Heat energy conversion on applied technology of geothermal energy direct utilization

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Abstract. Indonesia has a high geothermal energy resource, preserved in many fields. But not all geothermal fields are potential for indirect utilizations such as for electric power generation. A direct utilization of a low potential geothermal energy resource has been performed at Batukuwung geothermal field, Serang, West Java. A simple design of vegetable grain dryer has been created and constructed using galvanized metal pipes. A reduction of temperature from 63.1 degrees Celsius at the heat source to 41.5 degrees Celsius at the dryer tool through galvanized metal pipes is quite adequate for vegetable grain drying purposes. It is quite a prospect simple technology to be applied and developed in Indonesia as a geothermal energy country having various vegetable grain products from various plants such as coffee, corn, peanut and many other tropical plantations.

1. Introduction

Indonesia is a country having many volcanoes and rich in geothermal energy resources. It is known that geothermal resource potential in Indonesia reaches approximately 28.579 MW [1]. By now, only about 1,948 MW of that much energy potency has been utilized for electricity power generation [2]. The rest has not been utilized optimally. There is only limited direct utilization of geothermal energy in those fields as well as in other undeveloped ones.

Conti et al [3] found that geothermal energy direct uses are developing in over 80 countries in the world. Their importance within the global energy scenario is increasing continuously. Italian geothermal direct uses are developing significantly. Technology progress in the use of geothermal energy, cascade utilization is developed. The utilization of geothermal resources in cascade levels is sequential operation of geothermal heat by integrating different technologies for electricity generation, distribution and use of thermal energy, drying and dehydration processes, recreational uses, and any other direct-use of geothermal heat [4]. Prasetya et.al [5] also performed development of cascade geothermal direct use at Bonjol, West Sumatera, Indonesia.

To initiate direct utilization of geothermal energy in Indonesia, Sumotarto et al., [6] has started doing research in that field since 1999-2000. The first effort was a research in geothermal energy utilization for sterilization of mushroom growing media in Kamojang geothermal field [7]. The research continued to design a geothermal dryer for beans and grains.

The dryer designed and constructed in this research is intended to accommodate low economic agricultural farmers and planters in handling their products to have higher quality i.e. by decreasing water humidity of beans and grains that will be provided in the market. A simple dryer in size and price
is a tool required for most Indonesian farmers and planters. Dryer in this research is designed using less expensive material with simple design that can be easily imitated by the farmers and planters. This paper discusses a geothermal dryer design that has been constructed at Batukuwung geothermal field, Serang, West Java to see the technical feasibility of the demonstrated dryer.

2. Methodology

2.1. Batukuwung geothermal area
The research area was conducted at Batukuwung village, Serang, West Java. Geologically, volcanic rocks are distributed in the area [8] where hot water from water spring from geothermal reservoir is used to supply bathpool.

The three essential characteristics of geothermal reservoirs are an aquifer, an impermeable cap rock and a heat source i.e. the internal heat of the earth. Steam and hot water escape naturally through faults in the cap rocks forming fumaroles, geysers etc. This type of energy could be used for direct heating power generation and for many other purposes [9].

Although the geothermal energy potential in Batukuwung area has not been feasible to be used for electric power generation, the direct use is continuously performed by people surrounding the area such as for bathpool. In Batukuwung geothermal area, the hot water temperature in the surface reaching 63.1°C can be used for drying purposes. By applying simple physical technique, a drying tool has been designed and constructed in Batukuwung geothermal bathpool site.

2.2. Basic heat utilization
Traditionally, grains and beans drying have been done by heating the products under sunshine (solar drying). The products will be influenced by seasonal and weather changes, thus making the drying process un-continuous. This can be solved by using continuous energy resource supply such as geothermal fluid flows. The heat from geothermal hot water springs in Batukuwung area can be flown through metallic pipe and utilized the calor to flow through air in the drying room.

According to Kamaruddin et al [10], drying is the process of taking moisture out of a substance by applying heat to the substance. Drying temperature requirement of several crops can reach near 90°C, but usually a moderate temperature level 50 to 60°C with relative humidity (RH) level of around 40% may be adequate to conduct a drying process.

2.3. Heat and energy equations
Heat energy from geothermal resources can be used directly as well as indirectly. Heat transfer in heat exchanger tool can be utilized through metal medium. This heat transfer can take place in a number of ways. Conduction is when heat flows through a heated solid through a heat current moving through the material. It can be observed that conduction happens when heating a stove burner element or a bar of metal [11].

