Studies on Application of Solar Water Heating System Assisted Shell and Tube Heat Exchanger for Pasteurization of Milk: A Comprehensive Review

Tejash Patel[1] Romil Patel[2]
[1,2]Lecturer
[1,2]Department of Mechanical Engineering
[1]M. L. Institute of Diploma Studies, Bhandu, Gujarat, India [2]S. P. B. Patel Engineering College, Linch, Gujarat, India

Abstract— The present investigation is aimed to evaluate the performance of solar water heated shell and tube heat exchanger, to develop milk pasteurization system using solar heated water and to assess the chemical and microbial qualities of pasteurized milk prepared using solar heated water. Due to use of fossil fuels for the human activities found significant effect on environment as well as human health. The researchers from all around the world are searching for sustainable solution through non-conventional sources of energy like solar energy, windenergy, biomass energy, tidal energy etc. Among all renewable sources of energy, solar energy is very popular. Pasteurization is a process of heating and then rapidly cooling of food or liquid for the purpose of killing of bacteria.

Key words: Pasteurization, Milk, Flat Plate Collector, Shell and Tube Heat Exchanger

I. Introduction

Solar energy is renewable source of energy and it is available freely. Now days due to the global warming and many other reasons, solar energy is very much popular. It can be harnessed either by solar thermal and solar photovoltaic technologies. Solar thermal technologies can supply hot water or steam for cooling and heating purposes. To supply hot water or steam thermal collectors are used.[1-4].

India is the leading producer of milk in the world. The current per capita availability of milk is around 290 g/day/person. (Polyeyes, 2013)

Milk production in India, which was almost stagnant around 20 million tons between 1947 and 1970 at an annual growth rate of just 1%, started responding to market stimulus and inputs from 1970 onwards, registering and growth rate of 6% per annum. The milk production doubled by 1985 and in 1990 it had gone up to 51 million tones. The per capita consumption of milk, which had come down from 132 g in 1950 to 107 g in 1970 had gone up to 173 g in 1990 (Aneja, 1990), but after that it took an upward trend which is evident by current milk consumption of 290 g/day/person.

II. Solar energy

On earth's atmosphere the flow of solar radiation is 1353 W/m^2, this value is called solar constant. Of this, nearly 190 W/m^2 is absorbed by the atmosphere. The rest is divided into direct and scattered radiation. About 383 W/m^2 of direct and scattered radiation is reflected back mainly by clouds to space and the rest of the energy 473 W/m^2 is absorbed by the earth and can be used for various operations.

III. Application in food and dairy industry

Efforts have been made to design and develop solar collectors for dairies. Use of solar energy is being widely emphasized given the fact that solar energy is abundantly available in the country. Hot water needed for washing, sterilization of cans and bottles and pasteurization of milk can be easily done by solar heaters. Different types of solar water heaters were fabricated and used for application in dairies (Verma et al. 1984).

Reddy and Verma (1986) reported the tremendous scope of utilizing solar energy in dairy processing such as pasteurization of milk. Safapour and Metcalf (1998) reported that simple and reliable methods could be used in developing countries to pasteurize milk and water with solar energy.

Broos (1996) reported that in Ghana, solar dryers were used for drying for mainly okra, pepper and maize. It was reported that drying took on an average three days with the solar dryers compared to one week with sun-drying. Ayadi et al. (2008) reported that solar parabolic trough collector used to run a vapour absorption system for refrigeration plant and maintain a cooling system. This system was used successfully for the chilling of milk in bulk milk cooler.

Schnitzer et al. (2007) studies that solar drying and dehydration systems. They utilized solar radiation either as the solar power supply to heat the air or as a supplementary energy source. Conventional drying systems burn fossil fuels for their performance while the solar dryers take advantage of sun radiation for drying and dehydration processes in industries such as bricks, plants, fruits, coffee, wood, textiles, leather, green malt and sewage sludge.

Zahira et al. (2009) fabricated solar milk pasteurizer to provide a practical low-cost milk pasteurizer for the improvement of drinking milk quality in a developing country like Pakistan. It was observed that the maximum base temperature of a solar milk pasteurizer was reached at 100^0C and the milk temperature was reached the maximum value of 85^0C. They reported that pasteurizer have easily attained pasteurization temperature ranging from 65^0C to 75^0C in two to three hours. The change in intensity of solar radiation had a direct impact on solar milk pasteurizer. In commercial application the solar milk pasteurizer attained pasteurization temperature in 1 to 1.5 h and the time interval can be reduced by using mirror reflectors (Black, 1999)

Pandey and Gupta (2004) reported that the milk was pasteurized successfully by solar energy using aluminum foil on cardboard. The glass window on solar milk pasteurizer increased the performance of pasteurizer. They reported that heat gain and temperature rises with the increase in solar intensity. Dande et al. (2011) studied the utilization of solar energy in dehydration of cow milk and manufacturing of khoa and reported that the chemical and sensory quality of khoa prepared using solar energy was as acceptable as traditional method.

