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Performance evaluation and energy consumption analysis of dairy industry by milk pasteurization

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Abstract
Energy audit provides the route that helps to get better utilization out of the available resources. The need is to evolve the right strategy for energy saving measures to achieve economical and environmental benefits. Also energy saving is as good as environment saving. Conducting Energy Audit in dairies is not the suppressing the demand for energy use, but providing ways for efficient use of energy and steep rejection of its wastage. Energy is a decisive component of dairy industry. Dairy industry depends on fossil fuels for energy supply. Pasteurization is a relatively mild heat treatment, in which food is heated below 100°C. The aim of experiment was to investigate average quantity of milk, electricity consumption in per day. The data was analyzed of November 2016, December 2016, and January 2017 for New Alfa pasteurizer. The highest average quantity of milk, electricity consumption and thermal energy in shift B of November was 523.87 kg., 17.48 (KW) and 159.45(KJ×10^3) respectively. The lowest average quantity of milk, electricity consumption and thermal energy in shift A of November was 488.67 kg., 16.37 (KW) and 140.24 (KJ×10^3). Followed by The highest average quantity of milk, electricity and thermal energy consumption in December was 331.05 kg., 11.05 (KW) and 91.74 (KJ×10^3) in shift B and the lowest collection of milk 141.46 kg., Electricity consumption average 4.65 (KW) and thermal energy consumption 38.64 (KJ×10^3) in shift A of New Alfa pasteurizer. New Alfa pasteurizer's highest average quantity of milk in January (2017), 703.92 kg., electricity consumption average was 23.49 (KW) and thermal energy consumption 197.12 (KJ×10^3) in shift B while lowest average collection of milk, electricity, and thermal energy consumption was 396.67 kg., 13.24 (KW) and 111.04 (KJ×10^3) in shift A respectively.

Keywords: energy conservation, new alfa pasteurizer, pasteurization, specific heat, thermal energy

Introduction
Milk is an important liquid fluid for human health, it contain at least 3.25 percent milk fat. It also contain at least 8.25 percent protein, sugar (or carbohydrates) and vitamins and minerals. Otherwise whole milk is made up of water about 87 percent. India's milk production is estimated to have increased by 6.6 per cent to 176.35 million tonnes during the last financial year. "Milk production in the country is 165.4 million tonnes during 2016-17 and 176.35 million tonnes (provisional) during 2017-18," (source: The economics times July 27, 2018). The per capita availability of milk is around 355 grams per day in India in 2016-17. (Source: Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, GoI). Milk consumption pattern in India is consumed as liquid milk (45%), Ghee (28%), Butter (6.5%), Khoa (6.5%), Dhai (7.0%), milk powder (2.6), Channa, cheese and paneer (2.0%), Cream (0.5%), Ice-cream (0.2%) and others (1.7%) (Chandra *et al.,* 2007). "The average yield rates of exotic and crossbred cows are estimated to be as 10.85 kg and 7.40 kg per animal per day respectively and the average yield rates of indigenous and non-descript cows are estimated to be as 3.56 kg and 2.29 kg per animals per day. The average yield rates of indigenous and non-descript buffaloes are estimated to be as 5.86 kg and 4.04 kg per animals per day respectively," added the official. The survey noted that first five highest milk producing states are Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat and Andhra Pradesh during the Rainy Season. (*Source: the new Indian express July, 22, 2017*). Pasteurization is the process of the heating liquids for the purpose of destroying viruses and harmful organism. It was developed in 1864 to improve the keeping qualities of milk. Pasteurization typically uses heating and cooling cycle at temperatures above the boiling point of milk and above the freezing point. As society industrialized around the turn of the 20th century, increased milk production and distribution led to outbreaks of milk borne diseases. In 1938, milk products were the source of 25% of all food and waterborne illnesses that were traced to sources, but now they account for far less than 1% of all food and water borne illnesses. Pasteurized milk process is a diary process that

