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Cold pressed virgin coconut oil production: Enhancing energy efficiency through a closed tunnel hot air generation system

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ABSTRACT

The primary aim of this paper was to research and develop a closed tunnel house hot air production system, focusing on cost reduction in the cold-pressed coconut oil production process. The study's scope was centered on a case analysis of Tropicana Oil Co. Ltd. situated in Sampran district, Nakhon Pathom province. The research encompassed the design of a system capable of generating hot air and conserving thermal energy within a closed tunnel house environment. This included developing and constructing a prototype system tailored to this purpose. One of the key objectives was to assess the system's efficiency within the closed tunnel house setup. The broader goal was to enhance air temperature while reducing moisture content before initiating the coconut drying process. It was achieved through an electricity-powered hot air-drying technique, the process aimed to efficiently eliminate water or moisture from dried coconut, priming it for the subsequent cold-pressed oil extraction phase. The resulting system is anticipated to yield multiple benefits. It's projected to curtail energy consumption for operators by minimizing temperature losses within the system. This is facilitated by augmenting natural heat to elevate the air and container temperature during baking. Furthermore, this research unveiled insights into the optimal tunnel house configuration as a highly effective heat source. It also advanced knowledge in creating low-humidity heat storage systems and measurement/control mechanisms tailored for specific tasks. These innovations are anticipated to have applications beyond the coconut oil industry, extending to other sectors reliant on heat energy for production processes.

Keywords: Cold pressed virgin coconut oil production, Heat production, Closed tunnel hot air, Temperature control

INTRODUCTION

The company specializes in producing cold-pressed coconut oil and its derivatives [1]. Their target audience primarily comprises health-conscious consumers who prioritize chemical-free products [2]. With an annual production capacity of 125,000 liters, the company utilizes 1,500 kilograms of shredded coconut per day to create an array of cold-pressed coconut oil products and its derivatives. The production process involves extracting moisture from shredded coconut meat, followed by oil extraction through pressing and subsequent filtration to yield pure coconut oil [3]. A pertinent challenge in this process is the management of materials and energy during coconut meat baking. The energy consumed in drying, primarily resulting from water evaporation, constitutes a significant proportion of the overall electricity usage [4]. This expense stands at approximately 111,375 baht per month (based on a production cycle of 25 days per month), or an estimated 1,336,500 baht annually.

Hence, by elevating the temperature of the grated coconut meat, the utilization of aluminum shells and air during the baking process could potentially lead to a substantial reduction in energy costs. This reduction, estimated at a minimum of 200,475.00 baht annually, is based on a conservative 15 percent decrease in losses. Considering the system's construction cost of approximately 300,000 baht, the projected time for payback stands at approximately 1.50 years or, equivalently, 18 months.

Among the various stages, the dehumidification process of coconut shavings stands out as the most energy-intensive due to the requirement to convert electrical energy into heat [5]. In response, the authors proposed an innovative approach to harness natural energy within the production process. The objective is to substantially curtail energy usage in the coconut meat baking stage, with a target reduction of no less

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than 15% of the prevailing consumption. The crux of this approach is developing a specialized system that autonomously generates low-humidity hot air within a controlled tunnel environment. This innovative solution leverages a green tunnel as a heat accumulator, thereby augmenting the production of cold-pressed coconut oil. The adoption of this approach signifies a remarkable stride toward sustainable energy utilization in the production process.

The prototype from research was applied to the factory roof to harness solar heat as an energy source, aiming to reduce electricity consumption costs by more than 15 percent.

MATERIALS AND METHODS

a) Tools and equipment

Measurement and Temperature Control [6]: This tool is designed to both restrict temperature within predetermined values and adjust it within specified ranges or times; use this tool to measure and control the humidity and temperature of the baking simulation system. The temperature control system is depicted in Figure 1 (a).

Temperature and Humidity sensors and Data-logger [7]: Incorporating multiple functions, this low-power data logger integrates a high-sensitivity detector to rapidly and precisely capture temperature and humidity levels. Figure 1 (b) illustrates the temperature and humidity sensors and data-logger.

