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The Potential for Milk Pasteurization Using Portable Geothermal Milk Pasteurizer in Dauin, Negros Oriental, Philippines

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ABSTRACT

A geothermal vat pasteurizer is presented to exploit geothermal energy for direct use in Upper Bulak, Dauin in Negros Oriental. This pasteurization system includes one main vat pasteurizer with an involute water guide. The pasteurizer is equipped with an agitator mechanism with four hemispherical propellers. The geothermal fluid is channeled through a pipe, and because of the involute pathway, the geothermal fluid flows in a circular motion through the small cylindrical reservoir. This drives the movement of the propellers causing the agitator to rotate inside the pasteurizer. Hence, this geothermal vat pasteurization system is an efficient tool to utilize the heat from the source and use the fluid movement to drive the agitator to stir the milk for maximum heat distribution. A lumped system analysis is used to estimate the time the raw milk reaches the required temperature before clocking the milk for the pasteurization process. This analysis is verified by the actual recorded time of 3 minutes during the conduct of the study. The characteristics of the geothermal water in terms of temperature, pH, and the flow rate is studied. The characteristics of both the raw and pasteurized milk that uses the geothermal pasteurizer are analyzed. The results indicate that the geothermal resource can reach the required temperature and can hold it for the entire pasteurization process. The results of this study provide a good reference for geothermal direct use applications in the Philippines

1. INTRODUCTION

1.1 Rationale of the Study

The Philippines lies on the Pacific Ring of Fire where volcanic activity is concentrated around the Pacific Plate, giving it an abundant source of geothermal energy. This immense energy from beneath the ground reaches from Indonesia, the Philippines, and Japan, to Alaska, Central America, Mexico, and the Andes and on to New Zealand (Van Nguyen, Arason, Gissurarson, & Palson, 2015).

Electricity generation is the most common example of utilization of high-enthalpy geothermal resource (>150 °C). However, medium - to low-enthalpy resources (<150 °C), are more suited for other uses of geothermal energy called direct utilization (Dickson and Fanelli, 2003). Direct use of geothermal resources is the use of underground hot water to heat buildings, grow plants in greenhouses, dehydrate onions and garlic, heat water for fish farming, pasteurize milk, and for many other applications. People has been using hot springs for rituals, routine bathing, cooking, and therapeutic purposes at least since the Middle Paleolithic era. Today, direct geothermal use provides a relatively cheap and pollution-free source of energy (Garman, 2004; Goldstein and Hiriart, 2011; Van Nguyen, Arason, Gissurarson and Palson, 2015).

The Philippines has many potential geothermal resources, ranging from low to high enthalpy, which are generally located in mountainous areas with fertile land, making it and the surrounding areas suitable for agriculture, agro-industry, or tourism. The Department of Energy is conducting a study to find geothermal areas fit for low-enthalpy geothermal applications. The Geothermal Energy Management Division of the Department of Energy formulated a locally funded project "Detailed Resource Assessment of Selected-Low-Enthalpy Geothermal Areas in the Philippines." This aims to characterize the various low-enthalpy geothermal resources in the Philippines. These low-enthalpy geothermal areas remain untapped and largely ignored by investors because they are lacking impressive thermal manifestations as compared with the already developed high-enthalpy geothermal areas. These low-enthalpy geothermal areas are suitable for direct applications, such as, but not limited to, industry, agriculture, tourism, and health applications. Some areas considered are Banton Island in Romblon, Balut Island in Davao del Sur, and Maricaban Island in Batangas. These areas have surface temperatures of 64–68°C, 66–70°C, and 61–80°C, respectively (Halcon, Fronda, Del Rosario, Jr., Adajar, Sayco, Pastor, &Velasquez, 2015). The development of these resources will be beneficial to the host community, which are typically located in remote areas. In addition to that, the Philippine Council for Industry, Energy, and Emerging Technology Research and Development (PCIEERD) of the Department of Science and Technology (DOST) encourage researches that are geared toward sustainable energy—particularly the Assessment of Low-Enthalpy Geothermal Applications (Sabularse, 2018).

Milk pasteurization using geothermal energy has become the trend in most developing countries like Kenya and Indonesia (GMD, 2013; Jubaedah, et.al, 2015). Pasteurization is a mild heat treatment used on different types of food products. Louis Pasteur developed the pasteurization process (Bylund, 1995). It has been described as the process of heating milk to such temperature and for such periods of time as are required to destroy any pathogens that may be present whilst causing minimum changes to its composition, flavor, and nutritive value (Ahmad, 2012). The methods of pasteurization are Vat Pasteurization method and Continuous High-Temperature Short –Time (HTST) method.

Locally, the municipality of Dauin in Negros Oriental is very fortunate because it has a geothermal resource (hot spring) in Upper Bulak with recorded surface temperature that ranges from 55 to 80°C. The faults that control the distribution of most thermal features are the Lipayo and Masaplod faults and their branches (Bayrante, Hermoso, Candelaria, Pamatian, & Mejorada, 1997). These characteristics of the Dauin geothermal reserve make it ideal for direct utilization applications as enumerated above, one of which, pasteurization, shall be the focus of this study.