consumes large amount of energy consisting of electricity and fuel (Modi *et al*., 2014) [5]. The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place. The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket which seals the interpolate channel and directs the fluids into alternate channels. The survey of the literature regarding the plate heat exchanger and using of various compressor oils in the household refrigerator and air-conditioners are listed (Sreejith *et al*., 2014) [4]. The energy saving devices considered in this research work are waste heat recovery systems, economizers, cogeneration systems, vapour absorption system. Hence, realizing the importance of the need for energy conservation in industries on a long term basis. Diary industries may follow the energy conservation techniques as given in this paper. So in order to solve the energy crisis problem and meet the energy demands, it is necessary to perform audits, so that every industry utilizes its maximum energy available and runs efficiently (Iyer *et al*., 2006) [3]. The studied on the apparent specific heat of different milks varying in fat mass contents from 0.1% to 35%, were determined in the temperature range 1–59 °C by means of a continuous differential scanning calorimeter (DSC) method. The DSC measurement procedure was tested for reliability with distilled water before applying it to the milk samples which varied in fat content.

Data collection

The work was carried out in Gangol Sahkari Dugdh Utpadak Sangh (Parag Dairy) Meerut and data analyzed in the Department of Agriculture Engineering, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (India) during the month of November, December (2016) and January 2017.

Procurement of raw material

In dairy it was noted that the raw milk were collected from various villages and brought in tankers. The New alfa pasteurizer available in Parag Dairy. The work was done in three shifts (A, B and C) in 24 hours. Data collected manually and then were analyzed using various formulas.

New Alfa pasteurizer

New alfa pasterizer is mostly used for milk industry and liquid foods, this pasteurizer manufactured company Vulcan level Ltd Sweden. In this pasteurizer heat exchange mechanism AM 10 RCF type heat exchanger it is used for exchange the heat one place to another. It has adjustable temperature and pressure. The maximum working temperature up to 110^{0}C & design pressure up to 6 kg/cm^2. The capacity of the new alfa pasteurizer has 10,000 lit/hr. It has low capacity compare to Gea pasturizer.

Thermal energy

Thermal energy is energy possessed by an object or system due to the movement of particles within the system. Thermal energy is one of various types of energy, where 'energy' can be defined as 'the ability to do work.' Work is the movement of an object due to an applied force. A system is simply a collection of objects within some boundary. Therefore, thermal energy can be described as the ability of something to do work due to the movement of its particles.

$$Q = m.\ c_p.\ \Delta T$$

Where,
Q = Thermal energy (kj)
m = Quantity of milk (kg)
Cp = Specific heat (kj/kg, k)
ΔT = Temperature difference (°C)

Specific heat

The ratio of the amount of heat needed to raise the temperature of a certain amount of a substance by one degree to the amount of heat needed to raise the temperature of the same amount of a reference substance, usually water, by one degree. Because molecules of different materials have different weights and sizes, they require different amounts of energy to be heated to a given temperature. Knowing the specific heat of a material makes it possible to calculate how much energy is needed to raise the material's temperature by a given number of degrees. The amount of heat, measured in calories, needed to raise the temperature of one gram of a substance by one degree Celsius.

$$Cp=1674.72F+837.36SNF+4186.8M$$

Where,
Cp = Specific heat (kj/kg, k)
F = Fat (%)
SNF = Solid not fat (%)
M = Moisture, (water) (%)

Electricity

Amount of electricity was calculated by the using formula as fallow.

$$\text{Electricity used in per day (KW/kg)} = \frac{\text{Average electricity used in Per day}}{\text{Quantity of milk kg.per day}}$$

Results and Discussion

November (2016)

In November 2016, the New Alfa pasteurizer, pasteurized average highest quantity of milk 523.87 kg/day in shift B followed by 491.87 kg/day in shift C and lowest 488.67 kg/day in shift A (Table 1). Electricity consumption was depends upon quantity to be pasteurized. In November it was calculated highest in shift B (17.48 KW) followed by shift C (16.40 KW) and lowest in shift A (16.31 KW). Average specific heat used was calculated highest in shift B (3.31 KJ/kg./k) followed by shift A (2.71 KJ/kg./k) and lowest in shift C (2.45 KJ/kg./k). Thermal energy consumption in milk pasteurization was highest in shift B (159.45 KJ×10^3) followed by shift A (140.24 KJ×10^3) and lowest in shift C (136.0 KJ×10^3).