(a) (b)

Figure 1 (a) Measurement and temperature control; (b) Temperature and Humidity sensors and data-logger.

Air Velocity Meter: This device serves the purpose of measuring wind speed, temperature, and humidity, making it suitable for both general wind speed measurement and air conditioning applications. Featuring a 30 mm propeller, it's also capable of humidity measurement. Refer to Figure 2 (a) for the representation of the air velocity meter, which research uses to measure the air velocity of the air pump in the drying system model.

Illumination and solar sensor: Comprising a light sensor and a display, with illumination accuracy ±5% at 25°C, the illumination and solar sensor operates on the principle of converting incident light energy into current. This current's magnitude is determined by the light striking the sensor. The illumination and solar sensor interpret this current to calculate the light intensity and display the value on the screen. To visualize the illumination, a solar sensor measures the light intensity and ultraviolet light of the outside sun in the house; consult Figure 2 (b).

(a) (b)

Figure 2 (a) Air velocity meter; (b) Illumination and solar sensor.

Thermal Infrared Camera [8]: This instrument specializes in surface temperature measurement, accuracy ±2%, ±2°C, used to measure the heat outside the greenhouse. Operating based on the principle of non-contact and non-destructive infrared radiation assessment, it effectively gauges the temperature of an object's surface. The thermal imaging camera integrates key components like a lens, infrared detector, electronic circuitry, and a display. Here's how it works: the infrared detector captures emitted infrared rays from the target object via the device's lens, converting these rays into an electrical signal. This received infrared radiation encompasses both the target object's emission and reflections from other sources or surfaces, then, the electronic circuitry processes and transmits this data to the display. Refer to Figure 3 for a visual depiction of the thermal infrared camera.

Figure 3 Thermal Infrared Camera.

b) Prototype of closed tunnel hot air production system

The tunnel's design incorporates a semi-circular shape to minimize wind-related influences. Moreover, it is adept at accommodating a thermal energy-retaining covering material. Fabricated from

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stainless steel, the tunnel boasts dimensions of 3 meters in width, 4 meters in length, and 2 meters in height. Figure 4 presents a block diagram illustrating the tunnel's configuration. Utilize a temperature sensor to measure the temperature within the house. If the temperature reaches the specified level, the device will activate the air pump to draw hot air from the house through the grated coconut meat. This process aims to facilitate moisture absorption from the coconut meat, causing it to evaporate. For a more comprehensive understanding, both the interior and exterior of the tunnel are showcased in Figure 5 and Figure 6, respectively.

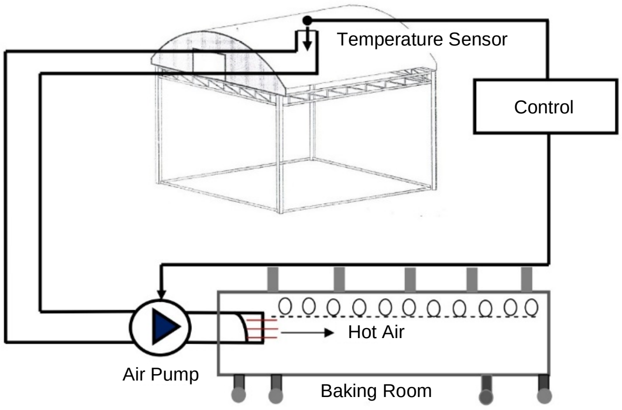

Figure 4 System Block diagram.

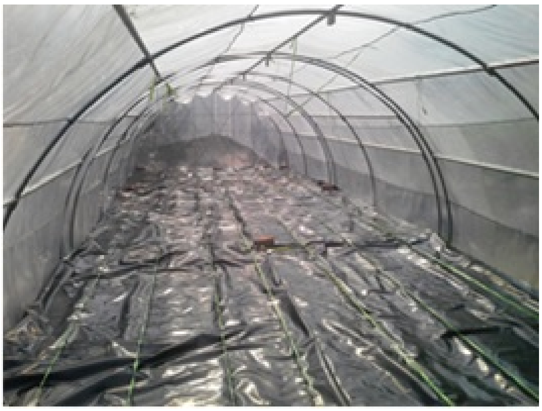

Figure 5 Inside tunnel.

