Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 9, September 2024

Thermodynamic Analysis of Milk Pastueraization System using Flat Plate Solar Collector

Salem Alabd, Mohd Shahid, Abdulbasit Mansour, Masroof Ahamad
Higher Institute of Engineering Technology, Tripoli, Libya
Satya College of Engineering, Haryana, India.
University polytechnic Jamia Millia Islamia Central University New Delhi, India

***Abstract*— currently more than 50% of all milk produced in world is processed. The world dairy industry has long relied on non-renewable energy sources, which are not only becoming more and more expensive but are also to blame for major health issues and environmental issues including global warming. As a result, the all governments, social and environmental organizations and scientific communities have all pushed for the adoption of green energies. Solar energy has emerged as the most promising among the green and renewable energies.**

The pasteurization of milk requires a significant amount of conventional energy, which is reduced when solar energy is used instead. Therefore, using solar collectors at the different angles β=φ+15, ß=φ, β=φ-15 calculate the amount of energy intensity and temperature of output water. Additionally, determine the quantity of collectors needed to heat milk to pasteurization temperature.

***Keywords*— Milk pasteurization Temperature, Energy intensity, Solar Flat Plate Collector**

Nomenclature:

Symbols	*Parameters*	*Units*
Ta	*ambient temperature*	(°C)
Tp,m	*absorber mean temperature*	(°C)
Tf_i	*inlet air temperature*	(°C)
UG	collector overall heat loss coefficient	$Wm^{-2} K^{-1}$
mw	*mass flow rate of water*	(kg/s)
C_{pw}	*sp.Heat of milk*	(j/kg°c)
ΔT	*rise of temp.in collector*	(°c)
Mm	*mass flow rate of milk*	(kg/s)
Tpm	*milk pasteurization temp*	(75°c)
Tim	*initial temperature of milk*	(°c).
I_d	*Hourly diffuse radiation*	
ϕ	*Latitude angle*	
β	*Collector tilt angle*	

INTRODUCTION

India is one of the dairy-producing countries with the quickest growth rates. Demand for dairy and food products is rising daily as a result of population growth and improvements in lifestyle. In the past 20 years, commercial energy consumption has climbed 6% in tandem with rising product demand, placing India fifth globally in terms of total energy consumption. Approximately 49% of all energy usage is in the industrial sector. Currently, natural gas is imported 31% of the time, crude oil 77% of the time, and coal 9% of the time [1]. The solar constant, or 1353 W/m2, is the amount of solar energy that passes through the earth's atmosphere per second. Of this, the atmosphere absorbs over 190 W/m2. Direct radiation and dispersed radiation make up the remainder. A total of 473 W/m2 of direct and scattered radiation is absorbed by the earth and can be used for a variety of purposes. Only around 383 W/m2 of this energy is reflected back to space by clouds. Since the implementation of the ninth plan, the Indian dairy industry has experienced significant expansion. India is the top milk-producing country in the world as a result, producing 127.9 million tonnes of milk annually in 2011–12 (and an anticipated 140 million tonnes in 2013–14) [2]. This indicates a consistent increase in the supply of milk and dairy products for our expanding population. Most milk production in India takes place in rural regions. Evidently, it can be a reliable source of money if handled and processed appropriately [3].

Milk and milk products are put through a number of unit processes in dairy processing plants, including filtering, clarifying, homogenization, pasteurization, sterilization (UHT treatment), cooling, packaging, and refrigeration. For the manufacture of UHT milk, powder, cheese, butter and liquid milk pasteurization, the corresponding steam pressures are 1.5, 2.2, 3, 3 and 10 bar [4]. Currently, liquid milk accounts for about 49% of the nation's total milk production. Around 26.5% of the whole milk is transformed into ghee, 7% into curd, and 6% into butter out of the remaining 51%. The remaining 11.5% of the milk is used to make other dairy products including ice cream, paneer, and khoa. Conduction, conduction-convection, and radiation are some of the ways that heat energy is transported in industrial processes. Electric resistance heaters use conduction to transfer heat energy. Furnaces and radiant heat dryers use radiation. In many processes, the equipment functions cyclically, as in regenerative furnaces and agitated process vessels, but frequently it does so in steady-state settings. Traditionally, fossil fuels (coal, petrol, diesel, etc.) are used to generate heat to produce steam/hot water, which is then used as a heating medium in PHE [5]. The combustion of these fossil fuels contributes to pollution as well as greenhouse gases

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 9, September 2024

(GHGs) [6], which contribute to global warming. Furthermore, these energy sources are non-renewable [7].
According to Li et al. [8], SWHs typically consist of solar collectors and a storage area. It operates on the principle of the thermosyphon or the disparity in density between hot and cold water. To satisfy the requirements for an acceptable pasteurisation, Nielsen and Pedersen [9] developed a milk pasteurisation system based on solar panels. They discovered that the solar panel provided a maximum temperature of hot water of about 100C through absorption of solar energy, which was successfully used for pasteurising milk. Water heating is one of the easiest, most affordable, and least expensive uses of solar heat, according to Agbo and Oparaku [10]. The price of heating 100 litres of water with a solar hot water system was compared by Philip [11, 12].
The pasteurisation procedure is crucial for industries, according to the literature assessment. It will benefit the environment if milk is pasteurised using solar energy. Therefore, one of the main goals of this research is to analyse solar-powered pasteurisation systems and determine the bare minimum number of collectors needed to pasteurise temperature.

