudy and yellowish color, tastes sour, and has stinky smell . Fresh neera has the composition of nutrients listed on Table 1: [6]

Table 1. The Composition of fresh coconut neera (g/100 ml)

No.	Composition	Content
1.	Total solids	15,20 – 19,70
2.	Sucrose	12,30 – 17,40
3.	Ash	0,11 – 0,41
4.	Protein	O,23 – 0,32
5.	Vitamin C	16,00 – 30,00

2.2 Evaporation

Evaporation is one of main methods in the chemical industry to condense dilute solutions. The general definition of evaporation is to remove water from the solution by boiling the solution in a suitable tube called an evaporator. Evaporation was used to condense a solution consisting of non-volatile solute and volatile solvent.

In most evaporation processes, the solvent used is water. Evaporation is done by vaporizing parts of the solvent so that thick liquid solution obtained is in higher concentration. Evaporation is different from drying; in evaporation, the residual evaporation is liquid, which sometimes becomes viscous liquid, not solid one. Evaporation is also different from distillation since the steam is usually in a single component, and although the steam is mixture, the evaporation process does not separate it into fractions [7].

Evaporation is different from crystallization emphasizing on the solution concentrating rather than solid or crystal making. At certain situation, for instance is in the evaporation of salted-water to make salt, the dividing line between evaporation and crystallization is not strict. It occurred as the evaporation sometimes produced crystal mud in the main liquid [8].

Heat transfer is the energy transfer occurred that was due to two systems that differ on temperature. The heat transfer occurred in evaporator is through condensation, conduction, convection and boiling. Condensation happens on the surface of the heater due to the influence of the heater's steam. Then, the conduction that took place on the outer surface of the heating pipe headed to the inner surface of the heating pipe in which it flowed through convection whose heating and boiling processes of heat

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happened when the neera boiled and then evaporated water from the dilute neera through the heating pipe [9].

2.3 Heat Transfer

The process of heat transfer through a flat wall in which there is hot fluid on one side and on cooler fluid on another side is stated by: [10]

$$q = h.A.(T_w\ T_b) \qquad (2.1)$$

According to Kreith (1973), for Biot value less than 0.1, internal resistance to heat transfer could be ignored since it was too low. If the internal resistance to heat transfer was ignored, it means that the temperature is considered homogeneous inside the material. For this reason, this condition is called a lumped system, with the energy balance at the system boundary shown on equation 2.2.

$$-m.C_p.\frac{dT}{dt} = h.A.(T - Tl) \qquad (2.2)$$

The minus sign on above equation shows that the internal resistance decreases if T> Tl. By separating the variables T and t at the differential time interval dt, we obtain:

$$\frac{dT}{(T - Tl)} = -\frac{h.A}{m.C_p}dt \qquad (2.3)$$

With the initial temperature (T_0) and the temperature of the material (T_b) at certain time (t), equation 2.3 can be integrated as follows:

$$\int_{To}^{Tb}\frac{dT}{(T - Tl)} = \int_0^t -\frac{h.A}{m.C_p}dt \qquad (2.4)$$

$$\ln(T - Tl)\Big|_{To}^{Tb} = -\frac{h.A}{m.C_p}(t - 0) \qquad (2.5)$$

$$\ln\left(\frac{Tb - Tl}{To - Tl}\right) = -\frac{h.A}{m.C_p}t \qquad (2.6)$$

$$\left(\frac{Tb - Tl}{To - Tl}\right) = e^{-\left(\frac{h.A}{m.C_p}\right)t} \qquad (2.7)$$

The value of $\left(\frac{Tb - Tl}{To - Tl}\right)$ is called as temperature ratio, in which Tb refers to the material's temperature after being cooked for t second, To is the initial temperature and Tl is room temperature. Equation 2.7 is identical to y=ax, in which the drying time (t) as x and ln TR as the value of y, so that the slope will be equal to hA/ρCpV. Therefore, the value of h can be calculated and is called h observation. The coefficient of convection will depend on the drying condition in the form of temperature (T) and the partial steam pressure under the vacuum pressure (p). The coefficient of convection will be linked empirically to those variables as follows:

$$h_{prediction} = aT^bP^c \qquad (2.8)$$

The a, b, c parameters on equation were determined by making a mathematical relationship as follows:

$$h_{obs} = \log a + b \log T + c \log P \qquad (2.9)$$

By using SPSS, equation (6) became multiple regression so that a, b, c parameters can be determined as follows: Y = aX1 + bX2 + cX3 (2.10)