In addition to the resource being an excellent direct-use geothermal energy source, thus making it feasible for a possible local application of geothermal pasteurization, this study aims to add to the local literature on the utilization of low-enthalpy geothermal resources for direct use. Moreover, Dauin has a dairy farm in Masaplod Sur, Dauin, Negros Oriental. The association “Dauin Dairy Farmers Association” (DADAFA) has been supplying raw milk to NORIENT—the dairy processing plant in Negros Oriental. The association delivers 200–250 L of milk every week to NORIENT. The existence of the local milk processing plant further adds value to the research, considering possible large-scale applications should the feasibility of pasteurization from direct-use geothermal resource be established.

1.2 Scope and Limitations

The study starts with the assessment of the geothermal resource that is used for the milk pasteurization in terms of temperature, pH and flow rate. The study is limited to the use of geothermal fluid as the heat source. This study is also conducted to prove that the Dauin hot spring can pasteurize milk.

The process utilized in this study is vat pasteurization. The agitator speed is variable and is dependent to the flow of the fluid that passes through the steel pipe. The flow rate over the pipe is the same flow rate that drives the agitator. The bucket method is used.

The heat transfer calculation is assumed to be one-dimensional transient state heat conduction until the required temperature is reached at a certain time t. Afterwards, the total rate of heat transfer is computed assuming that the system is in one-dimensional steady state heat conduction. The researcher use the concept of the thermal resistance network to solve for the overall thermal resistance in the system.

The researcher used cow’s milk for the pasteurization process. The testing of raw milk is limited to organoleptic test, alcohol test, and Californian mastitis test for it is the only available tests that NORIENT can conduct. The National Dairy Authority Central Visayas Department in Cebu can only provide the following tests for the pasteurized milk, namely fat content determination, solid-nonfat determination, total plate count, and coliform count/*Eschirichia coli* count.

2. METHODOLOGY

2.1 Research Design

This study used two research methods, experimental and descriptive methods. Experimental method measures the technical qualities of the milk pasteurizer using the geothermal fluid and the project site in Upper Bulak, Dauin, Negros Oriental. On the other hand, descriptive method explains the characteristics of the milk pasteurization using geothermal water.

2.2 Flow of the Study

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2.3 Environment

The project will be mounted in an area with geothermal energy source. For this study, it will be at a geothermal stream in Upper Bulak, Dauin, Negros Oriental.

Dauin is a town 15 kilometers south of Dumaguete in the province of Negros Oriental. The municipality of Zamboanguita borders the municipality of Dauin on the south and Bacong on the north. Mountains on the west separates it from Santa Catalina and on its east is the sea.

The geothermal resource can be found in a river in Upper Bulak, Dauin. The geothermal water used come from a boxed reservoir through an open four-inched pipe. Inches below the open pipe, another pipe is attached to it. This second pipe is used for malunggay drying by a private individual.

2.4 Design Conceptualization and Specification

The vat pasteurizer of the researcher has four major components – stainless steel container, water reservoir and piping system, temperature reading mechanism and the agitation mechanism. The stainless-steel container is the flask where the raw milk is heated. It holds the milk for 30 minutes and is heated to 65 ºC. It must be clean to prevent contaminations to the milk.

A hot water reservoir is used as container of the milk pasteurizer. A pipe connecting the source to the involute water reservoir is used as channel for the hot water. The temperature reading mechanisms are equipment that reads and monitors the temperature of the raw milk and the geothermal fluid. The last component is the agitation mechanism. All vats must be equipped with mechanical means of agitation. An agitator is designed to keep milk or milk product moving at all times by running constantly during the pasteurization cycle. This results in uniform product and temperature throughout the vat.

RESULTS

The milk pasteurization process used in this study is vat pasteurization. The raw milk is heated in batches for 30 minutes. The required temperature of the milk for the process is 65 °C. Indicating thermometers are used to monitor the temperature of the milk and agitators are installed for equal distribution of temperature throughout the vat. The materials used are all stainless steel to avoid contamination in the milk.

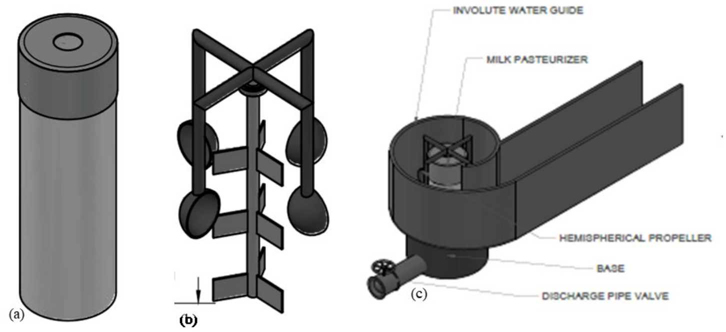

Figure 1. (a) Portable Milk Pasteurizer, (b) Hemispherical cones as propellers attached to the agitator, (c) Involute container where the hot water passes