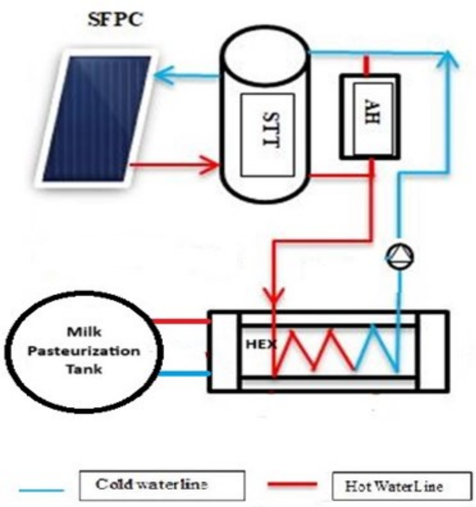


Fig. 1. Diagram of Solar Collector Milk Pasteurization System (SCMPS)

METHODOLOGY:

1. The solar energy is utilised in flat plate collector to produce hot water. The flow rate of water is determined by using following formula.
Heat given by hot water = heat taken by milk
mw cpw ΔT = mm cpm (Tpm – Tin)
The overall analysis of the system has been done the analysis of Flat Plate Collector (FPC) was carried out, wherein the results obtained from the first phase were utilized. The rate of useful energy gain (Q_u) delivered by the solar flat plate collector is given by eq. (1):

$$Q_u = A_c I_T \eta_c \quad (1)$$

In other terms, Eq. (3.2), can be rewritten as:

$$Q_u = ApS - q_l \quad (2)$$

The amount of solar flux absorbed by the absorber plate is given by Eq. (3):

$$S = I_b r_b (t\alpha) b + \{I_d r_d + (I_b + I_d) r_r\}(t\alpha) d \quad (3)$$

The instantaneous efficiency η_c of the collector is given Eq. (4):

$$\eta_c = F_R(\tau\alpha) - F_R U_L \frac{(T_{f,in} - T_a)}{I_T} \quad (4)$$

where is F_R represents the heat removal factor of the collector and it is given by:

$$F_R = \frac{\dot{m}Cp}{U_l A_p}\left[1 - exp\left\{-\frac{F' U_l A_p}{\dot{m}Cp}\right\}\right] \quad (5)$$

In Eq. (6), F' represents the efficiency factor of the collector.

$$F' = \frac{1}{WU_l\left[\frac{1}{U_l[(W - D_o)\emptyset + D_o]} + \frac{\delta_a}{k_a D_o} + \frac{1}{\pi D_i h_f}\right]} \quad (6)$$

The hourly solar radiation I_T falling on the tilted collector surface is given by Eq. (7):

$$I_T = I_b R_b + I_d R_d + (I_b + I_d) R_r \quad (6)$$

The tilt factor for the beam radiation R_b is given by following Eq. (8):

$$R_b \frac{\sin\delta \sin(\phi - \beta) + \cos\delta \cos\omega \cos(\phi - \beta)}{\sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega} \quad (7)$$

where, δ is the declination angle whose expression is given in Eq. (9):

$$\delta = 23.45 \sin\left(360 \frac{284 + n}{365}\right) \quad (8)$$

The time used for calculating the hour angle ω is the local apparent time and it can be calculated using the relationship given in Eq. (10).
Local Apparent Time = Standard time ± 4 (Standard time longitude–longitude of location) + (Equation of time correction) (9)
The time correction (in minutes) can also be calculated from the following empirical relation:

$$E = 229.18\,(0.000075 + 0.001868\cos B) - 0.032077\sin B - 0.014615\cos 2B - 0.04089\sin 2B) \quad (10)$$

where B = $(n - 1)360/365$ and n is the day of year.
2. The outlet temperature of hot water coming from the collector is determined and it has been seen either this temperature is sufficient to pasteurize milk or not.
3. Initially we use one collector, if it is not available to give sufficient temperature to pasteurize the milk the number of collector will increase.
In this way we will determine the no. of collector required to supply hot water of required temperature.