December 2016

In December 2016, the New Alfa pasteurizer pasteurized average highest milk 331.05 kg/day in shift B followed by 315.77 kg/day in shift C and lowest 141.46 kg/day in shift A (Table 2). Electricity consumption was depends upon quantity to be pasteurized. In December was calculated highest in shift B (11.05KW) followed by shift C (10.54 KW) and lowest in shift A (4.65 KW). Average Specific heat used was calculated highest in shift B (2.62 KJ/kg./k) followed by shift A (2.51 KJ/kg./k) and lowest in shift C (2.15 KJ/kg./k). Thermal energy consumption in milk pasteurization highest average in shift B (91.74 KJ×10^3) followed by shift C (87.62 KJ×10^3) and lowest in shift A (38.64 KJ×10^3).

January (2017)

In January 2017, New Alfa pasteurizer pasteurized average highest milk 703.92 kg/day in shift C followed by 589.32 kg/day in shift B and lowest 396.66 kg/day in shift A (Table 3). Electricity consumption was calculated highest average in shift C (23.49 KW) followed by shift B (19.66 KW) and lowest in shift A (13.24 KW). Average Specific heat used was calculated highest in shift C (3.35 KJ/kg./k) followed by shift B (3.34 KJ/kg./k) and lowest in shift A (2.15 KJ/kg./k). Thermal energy consumption in milk pasteurization highest average in shift B (198.42 KJ×10^3) followed by shift C (197.12 KJ×10^3) and lowest in shift A (111.04 KJ×10^3).

No. 1: Date and shift wise data distribution of New Alfa Pasteurizer for November month