Schnitzer et al. (2007) found that in the Austrian dairy industry over 80% of the heating demand was met using solar energy for temperatures in the range from 60°C to 80°C, making solar energy ideally suited for heating in dairy processing plants. Furthermore, they reported that this temperature is suitable for operations such as washing water in cheese production, preheating of cheese milk, outside cleaning, pasteurisation, whey conditioning, and cleaning in place (CIP) operations.

IV. Application of Solar Water Heating System (SWHS):

Li et al. (2007) reported that SWHs are usually composed of solar collectors and a storage space. It works on the basis of the density inequality of hot and cold water or thermo syphon. In colder countries, integrated collector/ storage SWHs is more common because of simple and compact structure. Batch solar collectors are more suitable for compensating sun radiation limitations in the evening and afternoon.

According to Benz et al, (1999) solar heating can be applied in milk, cooked meats (sausage and salami) and brewery industries at medium temperature for pasteurization and many other heat treatments like sterilizing, drying, cooking, hydrolyzing, distillation, evaporation, extraction, polymerization washing and cleaning.

Nielsen and Pedersen (2001) established a solar panel based milk pasteurization system to meet the demands for an acceptable pasteurization and found that the solar panel gave a maximum temperature of hot water about 100^0C through absorbing solar energy which was used successfully for pasteurization of milk.

According to Agbo and Oparaku (2006), water heating is one of the simplest and cheapest applications of solar heat and one of the least expensive. The solar collector is the main component of a solar hot-water system. It transforms radiant energy from the sun in the spectral range 0.3-3µm, into usable heat.

A. *Basic components of a solar water heating system:*

Patel et al. (2012) reported that SWH generally consists of a solar radiation collector panel, a storage tank, a pump, a heat exchanger, piping units, and auxiliary heating unit.

According to Agbo and Oparaku (2006) the basic elements of common solar water heaters are the flat-plate collector, heat transfer fluid and the storage tank. Other components such as heat exchanger, pumps, pipe network, valves, auxiliary energy source and control system can be included.

B. *Heat Exchanger;*

According to Alawa and Ohia (2013) heat exchanger are equipment that transfer heat from one medium to another. It is a device in which energy is transferred from one fluid to another across a solid surface.

Eckert and Drakes (1987) reported that a heat exchanger is a device that transfers thermal energy from a high-temperature fluid to a low- temperature fluid with both fluids moving through the device.

V. Application of Heat Exchanger in Food and Dairy Industries:

Shinde et al. (2012) reported that shell and tube heat exchanger (S&THE) are widely used in many industrial areas, such as power plant, chemical engineering, petroleum refining, food processing etc. According to Master et al. (2006) more than 35-40% of heat exchangers are of the shell and tube type due to their robust geometry construction, easy maintenance and possible upgrades.

A very important advantage of the tubular heat exchangers are their superior sanitary and yet very simple designs. Tubular heat exchangers offer much longer continuous operation than the plate heat exchanger with lower pressure drops. (Christie, 1998)

Prakash et al. (2011) and Gut et al. (2004) reported that the plate heat exchanger are mainly used for heating applications in dairy, food processing and brewing industries for high temperature short time pasteurization of milk and fruit juices. These types of heat exchanger are capable of recovering heat efficiently at low temperature differentials.

VI. Pasteurization of Milk:

According to Pandey and Gupta (1983) the actual definition of pasteurization is, the heating of milk to specific temperatures for a specific time to reduce undesirable enzymes and bacteria to negligible levels. It is important that pasteurization is a function of time and temperature not just temperature. Imele et al. (2002) reported that pasteurization is a process to prevent the spoilage of milk. It has been used since the early 1900s (heating raw milk to 720C for 15 minutes). It is expected to remove/reduce microorganisms from milk.

According to Food Safety and Standards Authority of India (FSSAI) the terms “Pasteurisation”, “Pasteurised” and similar terms shall be taken to refer to the process of heating every particle of milk of different classes to at least 630C and holding at such temperature continuously for at least 30 minutes or heating it to at least 71.50C and holding at such temperature continuously for at least 15 seconds or an approved temperature time combination that will serve to give a negative phosphatase Test. (FSSAI notification, 2012)

VII. Conclusion:

Solar pasteurization system is very important for the purpose of killing of bacteria present in milk. From the research work by different scientists following points are drawn as a conclusion:

- A pasteurization temperature required for milk is 63 and 78 degree Celcius.
- Quality of milk should be investigated.
- A HE is important for pasteurization of milk.
- Temperature ranges for pasteurization system ranges from 60 to 75 degrees Celsius which can be easily obtained by Flat plate collector.