RESULT

The amount of solar energy incident on a surface is depending on angle of incidence. For the given system the amount of solar energy calculated for the different angles. In the months of summer, at an angle β=φ+15, the amount of solar energy available is 806.12 Wh/m2 and at an angle equal to β=φ, the amount of solar energy is 887.36 Wh/m2. For the angle of β = φ-15, solar energy available is 925 Wh/m2. Hence the amount of solar energy available is increases as we move from β = φ+15 to β = φ-15.
For the utilization of solar energy there is use of solar flat plate collectors. Number of solar collectors used is depends upon the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 9, September 2024

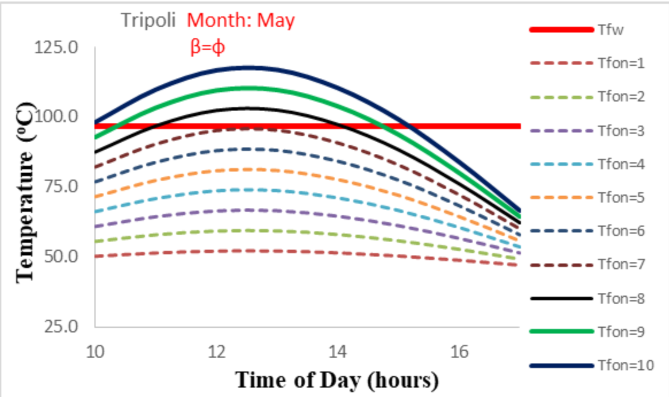
temperature required for the pasteurization. For the given system temperature of water required is 96.8C°, so for achieving the temperature use number of collectors as shown in Figure 2 and the number of Flat plate collector for this study related to months and location as shown in table 2. The maximum energy available at 12.5 ST is 887.36 Wh/m2 for the month of May, and lowest in a day at 16.5 ST. presented in table 1.

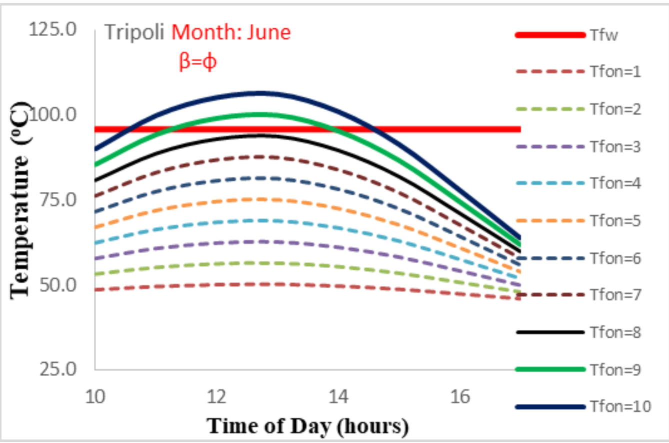
TABLE I: Incident Radiation for the different month.

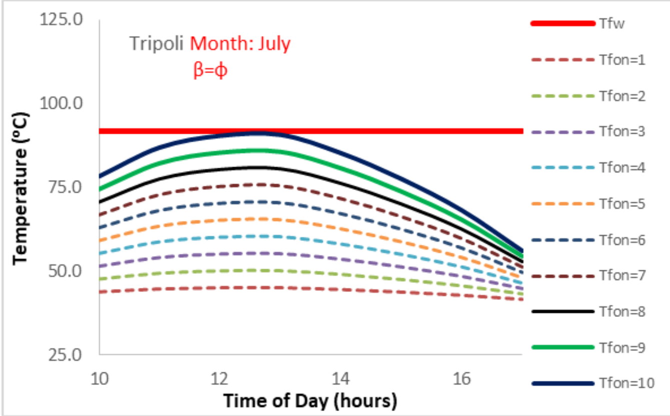
Time	Month(incident radiation Wh/m^2)			
	May	*June*	*July*	*August*
09:00	442.33	430.20	370.15	360.87
10:00	638.56	606.61	512.96	496.10
11:00	780.12	709.16	605.34	594.38
12:00	851.50	762.79	639.13	629.31
13:00	845.43	766.53	638.18	648.85
14:00	754.87	702.56	573.11	583.14
15:00	608.41	590.42	483.71	494.58
16:00	500.47	436.01	375.88	372.58
17:00	306.79	275.98	239.35	232.99