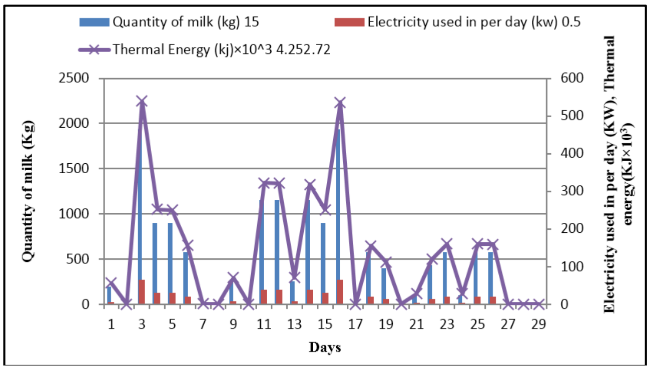

Fig 1(a): Quantity of milk, electricity, and thermal energy in shift A

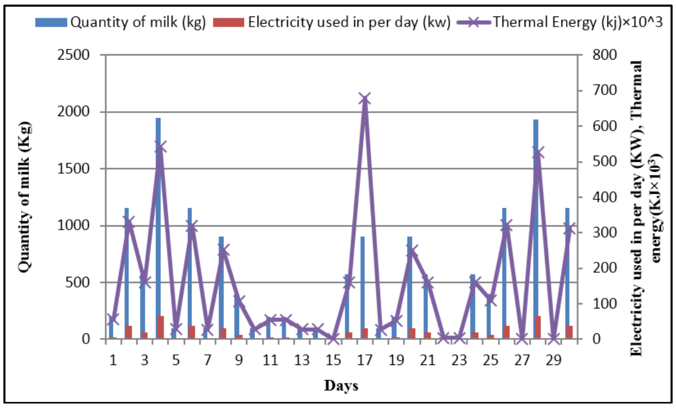

Fig 1(b): Quantity of milk, electricity, and thermal energy in shift B

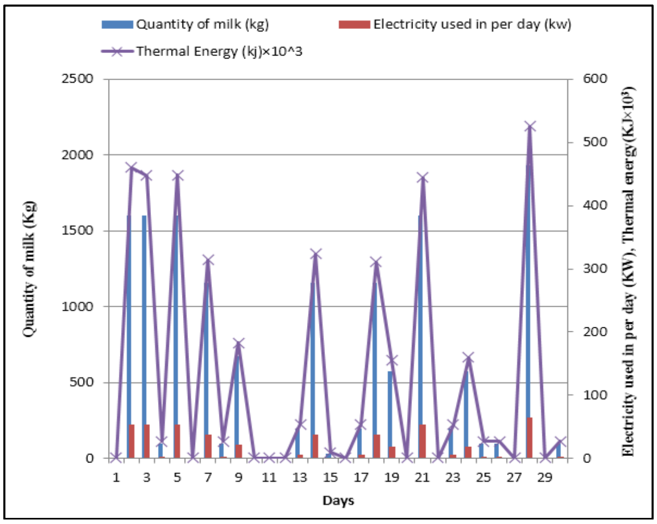

Fig 1(c): Quantity of milk, electricity, and thermal energy in shift C

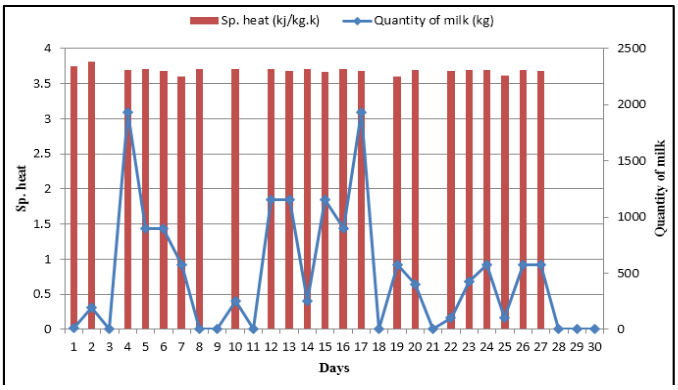

Fig 1(d): Specific heat and quantity of milk in shift A

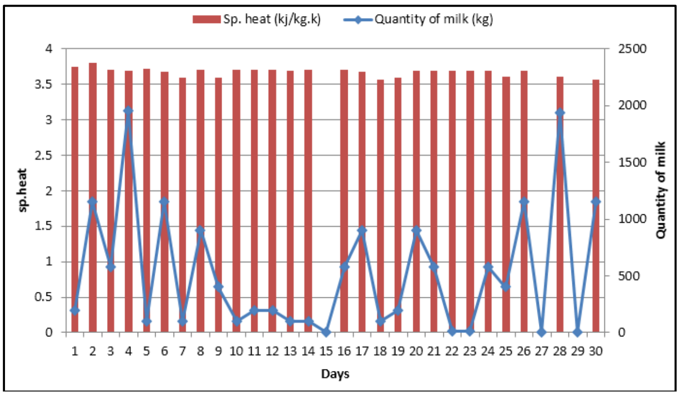

Fig 1(e): Specific heat and quantity of milk in shift B

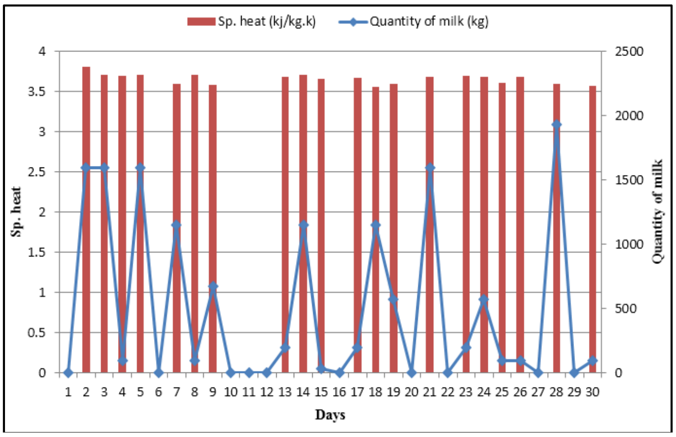

Fig 1(f): Specific heat and quantity of milk in shift C

No 2: Date and shift wise data distribution of New Alfa Pasteurizer for December month