Figure 6 Outside tunnel.

RESULTS AND DISCUSSIONS

a) Efficiency of closed tunnel hot air production system

Conducting temperature data storage tests inside and outside the tunnel has been instrumental in elevating heat levels from external sources. The system's efficiency capitalizes on varying heat accumulation, contingent on weather conditions. Notably, daytime temperatures within the tunnel can rise 10-20°C higher than the exterior, while nighttime temperatures align closely. A heat collector with heat-storing materials [9] has been implemented to optimize this. This augmentation prolongs heat accumulation and transfer from the baking process, effectively leveraging the stored heat within the tunnel for continuous baking. The evolved system for generating hot air within the enclosed tunnel encompasses a control unit that monitors the tunnel's temperature. Activation of the blower to draw in hot air for subsequent baking is triggered when the tunnel's temperature surpasses 50°C [10]. Furthermore, the terminal section of the tube exhibits temperatures 15-25°C higher than outdoors. The incorporation of 9 temperature sensors inside and outside the tunnel, coupled with the strategic placement of black plastic on the tunnel floor, has notably augmented heat accumulation via solar radiation [11]. This approach has demonstrated the capacity to elevate temperatures beyond the original range of 20-35 degrees Celsius, as illustrated in Figure 7.

Figure 7 Using a blower to draw hot air to use in baking.

Experiments were also conducted to expel hot air from the tunnel, employing an air pump to channel the heated air for drying to eliminate moisture from the shredded coconut meat. During the experiment, 400 g of shredded coconut was placed in an aluminum tray and subsequently positioned within an incubator. This incubator harnessed the hot air sourced from the tunnel to facilitate moisture removal. Impressively, the outcome revealed that approximately 200 g of moisture could be effectively eradicated within 90 minutes. Refer to Figure 8 and Figure 9 for visual insights into this process.

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Figure 8 Coconut meat before baking, weight 400 g.

Figure 9 Coconut meat before baking, weight 200 g.

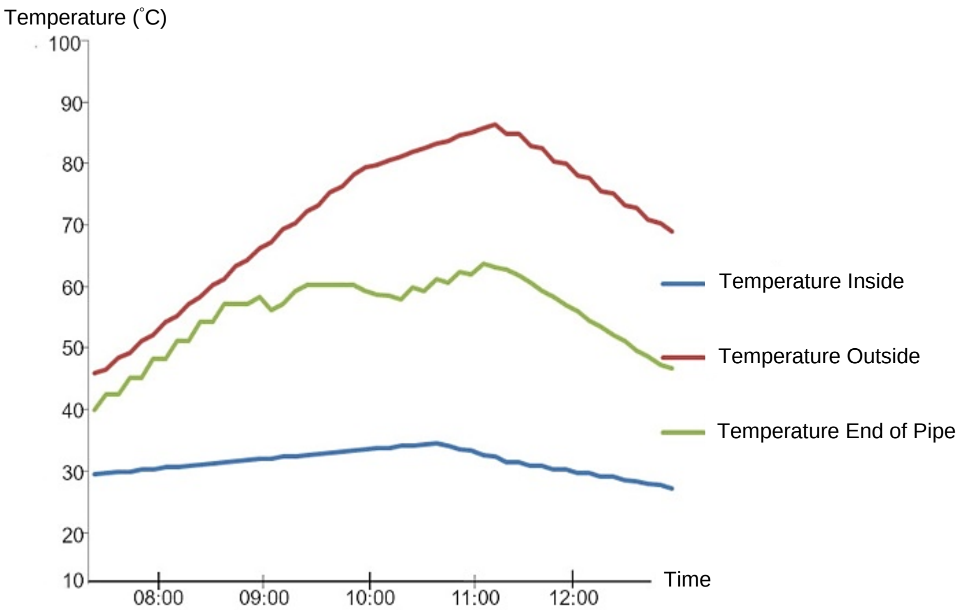

Figure 10 Coconut meat before baking, weight 200 g.