TABLE II: Number of collectors required for the different month

Month	Minimum No of collectors required
May	7
June	8
July	10
August	10







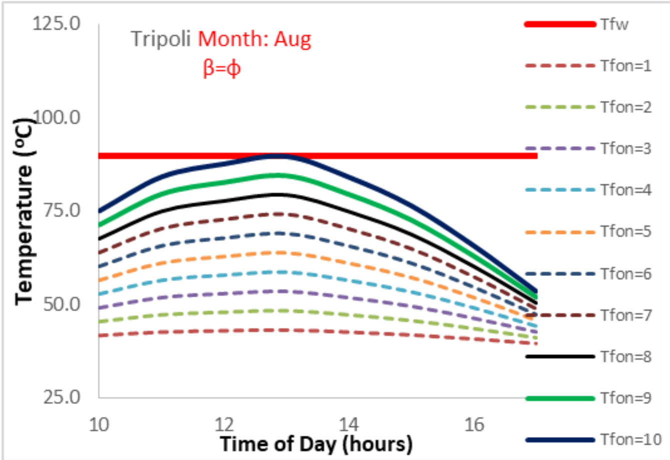


Fig. 2. Number of solar collectors require to achieve outlet temperature.

Since MATLAB is a highly powerful technical language software for mathematical programming (Shailendra Jain [13]. MATLAB 17a was used to solve the mathematical expressions of the SFPC. The results so obtained for the SFPC have been provided in the present subsection. The location was selected from Libya to carry out the study and this was: Tripoli ('32 ° 8877'N, 13 1872°E'). The input data for the analysis were collected on 15th May. The initial conditions that were considered for the analysis is listed in Table 3 were use.

TABLE III: Performance of FPC for the whole day on 15 of May in Tripoli

$IST\,(h)$	10:00	11:00	12:00	13:00	14:00	15:00	16:00
$IT\,(W/m^2)$	698.18	808.13	863.56	859.22	789.36	676.05	514.8
$T_0\,(°C)$	73.86	76.78	78.55	78.03	76.50	74.48	69.00
$Q_u\,(W)$	638.56	780.12	851.50	845.43	754.87	608.41	500.4
$Q_l\,(W)$	415.51	477.40	483.10	489.85	401.59	343.13	391.4
η_i	0.51	0.57	0.60	0.59	0.58	0.47	0.46

CONCLUSION:

Libya has enough of sunlight virtually all year round because it is located in Mediterranean climate a hot, very dry summers and warm winters. Utilising this enormous amount of energy, which would otherwise be lost, for beneficial activities would not only protect the environment but also benefit business owners financially. Dairy businesses can use solar water heating systems to process raw materials and create finished goods. It has been used in the dairy sector for pasteurisation, sterilisation, preheating, and the production of paneer, among other things. Given the current situation, the same can be adopted for additional processing units as well as other dairy and food processing factories.

REFERENCES:

[1] Desai, H.; and Zala, A.; (2010) An overview on present energy scenario and scope for Energy conservation in Dairy Industry. National Seminar on „Energy Management and Carbon Trading in Dairy Industry.

[2] Anonynomous. (2014). Rising Milk Production- Future propects. Indian Dairyman. 66(7)

[3] Nandi, P. (2009). Solar thermal energy utilization in food processing industry in India. The Pacific Journal of Food Science and Technology, 10(1):123-131

[4] Anonynomous. (2005). Energy use in dairy processing. Bulletin of International Dairy Federation.

[5] Chauhan, K.A.; Kalra, K.K.; Singh, V.R. and Raina, B.B. (2006). A Study on the Economics of Milk Processing in a Dairy Plant in Haryana. Agricultural Economics Research Review. 19:399-406

[6] Rai, G.D. (2006). Solar Energy Utilisation, Mechanical Engineering Department, Samrat Ashok Technological Institute Vidisha (M.P.).

[7] Twidell, J. and Weir, T. (2006). Renewable Energy Recources 2nd Ed. Taylor and Francis, Milton park, Abingdon, pp-146-147

[8] 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.

[9] Benz, N.; Gut, M. Beikircher, T. (1999). Solar process heat with non-concentrating 84 Collectors for food industry. Proceedings of Solar World Congress.pp.1209–1214.

[10] Nielson, K.M. and Pedersen T.S. (2001). Solar panel based milk pasteurization. Control EngineeringWorking Pare Series, ISSN 0908-1208.

[11] 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.

[12] Philip, S.K. (2006). "Introduction to solar water heaters for village milk cooperatives" Indian Dairyman, 58(1):65-69.

[13] Salem Alabd Mohamed, Munawar Nawab Karimi, 2019. Simulation of Lithium Bromide- Water (LiBr-H2O) Vapor Absorption System (VAS) powered by Solar Flat Plate Collector (SFPC). IOP Conference Series: Materials Science and Engineering. vol. 691 (2019) 012031, IOP Publishing, DOI:10.1088/1757-899X/691/1/012031.

[14] Hardik, Joshi, P. Ranpariya, (2015), Design a solar collector for VAR system with 1TR capacity at its maximum COP, International Journal of Advance Research in Engineering, Science & Technology (IJAREST), ISSN(O):2393-9877, ISSN(P): 2394-2444, Volume 2, Issue 4.