In finding Cp value of thick sugar liquid, equation 2.8 was used as follows:

$$Cp\ \ (1\ 0{,}007(^o\ Brix))\ x\,4187 \quad (J/kg.°C) \qquad (2.11)$$

Density was obtained from equation 2.9 as follows :

$$981{,}4\ 4{,}5(^o\ Brix)\ 0{,}23T$$

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The coefficient value of convection (h) was vary as it lied on the initial concentration or indicated by °Brix before the cooking. The coefficient of convection was linked empirically to the variables on equation 2.10.

$$h = 10^a . Brix^b \qquad (2.13)$$

Heat types of neera is the amount of heat needed to change the neera under certain conditions along with the temperature of mass unit as much as one degree. The size of the heat type of neera itself depended on the degree of the brix of the room. In addition, Brix is interpreted as concentration of 100 grams of pure sucrose in 100 gram solution. According to [11] to calculate the heat type of neera, the equation used was as follows:

C = 1- 0,006B (2.14)

C = Heat type of neera (Kkai/kg oC)
B = Brix degree of neera

Crystal coconut sugar (crystalline coconut sugar) was the result of processing the neera of palm tree in the form of powder [12]. The difference between crystalline coconut sugar and brown sugar is that there is no molding process, but rotation process (centrifuge) on the production of crystalline coconut sugar, it will take the form of powder or crystal, so that sometimes the crystal coconut sugar is also called crystal sugar. Basically, the production of crystalline coconut sugar is to convert the dissolved sugar compound into solid sugar in the form of crystal or powder.

The strength of crystal sugar compared to brown sugar (molded) was it was more soluble, it could be stored longer, had more attractive shape, its packaging and transportation was easier, had more distinctive taste and aroma, could be enriched with other ingredients such as spices, vitamins and iodine [13], and the price was more expensive than the ordinary molded coconut sugar. The use of crystalline coconut sugar is the same as granulated sugar (sugar cane) which can be used as cooking spices, sweetener (syrup, milk, soft drinks) and for sweetener purposes at the food industry such as bread dough, cakes, kolak, etc.

The materials used for the production of crystalline coconut sugar at the home industry level are fresh neera as raw material, lime betel (laru) or sulfite and coconut oil/milk. Lime betel (laru) and sulfite had function to neutralize the neera to a degree of acidity (pH) ranging from 6.0 to 7.0 so that fermentation was inhibited, while coconut oil/milk was used to keep the foam or froth from overflowing while being cooked. The raw material for crystalline coconut sugar could be come from self-made coconut sugar or from sugar traders [14].

The process of making crystalline coconut sugar can be done in two ways involving crystalline coconut sugar made from coconut neera and ready-made coconut sugar. The production of crystalline coconut sugar made from molded coconut sugar is due to the high demand from consumers, so that the producers even buy molded coconut sugar in the market to be processed into crystal coconut sugar because the profits will be higher and it also utilizes (recondition) the molded coconut sugar products. Actually, the process of producing crystalline coconut sugar included the process of adjusting pH and filtering neera or the selection of molded sugar, heating/cooking the neera or sugar solution, the process of solidification, the process of granulation/crystallization, sifting, drying and packaging [15].

3. Working Methodology

In the process of making this crystal sugar, there needed a tool which was able to reduce water content of neera so that it was able to be continued to the process of crystallization later on, the tool was an evaporator. In this evaporator, there was a heat transfer process originating from a steam boiler that had been accommodated and this steam was flowed into the evaporator through a pipe as a place for hot steam to flow. In this research, the temperature of the steam boiler was set to a maximum of 140 ^oC and the pressure of boiler was 2 atm. This process was expected to cause the water content in the material reduced as expected.

This evaporation process also had vacuum pressure originating from the water pump by utilizing condensation process. The vacuum pressure was set to a maximum of 40 bar, while this

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pressure was getting higher over time and was able to exceed the pressure that had been determined. To prevent this to occur, the pressure was decreased by opening the air valve of vacuum pump so that the vacuum air released and the pressure decreased.

In this process, stirring was also performed by the motor power source which had been connected to the evaporator. This stirring was intended to ensure that the temperature of material inside the evaporator was evenly fast and the evaporation process did not take long time. The topic of this research was the heat and mass transfer of material toward predetermined length of time. In this process, the temperature of material was increasing over time due to the continuous flow of steam in the evaporator. By the increase of material temperature, there was definitely a process of water evaporation dissolved in the material so that neera that was poured with high initial water content was able to have the process of crystallization by using the existing crystallizer.

3.1 Research Area

The research took place at CV Sumber Rejeki workshop in Yogyakarta and conducted in January up to March.