Figure 10 illustrates the temperature records at the end of the pipe employed for baking. By utilizing an air pump to direct the heated air externally, a comparison was drawn between the interior and exterior temperatures and the temperature outside the tunnel. This analysis revealed that the average temperature at the pipe's end used in the baking process ranged from 40 to 60°C. This was in contrast to the average temperature within the tunnel, which ranged from 46 to 8°C, and the average temperature outside the tunnel, falling within the range of 27 to 33 degrees Celsius.

The amount of coconut introduced to the incubator per drying cycle remained consistent at 10 kg, originating from coconuts with an initial moisture content of about 65% (wb = 0.6) before drying. Before entering the factory production line, the desired moisture content was targeted at 25% (wb = 0.25). As a result, the volume of water to be eliminated per cycle equated to 5.3 kg.

In daily operations, baking occurred thrice, each lasting 150 minutes. Consequently, the aggregate water removal from raw materials amounted to 15.9 kg per day, equivalent to an energy demand of 95.40 MJ per day (factoring in water evaporation at 6.0 MJ/kg). The heat at the end of the pipe can be estimated using Equation (1).

$$Q_{blow} = (C_p(T_{in} - T_{out}) + L_v \Delta q)\varrho_a F_v \tag{1}$$

Where, Q_{blow} is ventilation heat, C_p is the specific heat capacity of dry air, T_{in} is the inside tunnel temperature, T_{out} is the outside tunnel temperature, L_v is the latent heat of vaporization, Δq is the specific humidity difference from inside to outside, ϱ_a is the density of air, F_v is the volumetric airflow due to ventilation.

Given these parameters, the amount of heat is calculated to be 101.835 MJ.

b) The efficiency of the closed tunnel hot air production system in Phase II

After placing black plastic on the tunnel floor to facilitate heat accumulation from the sun's rays, various measurements were taken, including wind speed, light intensity, and temperature at

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different locations. This resulted in significant heat buildup within the tunnel, raising the temperature by approximately 20 - 35 degrees Celsius compared to its initial state.