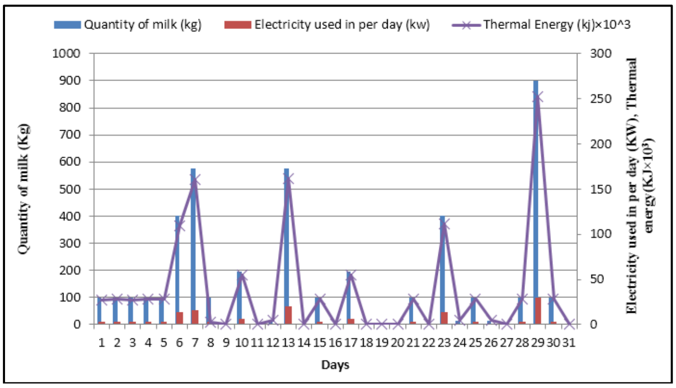

Fig 2(a): Quantity of milk, electricity, and thermal energy in shift A

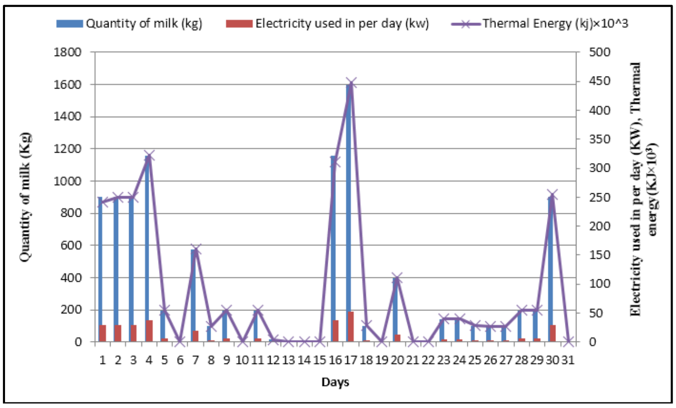

Fig 2(b): Quantity of milk, electricity, and thermal energy in shift B

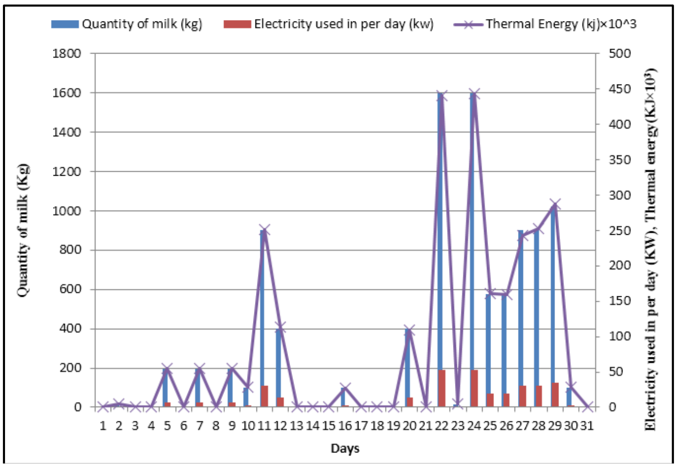

Fig 2(c): Quantity of milk, electricity, and thermal energy in shift C

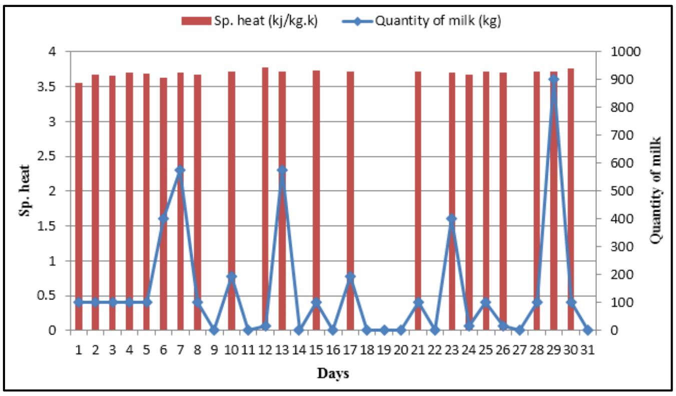

Fig 2(d): Specific heat and quantity of milk in shift A

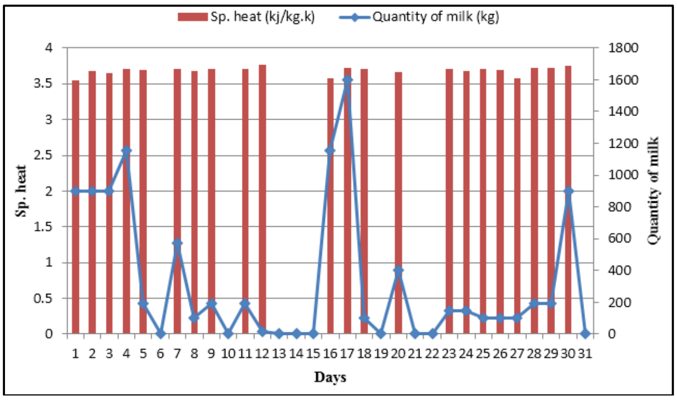

Fig 2(e): Specific heat and quantity of milk in shift B

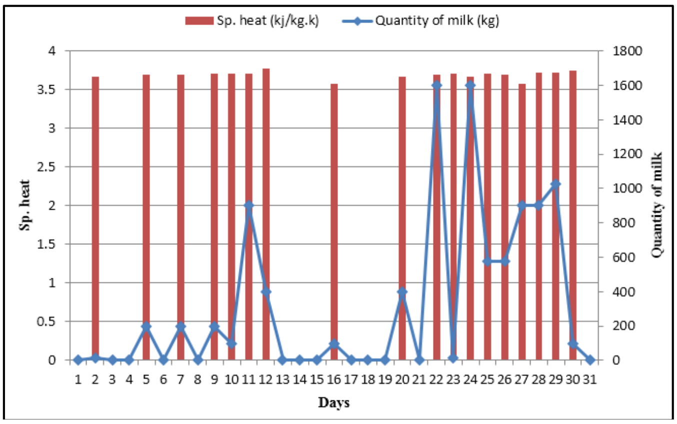

Fig 2(f): Specific heat and quantity of milk in shift C

No. 3 Date and shift wise data distribution of New Alfa Pasteurizer for January month