3.2 Tools and Material

The tool used in this research was one unit of crystal sugar processing consisting of boiler and evaporator as shown on the figure 1. In this research, the hot steam produced originating from the boiler by utilizing the process of water cooking in the boiler. To measure the temperature of material and heating pipe, a medium digital thermocouple was used while measuring the mass transfer with refractometer was used to measure brix content.

The materials used in this research were coconut neera and sugar cane produced by the farmers in Kokap of Wates District, Kulon Progo Regency.

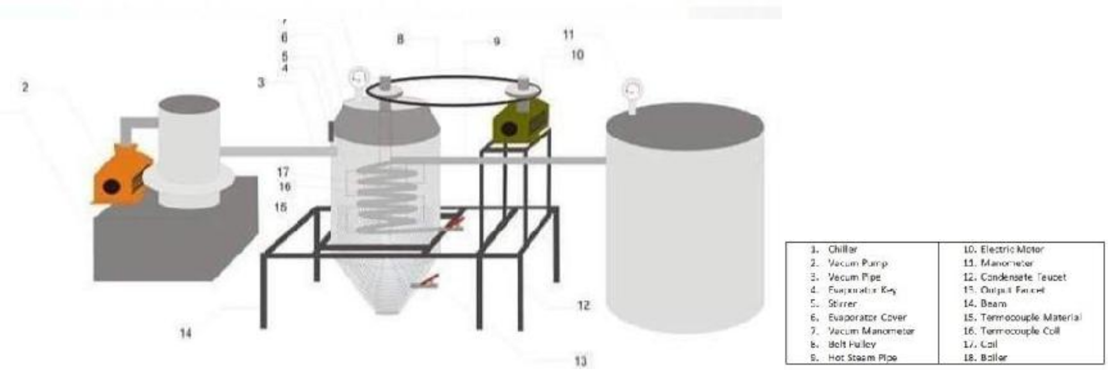

Figure 1. Evaporator for Making Ant Sugar

4. Experiment and Result

4.1 Material Temperature Changes

In the making of cant sugar in the evaporation process, the material temperature increased along with the increase of winding temperature and time. The increase of material temperature was because of the heat supply from the winding in the evaporator through convection process, it can be seen on figure 2.

On figure 2 above, it can be seen that the material temperature increased significantly in the first 15 minutes but in the following time, the material temperature was constant and slowly decreased but here the material temperature was claimed to be constant because the decrease tended to be small. In the first 15 minutes, the material was boiled first by entering heat steam flowed through the winding of boiler without using vacuum pressure. The heat transferred from the winding to material through convection process.

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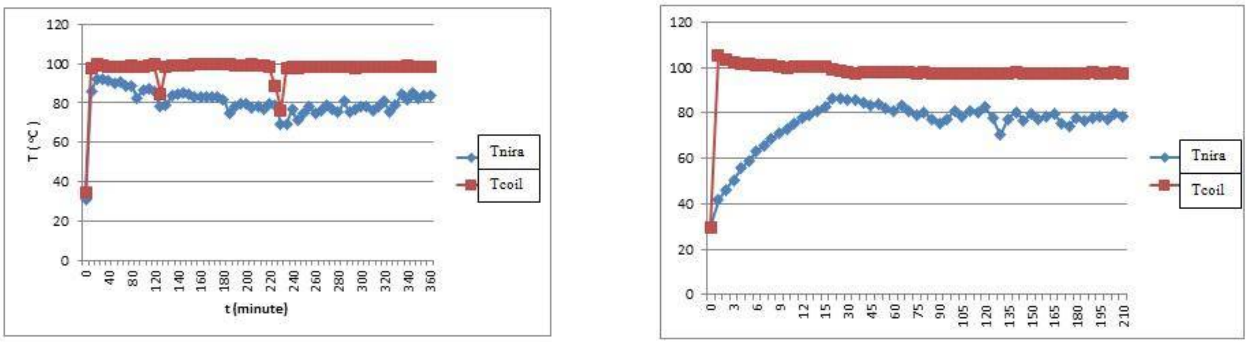
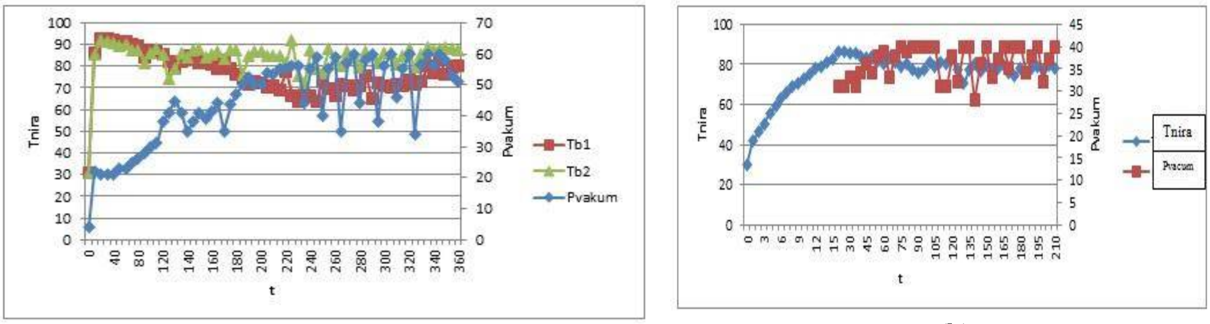