REFERENCES

[1] Pandey, M.M. and C.P. Gupta. 2004. Pasteurization ofmilk by solar energy. Pergamon Press. New York.
[2] Pandey, M.M. and C.P. Gupta. 1983. Pasteurizationof milk by solar energy. Proceedings of internationalsolar energy, New Delhi, India. 7(2): 21-27.
[3] Razzak, Faik, Haddad, N. Ayoob ,Yalda and Nakeya.1985. Utilization of solar energy in liquid milkprocessing. Magallatbuhut al-taqat al-Samsiyya, 3(2): 35-45.
[4] Reddy, J.M. and R.D. Verma. 1986. Feasibility studieson utilization of solar energy in Dairy Processing.Journal of the Institution of Engineers: AgriculturalEngineering Division, 66: 45-55.
[5] safety: A brief history and update. Rev.Sci.Tech.Off.Int.Epiz. 16(2)441-451 http://www.polyeyes.com/Article/Per-capita-Milk-Availability-in-India-to-Touch-290-gram-per-day-in-2013.
[6] Aneja, R.P. (1990). Improving the hygienic quality of milk. Indian Dairyman, 42: 41-44.
[7] Verma, R.D.; Sarma, S.C.; Kohli, R.K. and Nayyar, V.K. (1984). Design and development of solar collectors for dairies. Indian Dairyman. 36(7): 386.
[8] Reddy, J.M. and R.D. Verma. (1986). Feasibility studies on utilization of solar energy in Dairy Processing. Journal of the Institution of Engineers: Agricultural Engineering Division, 66: 45.
[9] Broos, P. (1996). Solar cells as optical systems: a matter of computation. Delft University of Technology Science Research Bulletin. 4:8–12.
[10] Schnitzer, H.; Christoph, B. and Gwehenberger, G.; (2007). Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes: Approaching zero emissions, J. Cleaner Production 15:1271–1286.
[11] Zahira, R.; Akif, H.; Amin, N.; Azam, M. and Haq, Z. (2009). Fabrication and performance study a solar milk pasteurizer. Pak. J. Agri. Science, 46(2):162- 170.
[12] Pandey, M.M. and Gupta, C.P. (2004). Pasteurization of milk by solar energy. Pergamon Press. New York.
[13] Li, Z.; Guo-Qiang, Z.; Dong-Mei, L.; Jin, Z.; Li-Juan, L. and Li-Xin, L. (2007) Application and development of solar energy in building industry and its prospects in China. Energy Policy; 35:4121–4127.
[14] Benz, N.; Gut, M. Beikircher, T. (1999). Solar process heat with non-concentrating collectors for food industry. Proceedings of Solar World Congress.pp.1209– 1214.
[15] Nielson, K.M. and Pedersen T.S. (2001). Solar panel based milk pasteurization. Control EngineeringWorking Pare Series, ISSN 0908-1208.
[16] Agbo, S.N. and Oparaku, O.U. (2006). Positive and future prospects of solar water heating in Nigeria. The Pacific Journal of Science and Technology, 7(2):191-198.
[17] Alawa, B.T.L. and Ohia, I.O. (2013). Performance evaluation of heat exchanger in a polyethylene Plant. International Journal of Engineering and Technology Innovation. 3(1);49-57
[18] Eckert, E.R.G. and Drake, R.M. (1987). Analysis of Heat and Mass Transfer. Hemisphere Publ., Washington DC, USA.
[19] Shinde, S.S.; Joshi,S.S. and Pavithran, S. (2012). Performance Improvement in Single phase Tubular Heat Exchanger using continuous Helical Baffles. International Journal of Engineering Research and Applications. 2(1): 1141-1149.
[20] Christie, I.S. (1998). Observations on current dairy processing equipment design and processing trends in dairy industry. Indian dairyman. 50(6):7-11.
[21] Prakash, A.B.; Rao, B.S. and Sastry, R.C. (2011). Heat Recovery Studies of Process Fluids in Corrugated Plat Heat Exchangers. ICCEBS. pp-324-328.
[22] Gut J.A.W., Fernandes R., Tadini C.C. and Pinto J.M. (2004). HTST Milk Processing: Evaluating the Thermal Lethality inside Plate Heat Exchangers, International Conference on Engineering and Food.
[23] FSSAI (2012). Manual of Methods of Analysis of Foods: Milk and Milk Products, Food Safety and Standard Authority of India, Ministry of Health and Family Welfare, Government of India. New Delhi.
[24] Panchal, Hitesh, Romil Patel, Sudhir Chaudhary D.K. Patel, Ravishankar Sathyamurthy and T. Arunkumard. 2018. "Solar energy utilisation for milk pasteurisation: A comprehensive review" Renewable and Sustainable Energy Reviews 92 (2018) 1–8.
[25] Panchal Hitesh, Patel Jay, Chaudhary Sudhir. A comprehensive review of solar milk pasteurization system. J Sol Energy Eng 2018;140(1):1–8.
[26] Panchal, Hitesh, Romil Patel, and Ravishankar Sathyamurthy. 2018. "Investigation and Performance analysis of Solar Milk Pasteurisation system" International Journal of Ambient Energy 0143-0750.
[27] Panchal, Hitesh, Romil Patel, and K. D. Parmar. 2018. "Application of solar energy for milk pasteurisation: a comprehensive review for sustainable development" International Journal of Ambient Energy 0143-0750.