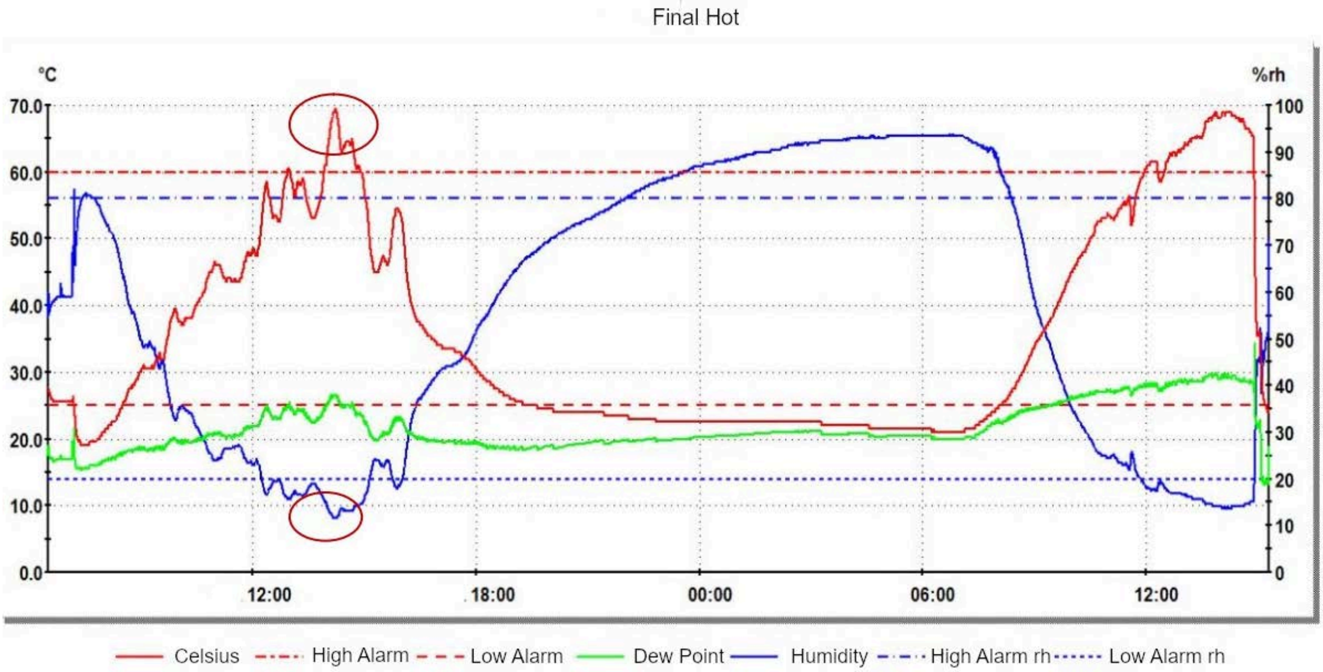

Figure 11 The temperature inside tunnel.

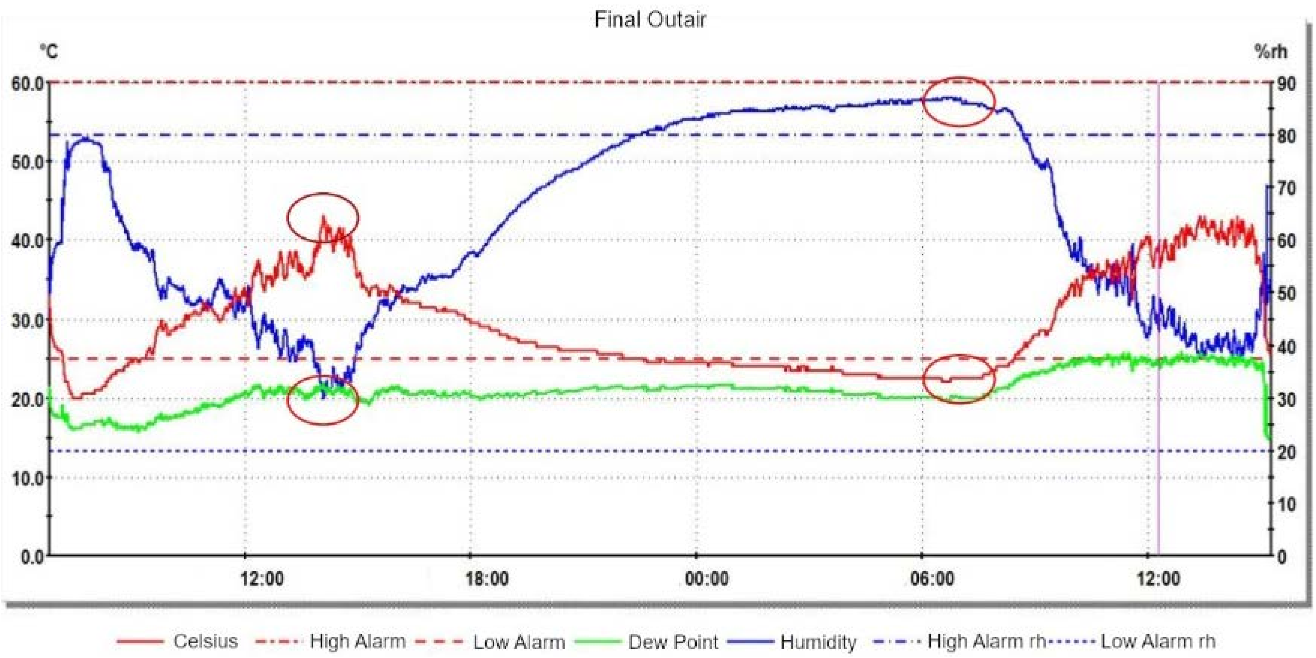

Figure 12 The temperature outside tunnel.