a) (b)

Figure 2. Temperature changes during the process of (a) Fresh Neera and (b) Turmeric Neera processing

From figure 2, there was an increase of winding temperature accompanied by the increase of material temperature, which showed that the material temperature itself was not able to be constant even though the heating source temperature itself was already constant. This was caused by the relationship between pressure and temperature; the lower the pressure was, the lower the temperature woould be and vice versa; so, making the pressure and temperature to be constant was difficult to be done. This can be seen on figure 3, as follows:



(a) (b)

Figure 3. Temperature and vacuum pressure changes during the processing process of (a) Fresh Neera and (b) Turmeric Neera

On figure 3, it can be seen that the material temperature decreased when the material temperature reached the maximum point or it could be said if the final point of evaporation process was complete, the material temperature decreased. In addition, at the same temperature, the lower the air pressure in the evaporator, the slower the material temperature changes would be. It explained that the more vacuum, the air medium as the heat conductor decreased in which it caused the material temperature decreased as well.

Not only them which influenced the material temperature. In this experiment, we used fresh neera without any mixture which then compared with neera that had been mixed with mpon-mpon (turmeric). The influence of initial concentration differred between evaporation process with fresh neera as the basic material and turmeric-mixed neera, it can be seen by patching the material temperature toward time with the similar treatment. Later, we could find out the influence of material concentration on the duration of cooking during the evaporation. This influence can be seen on Figure 4.

From the figure 4, it can be seen if there was a difference in the time temperature to reach the maximum point. From the figure, we can see that in order to reach the temperature of evaporation point, neera which was mixed with mpon-mpon needed a shorter time compared to the process of fresh neera. The material temperature experienced significant changes in the first 15 minutes, in the

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rest after that the material temperature tended to be constant even though it slightly decreased. This showed that the material temperature reached the evaporation point (maximum point).

Figure 4. Temperature changes toward time during the process of neera processing

4.2 Heat Transfer Analysis

The determination of convection coefficient was done by using linear regression analysis as on equation 2.7. To calculate the convection coefficient (h), we needed density data (ρ), specific heat (Cp), material surface area (A). To calculate the density of the material we used equation 2.12, the calculation example here we took on the fresh neera data for the third replication. It was known that the initial material brix was 18.1 and the temperature of the material was 46.85 ^{o}C then,

Then what needed to be sought was the magnitude of the specific heat by using equation 2.11 in the same way the specific heat obtained at the third replication of fresh neera was 3.657 (KJ/kg.°C). After everything was known, we were able to use linear regression, an example is shown on Figure 5.

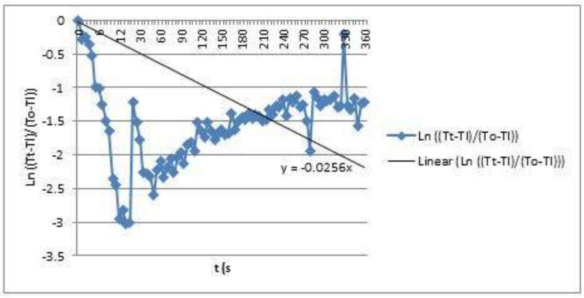

Figure 5. Relationship between Ln TR versus time of evaporation

Slope in the Figure 5 was used to calculate the value of h observation so that the result was 15.37 W/m2oC. In the same way, the value of the observation on convection coefficient in neera evaporation process to be made into crystal sugar can be seen on Table 2:

Table 2. Calculation results of h observation value for fresh neera material

Repetition	h obs (W/m^2.^{o}C
1	20,226
2	21,82
3	22,134

In the process of fresh neera evaporation, the value of the heat transfer coefficient ranged 20-22 (W/m^{2o}C). It showed that when the initial cooking for this concentration needed more than 20 Watts to heat the material by 1 oC for an area of 1 m2 of material. In the process of the third replication, it had the greatest convection coefficient, this was because the material had undergone a process of acidification, but there was no significant difference.