Testing of the Raw Milk

Milk quality control is the practice of specified hygienic methods and use of approved tests to ensure good milk quality. The tests are designed to help you reduce milk spoilage (Smallholder Dairy Project, 2003). The raw milk undergoes tests before placing it into the vat. NORIENT is the agency that will test the raw milk. The purpose of conducting this test is assess that the raw milk to be used for the pasteurization process is in good quality. The tests are organoleptic test, the alcohol test, and Californian mastitis test. The raw milk is positive of the alcohol test and negative of the Californian mastitis test. This means that the raw milk contains high level of lactic acid that is why it did not pass the alcohol test. NORIENT will not receive this kind of milk for they use continuous process and will cause clogging of pipes. However, the milk can still be used for vat pasteurization process

Properties of the geothermal area

The geothermal vat pasteurizer did attain the required temperature for vat pasteurization. The average recorded source temperature is 75.23 °C. Vat pasteurization only requires a minimum of 65 °C of heat to kill harmful bacteria. Eventually, the milk in the vat will attain thermal equilibrium. Furthermore, the average recorded pH of the source is 1.53 that proves to be acidic. The project site is in Upper Bulak, Dauin in Negros Oriental. The yellowish crystal deposits near the riverbank proves that the area is rich in chloride-sulphate. The rotten egg like smell also proves the existence of Sulphur in the area. Moreover, the calculated volumetric flow rate of the source is 128.63 in^3/s. This flowrate is what the researcher used to compute for the agitator speed. The agitator is needed for equal distribution of heat in the milk container. The speed of the agitator is approximately 25 revolutions per minute.

LABORATORY ANALYSIS RESULTS AND EVALUATION

	Milkfat	Evaluation	Milk Solid non fat	Evaluation	TPC	Evaluation	Coliform Count	Evaluation	*E. coli*	Evaluation
Standards[1] *(based on source of sample)*	≥3.0 %	Passed? (Y/N)	≥8.25 %	Passed? (Y/N)	50,000 cfu/mL	Passed? (Y/N)	≤100 cfu/mL	Passed? (Y/N)	Negative	Passed? (Y/N)
Sample A-Raw Milk	4.0	Y	8.25	Y	3.6×10^4		2.9×10^3		No Growth	
Sample B-65°C (30 minutes)	3.6	Y	8.31	Y	$<1.0 \times 10^2$	Y	<1.0x10	Y	No Growth	Y
Sample C-65°C (30 minutes)	3.6	Y	8.32	Y	$<1.0 \times 10^3$	Y	<1.0x10	Y	No Growth	Y
Sample D-65°C (30 minutes)	3.9	Y	8.29	Y	$<1.0 \times 10^3$	Y	<1.0x10	Y	No Growth	Y
Sample E-65°C (30 minutes)	4.0	Y	8.29	Y	$<1.0 \times 10^3$	Y	<1.0x10	Y	No Growth	Y
Sample F-65°C (30 minutes)	4.1	Y	8.75	Y	$<1.0 \times 10^2$	Y	<1.0x10	Y	No Growth	Y
Sample G-65°C (30 minutes)	4.1	Y	8.75	Y	$<1.0 \times 10^3$	Y	<1.0x10	Y	No Growth	Y
Sample H-72°C (15 seconds)	3.2	Y	9.04	Y	$<1.0 \times 10^3$	Y	<1.0x10	Y	No Growth	Y
Sample I-72°C (15 seconds)	3.2	Y	9.02	Y	$<1.0 \times 10^3$	Y	EST 5.0x10	Y	No Growth	Y

[1]*Reference: Dairy Safety Regulations of National Dairy Authority*

Figure 2. Laboratory result of the pasteurized milk. (National Dairy Authority – Central Visayas Department)

Characteristics of the pasteurized milk

All of the milk samples that undergo laboratory test passed the Philippine national standard for fresh milk. The milk samples were sent to the National Dairy Authority Central Visayas Department in Maguikay, Cebu. In reference to Table 7, the pasteurized milk meets the minimum and the required standards for pasteurized milk. The percentage of the pasteurized milk fat and milk solid nonfat did not go below the required minimum values of 3.0 and 8.25. For the plate count and the total coliform, the pasteurized milk samples did not go above the maximum microbial content. The Philippine standard for the maximum microbial content for the total plate count is 50,000 and 10 for the total coliform. The pasteurized milk is also negative for E. coli. Thus, milk using low-enthalpy geothermal fluid using the portable pasteurizer meet the required standards for the pasteurized milk and therefore found to be safe for consumption.

CONCLUSION

Based on the findings of the study, the fabricated geothermal vat pasteurizer has produced a pasteurized milk that passed the standards that the Philippine DTI Bureau of Product Standards set for fresh milk.

The geothermal source in Upper Bulak, Dauin in Negros Oriental reached 75.23 °C, which is enough to meet the required temperature for the vat pasteurization process. With the flow rate of the working fluid of 128.63 in^3/s, the speed of the agitator is approximately 25 revolutions per minute. It gave the milk inside the geothermal vat pasteurizer constant motion and equal distribution of heat.

Based on the tabulated results in figure 2, the pasteurized milk meets the standards set by the Philippine National Standards for fresh milk making it safe for human consumption.

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