Calculation of energy transfer is performed when the equipment is in operation with steady state energy transfer (heat flow). The calculation is based on phenomena where energy (heat) flows across a cylindrical pipe (Figure 1). Outside the heat exchanger the air is assumed to flow convectional into the drying room. There is assumed no other mode of heat flows i.e. radiation, because of the high speed of convection air current.

Using the principle of heat flow [12], in a general equation the temperature for the system is as follows
\[
q_r = \frac{2\pi Lk(T_{s,1} - T_{s,2})}{\ln\left(\frac{r_2}{r_1}\right)}
\]

where
\[
q = \text{heat transfer rate [W]}
\]
\[
r = \text{pipe radius [m]}
\]
\[
L = \text{pipe length [m]}
\]
\[
T = \text{temperature [K] or [C]}
\]
\[
k = \text{thermal conductivity [W/m.K]}
\]
\[
h = \text{convection heat transfer coefficient [W/m}^2.\text{K].}
\]

Thermal Resistant.

The heated water/air temperature produced from the heat exchanger can be calculated using a log-mean temperature difference

\[
\Delta T_{lm} = \frac{(T_i - T_o) - (T_s - T_o)}{\ln\left(\frac{T_s - T_i}{T_s - T_o}\right)}
\]

where \(T_i\) and \(T_o\) are temperatures of the fluid as it enters (in) and leaves (out) the bank, respectively and \(T_s\) is the temperature of the tube outside surface.

Prasetya et.al (2017) [5] applied a principle that heat transfer in the flowing fluid in pipe is based on conduction and convection process.

2.4. Dryer tool design

The dryer used in the research has been made of a liquid-air heat exchanger to produce hot air that will be blown into drying room filled with trays of grains or beans. Figures 1 & 2 show the design of the dryer equipment. The geothermal fluid is flown into a bank of steel pipes, fresh water and air are blown outside the pipes to extract heat from geothermal fluids inside the tubes for drying process.

With respect to the temperature and media i.e. hot water at Batukuwung geothermal heat source, the drying tool is designed using metallic pipe especially galvanis pipe. Figures 2 show the design of grain drying equipment to be installed at the Batukuwung bathpool with hot water from geothermal hot springs.

3. Results

Using the design, the dryer has been connected to the bathpool hot water supply (Figure 3-A). To prevent the tool from rain water and bad climate condition, a roof can be constructed above dryer tool that was placed inside a drying oven room (Figure 3-B). The use of oven room have significant benefit compared to open drying process such as using sun light drying. Helvaci et al [13] experimented olive leaves drying using geothermal dryer oven. By the demonstration in this research, it is observed that hot air has drying temperature reached 41.5°C (Figure 4), appropriate for agriculture and plantation grain and bean drying purposes continuously.

The use of heat energy from geothermal resource could also clean environmental air and efficient cost. The experience was demonstrated in Menengai, Kenya, Africa. The mechanical drying processes uses oil/diesel operated dryers, which are considerably expensive energy sources and with high carbon footprint (42 kg CO\(_2\)/ton product). By using geothermal energy this can be reduced by 95% [14]. Using similar model, a geothermal dryer has been designed and constructed on industrial capacity. Geothermal fluid is supplied into heat exchanger based dryer at 130°C and flown out at 93°C. This design could provide a vegetable beans and grains (maize) drying temperature of 49°C and providing a result of 42% relative humidity [15].
A geothermal coffee dryer has been experimented by Prasetyo et al [16] in Wayang Windu geothermal field, West Java, Indonesia. Hot water with a temperature of 80°C flows in a closed loop system to heat the air inside the drying apparatus. The coffee drying is done at 50°C from water content (humidity) of 60% to 12% remaining in total time of 12.5 hours.

Although conventional drying methods such as open air sun drying are still the most common method in the world, it is not suitable for drying purposes due to contamination with dust, soil, insects and uncontinuous heat flow [13]. Geothermal fluids flow at constant flowrate throughout the year is considered as continuous resources.

A different drying technique was experimented by Sandali et al[17]. A new technique of heat supply was using a double level tubular heat exchanger with geothermal water to improve the thermal performance of a direct solar dryer. By using heat exchanger, the lowest drying air temperature was found to be 46°C, while the highest one was 58°C.

