

**PERPINDAHAN PANAS DAN MASSA PADA PENGOLAHAN GULA
SEMUT MENGGUNAKAN *DIRECT-TYPE EVAPORATOR* DAN
INDIRECT-TYPE CRYSTALLIZER DENGAN VARIASI PERLAKUAN
AWAL NIRA KELAPA**

INTISARI

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Gula semut merupakan gula dari nira kelapa yang berbentuk butiran/serbuk. Keunggulan gula semut dibandingkan gula kelapa cetak yaitu ukuran partikelnya kecil, umur simpan lebih lama, dan kadar air rendah. Tujuan penelitian ialah menganalisis proses perpindahan panas dan massa proses pengolahan gula semut menggunakan *direct-type evaporator* dan *indirect-type crystallizer* serta menentukan kinerja kedua alat tersebut. Penelitian ini menggunakan nira kelapa segar yang mendapat perlakuan nira disimpan suhu 4°C selama 24 jam, nira disimpan suhu 7°C selama 24 jam, dan nira disimpan suhu 27°C masing-masing sebanyak 15 liter. Nira segar diuapkan menggunakan *direct-type evaporator* dari brix 22 % hingga mencapai brix 76 % (kental). Pengukuran suhu dilakukan pada bahan (T₁), diatas bahan (T₂), lingkungan (T₃), dan cerobong (T₄). Selanjutnya, nira kental di evaporasi lanjut pada *indirect-type crystallizer* hingga mencapai brix 95 % (titik jenuh), ketika mencapai titik jenuh pemanasan dihentikan dan siap dikristalisasi. Pengukuran suhu dilakukan pada bahan (T₁), diatas bahan (T₂), uap (T₃), air (T₄), cerobong kompor (T₅), dan lingkungan (T₆).

Hasil penelitian menunjukkan koefisien perpindahan panas gabungan (U) selama proses evaporasi perlakuan nira disimpan pada suhu 4°C, nira disimpan pada suhu 7°C, dan nira disimpan pada suhu 27°C pada evaporator adalah 76,33 W/m².K, 147,67 W/m².K, dan 129,33 W/m².K, sedangkan pada kristalisator adalah 11,37 W/m².K, 45 W/m².K, dan 73,33 W/m².K. Konstanta penurunan kadar air (k) selama proses evaporasi ketiga perlakuan secara berurutan adalah sebesar 0,0022/menit, 0,0038/menit, dan 0,0033/menit, sedangkan pada kristalisator adalah 0,143/menit, 0,317/menit, dan 0,35/menit. Konstanta laju penurunan suhu (k_T) dan konstanta laju penurunan kadar air (k_M) selama proses kristalisasi adalah 0,03/menit, 0,03/menit, dan 0,05/menit, dan untuk k_M 0,8917/menit, 0,8667/menit, dan 0,8767/menit. Efisiensi pemanasan rata-rata pada evaporator untuk ketiga perlakuan secara berurutan sebesar 22,54 %, 35,36 %, dan 31,15 %, sedangkan efisiensi pemanasan rata-rata kristalisator secara berurutan sebesar 38,12 %, 71,47 %, dan 54,85 %.

Kata kunci: Gula semut, perpindahan panas, perpindahan massa, kristalisator berpemanas uap

**HEAT AND MASS TRANSFER OF PALM SUGAR PROCESS USING
DIRECT-TYPE EVAPORATOR AND INDIRECT-TYPE CRYSTALLIZER
WITH VARIATION OF INITIAL TREATMENT OF SAP RAW
MATERIAL**

ABSTRACT

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Palm sugar is a type of sugar made from coconut sap in the form of granules/powder. Palm sugar has advantages compared to other type of coconut sugars, it has smaller particle in size, longer shelf life, and low moisture content. The purpose of this study was to analyze the process of heat transfer and mass transfer during the palm sugar manufacturing process and determine the performance efficiency of the direct evaporator and indirect crystallizer. The material used in this study was 15 liters of fresh coconut sap divided into three treatments of stored coconut sap at 27°C, stored coconut sap at 7°C for 24 hours, and stored coconut sap at 4°C for 24 hours. The evaporation process of fresh coconut sap (brix 22 %) is done until the coconut sap becomes half thick (brix 76 %) using a direct evaporator. Temperature measurements are carried out on the material (T_1), above the material (T_2), environment (T_3), and the chimney (T_4). Then, half-thickened coconut sap is evaporated further in the indirect crystallizer until it reaches the saturation point performed with continuous stirring using an automatic stirrer, when it reaches the saturation point, the heating process is stopped and the coconut sap is ready to be crystallized. Temperature measurements are carried out on materials (T_1), above materials (T_2), steam (T_3), water (T_4), chimney stoves (T_5), and environment (T_6).

The combined heat transfer coefficient (U) during the evaporation process on the treatment of stored coconut sap at 27°C, stored coconut sap at 7°C, and stored coconut sap at 4°C in the evaporator respectively are 76.33 W/m².K, 147.67 W/m².K, and 129.33 W/m².K, while in the crystallizer respectively are 11.37 W/m².K, 45 W/m².K, and 73.33 W/m².K. The constant decrease in water content (k) during the evaporation process respectively are 0.0022 /minute, 0.0038 /minute, and 0.0033 /minute, while in the crystallizer in sequence are 0.143 /minute, 0.317 /minute, and 0.35 /minute. Temperature drop rate constants (k_T) and water rate decrease constants (k_M) of crystallization with the treatment respectively are 0.03 /minute, 0.03 /minute, and 0.05 /minute, and for k_M respectively are 0.8917 /minute, 0.8667 /minute, and 0.8767 /minute. The average heating efficiency in the evaporator with the treatment in sequence are 22.54%, 35.36%, and 31.15%, while the average heating efficiency in the crystallizer correspondingly are 38.12%, 71.47%, and 54.85%.

Keywords: palm sugar, heat transfer, mass transfer, steam heated crystallizer