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Next was the process of evaporating the mixed-neera by adding 100 gram turmeric. The mpon-mpon was added directly from the first process of the evaporation until a predetermined time with stirring coming from the electric motor on the device. For the calculation of the coefficient of heat transfer itself, can be seen on Table 3:

Table 3. Calculation results of the value of h observation for turmeric neera material

Repetition	h obs (W/m².°C
1	25,41
2	23,93
3	17,03

In the results of the calculation of h observation, mpon-mpon neera was greater than the observation of fresh neera. The most influential matter was the surface area of the material itself. It can be seen that the surface area of the material in the fresh neera process was 1.321 m2 while in the mpon-mpon mixed-neera was 1.175 m2. Therefore, we can see if the smaller the surface area of the material was, the greater the convection coefficient would be and vice versa, the greater the surface area of the material was, the smaller the convection coefficient would be. In other words, the convection coefficient was inversely proportional to the surface area of the material.

Based on the h observation values on Tables 2 and 3, it can be used to determine the convection heat transfer coefficient as a function of temperature and pressure or called h prediction. By using SPSS 16 program, h prediction was obtained from the initial concentration function of each variation and repetition. On equation 2.10, the predictive coefficient of heat transfer convection (h) was obtained in this experiment. By plotting log h vs log initial brix, the values of variables a and b were obtained on equation 2.13, so that the equation h (initial brix) was obtained to determine the predictive value of h. The equation h (initial brix) was as follows:

$$h_{evaporasi} \; 10^{1.,753} x \; Brix^{0,296}$$

Table 4. Comparison of the value of heat transfer coefficient (h) observation with predictions at the stage of fresh neera evaporation

Repetition	h (W/m².°C)	°Bx	H pred
1	26,093	19,7	23,43
2	24,852	19,1	23,65
3	15,372	18,1	24,03

The value of the predictive convection heat transfer coefficient (h) for evaporation was then used to determine the temperature of the predicted material by using equation 2.7 so that the relationship between the observation temperature with the prediction during evaporation and crystallization can be seen on Figure 6.

According to Figure 6, the value of R^2 was almost close to 1, this value showed that the prediction obtained was very accurate. And the calculated F value as much as 1,237 was smaller than F table value of 5.14 so that it could be said that equation 2.7 was able to be applied well to the processing of crystal sugar processing made from fresh neera by using this evaporation tool.

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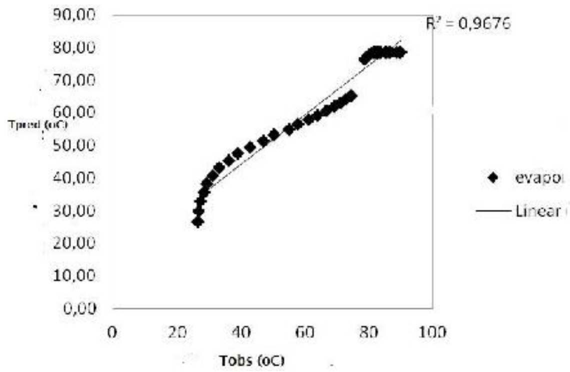
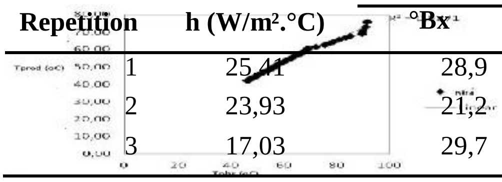


Figure 6. Relationship between observation and prediction material temperature during the fresh neera evaporation process

Table 5. Comparison of the value of the heat transfer coefficient (h) observation with prediction at the evaporation stage of turmeric neera

Repetition	h (W/m².°C)	°Bx	H pred
1	25,41	28,9	20,92
2	23,93	21,2	22,93
3	17,03	29,7	20,75



From Figure 7, the obtained R^2 was almost close to 1, this value showed that the prediction obtained was very accurate. And the calculated F value was smaller than the F table value (3.551<5.14) so it could be said that equation 2.7 was able to be applied well to the process of crystal sugar processing made from turmeric neera by using this evaporation tool.

Figure 7. Relationship between observational and predictive material temperature during the evaporation process of turmeric neera

5. Conclusion

In this research, the process of crystal sugar processing with an evaporator showed that the convection heat transfer coefficient value (h) obtained for the raw material of fresh neera namely hevaporation1 ranged from 20-22 W/m2°C; whereas turmeric neera obtained 17-25 W/m2°C. 4. The result of F test revealed by this mathematical model was able to be applied to heat transfer in the process of making crystal sugar by using an evaporator

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