Based on the data presented in Figure 11 and Figure 12, the maximum temperature difference recorded was approximately 26 degrees Celsius, fluctuating between 70 and 44 degrees Celsius. In practical experimentation, hot air from the tunnel was tested using an air pump for drying. This involved employing hot air to eliminate moisture from 500 grams of shredded coconut placed in an aluminum tray. Subsequently, the tray was positioned in a cabinet that utilized the hot air from the tunnel for moisture removal. The results indicated that around 270 grams of moisture (water) could be extracted within approximately 150 minutes, as illustrated in Figure 13.

The heat energy balance of the tunnel is based on the principle that energy entering the system equals energy leaving the system. In other words, the net energy is zero. This balance can be achieved through analyzing various factors contributing to energy input and output.

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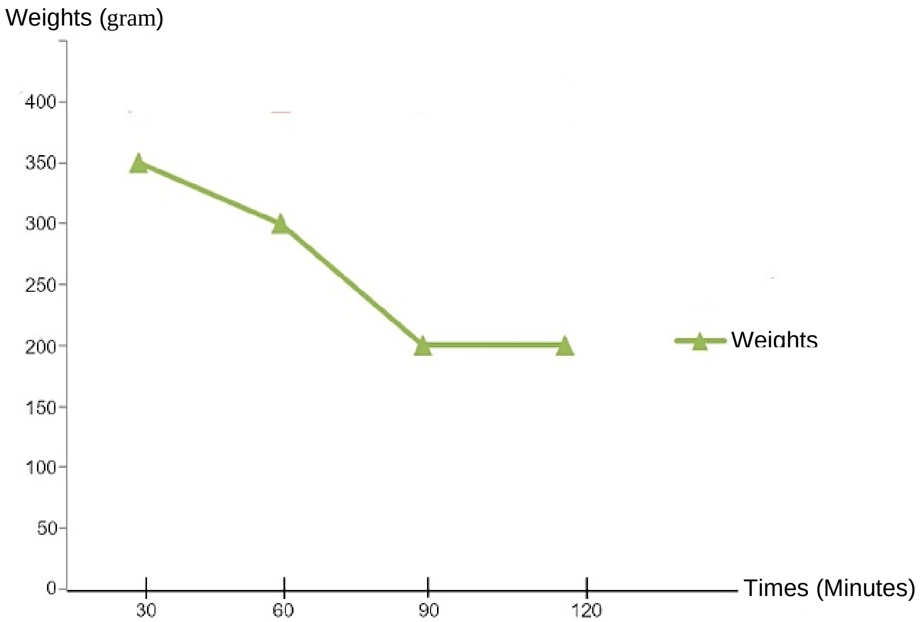

Figure 13 Dehumidification process in 500 grams of grated coconut meat.

c) Heat energy balance of the tunnel

Energy entering the system is equal to energy leaving the system. Net energy is equal to energy entering the tunnel - energy leaving the tunnel since the net energy equals zero.

1) The energy that is put into the tunnel consists of:

a) Heat energy from solar radiation.

b) Heat energy, exothermic heat for condensation.

2) Energy from the tunnel

a) Transfer of heat energy, input into various joints around the tunnel.

b) Heat energy and ventilation transfer to the outside depending on the environment.

c) Transfer of heat energy, suction of warm air by fan.

d) Tunnel data collection

The author used a thermal infrared camera to collect temperature data at various points in the tunnel: the temperature at the surface of the covering material, the temperature under the tunnel, the temperature out of the tunnel, and the temperature at which the blower enters the cabinet.

CONCLUSION

The company aims to reduce thermal energy consumption. Tropicana Oil Co., Ltd. strives to transform the factory into a green facility that relies on natural sources to conserve energy and contribute to environmental preservation. Thus, the findings of this research demonstrate how solar heat can be harnessed for heating purposes in the factory, the prototype was applied to the factory roof to harness solar heat as an energy source for the factory, aiming to reduce electricity consumption costs by more than 15 percent.

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