Massarotti [18] performed application of geothermal energy for environmental purposes. Geothermal energy at medium enthalpy is considered to produce heat for thermal drying of wastewater sludge and to power an Organic Rankine Cycle system for electric energy production. The dryer is designed which then to achieve a final solids content of dry sludge higher than 90.0%.

Nyambura [19] applied geothermal energy heat exchanger for milk pasteurization successfully. Hot water at 80°C heats milk to a temperature of 65°C–67°C for a period of 30 minutes. Milk is then cooled in two processes; using room temperature water and using ice water to temperatures as low as 4°C.
Figure 3. Construction of agriculture, plantation grain and bean dryer at Batukuwung bathpool, Serang, West Java.

Figure 4. Installation and use of geothermal powered dryers in Batukuwung geothermal field, Serang, West Java.

The construction of dryer design in this research creates a tool that has been applied quite properly. The hot spring water having 63.1°C temperature from hot water spring of Batukuwung geothermal field in Serang, West Java could produce hot air of 41.5°C for drying purpose. With the suitable tool design and less expensive material cost i.e. galvanized metal pipe, it can be made by low economic farmers and planters who need drying process of their products.

4. Results and discussions
Kostoglou et al [20] used low-temperature geothermal waters efficiently in drying various vegetables and fruits, replacing sun-drying or drying using conventional fuels. The unit uses low-cost geothermal water to heat atmospheric air to 56–58°C. The hot air was then used for tomato dehydration plant. Afuar et al [21] have other example, i.e. performed a drying process of tomato using geothermal brine with temperature 175-190°C. This water was used to heat up the surrounding air the tomatoes chamber. Tomatoes drying process needs temperature range of 50-70°C.

The other experience is using geothermal fluid energy for rice drying. Van Nguyen et al [22] used water from a geothermal well for the direct heating of a rice drying plant in the Kotchaney geothermal field. The temperatures of the inlet and outlet geothermal water are 75°C and 50°C respectively. The heated air is blown into the drying zone to dry the rice. The temperature of the heated air is kept below 40°C to prevent cracking of the rice. The rice is dried to decrease the moisture content from 20 to 14 percent and then air-cooled.
Meanwhile Mubarak et al. [23] performed experiment of drying fish using geothermal hot water. The temperature of hot water entering the exchanger is 80°C and the temperature of the air entering the drying chamber is maintained at 60°C. From the further experimental result is obtained that the average water temperature flows out of the chamber is in the range of 76-78°C and the temperature in the chamber is in the range of 57-62°C.

The drying process is expensive due to equipment, fuel, electricity and labour cost. Reykdal [24] performed operation using a method of unexpensive drying and storing of harvested grain. It is found that in Iceland, geothermal energy has been a cheapest energy source for grain drying. Meanwhile Hwangbo et al [25] performed a comparison of geothermal and air heat source for drying vegetable fruit i.e. red pepper. In winter session especially, the use of geothermal is more efficient compared to heat air source, it has a continuous steady heat flow.

The experiments and operation in this research at Batukuwung geothermal area for drying tool is using a hot water of 63.1°C to be flown into galvanis pipe heat exchanger that can produce drying air of 41.5°C. From these experiences it is realized that drying process of agricultural beans and grains are feasible, the drying temperature is necessarily below 50°C just to reduce humidity of the objects. Otherwise instead of drying, if temperature is above 50°C the objects is being cooked in the range of boiling or baking temperature. With simple technology it is reliazed that the cost for construction is efficient.

5. Conclusions
With the survey, analysis, study and designing and construction of geothermal energy dryer at Batukuwung geothermal area, it can be concluded that:

- Geothermal energy can be directly used for agriculture & plantation heat utilization process.
- Calor can be computed using heat transfer principle to be applied for geothermal energy direct utilization.
- Drying temperature can be analized and arranged according to the field condition. With data and available material, the dryer has been designed and applied well at an example location: Batukuwung geothermal area, Serang, West Java.
- To protect the drying tool, additional tool can be constructed such as metal oven as a drying room and roof to prevent the dryer tool from rain water of irregular rain falls.
- Utilization of the geothermal resources for drying grains is quite worthy and is an opportunity to increase the quality of the drying material, save the environmental air as well as lowering the cost of drying.

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