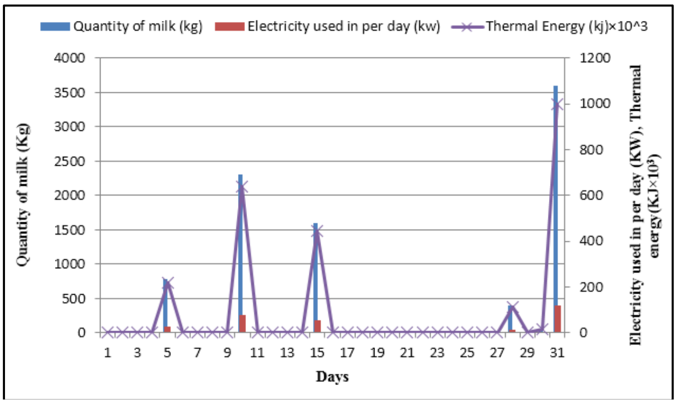

Fig 3(a): Quantity of milk, electricity, and thermal energy in shift A

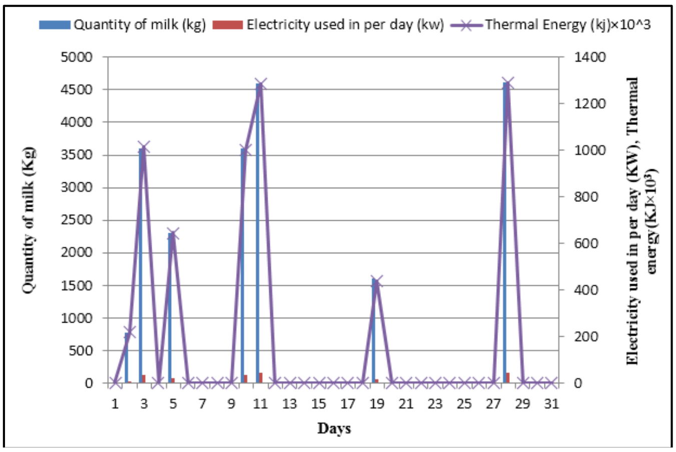

Fig 3(b): Quantity of milk, electricity, and thermal energy in shift B

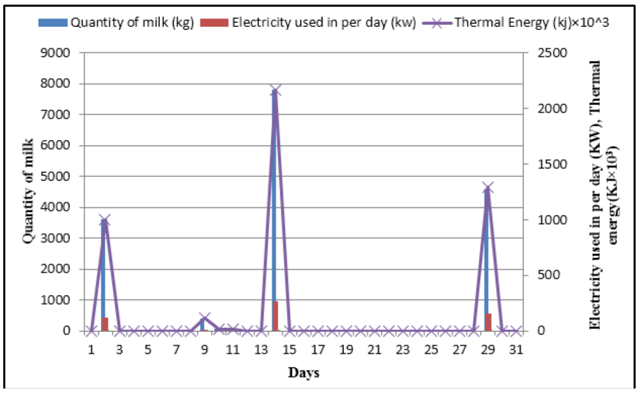

Fig 3(c): Quantity of milk, electricity, and thermal energy in shift C

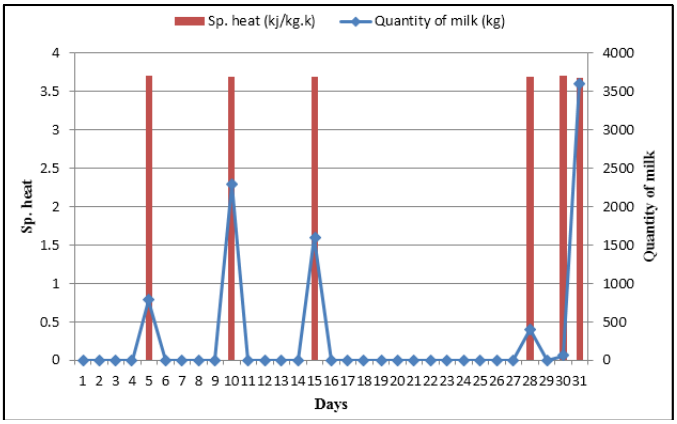

Fig 3(d): Specific heat and quantity of milk in shift A

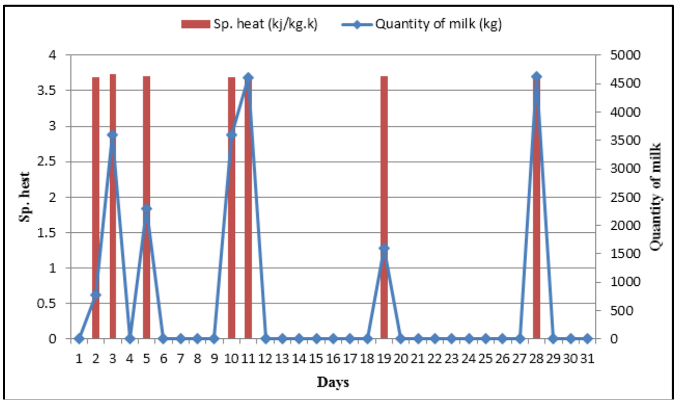

Fig 3(e): Specific heat and quantity of milk in shift B

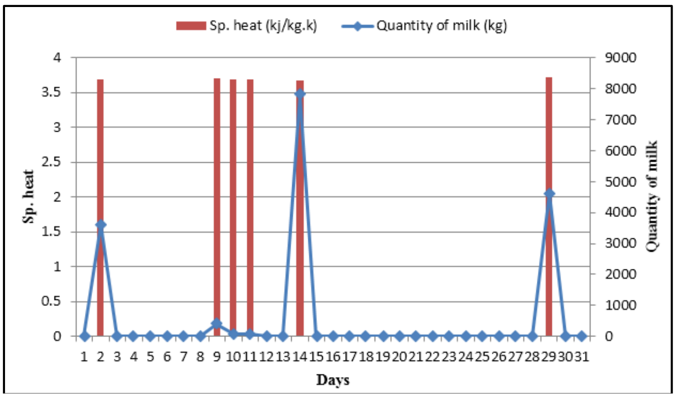

Fig 3(f): Specific heat and quantity of milk in shift c

Conclusion

The results also show that with improvements as suggested proposal in the dairy industries, considerable savings in energy expenditure can be obtained. The major reason why Indian dairy sector not catching up with the rest of the world is the fact that India being a developing country has all its potential resources scattered all over and we never figured out how to make the optimum use of these resources by bringing them under one roof. This is what is achieved from this paper i.e. implementing simple energy efficient, technologically feasible methods to reduce the milk processing energy cost to optimum. The suggested alternative method has very short payback period of 3 months only and the process energy audit indicates that loss of energy in milk dairy process are very high, so improvement chance are also high. All the parameters like, electricity, thermal energy and specific heat consumption are depend on the quantity of milk, So the quantity of milk which will be higher in the shift all the parameters will be more in the same shift. In November (2016) the milk quantity to be pasteurized was highest in shift B and lowest in shift A. In December (2016) the milk quantity to be pasteurized was highest in shift B and lowest in shift A. During January (2017) the milk quantity to be pasteurized was highest in shift C and lowest in shift A. So that the electricity consumption highest in shift B and lowest in shift A, in November (2016), where as in highest in shift B, lowest in shift A in December (2016) and January (2017) the highest in shift C, lowest in shift A. The specific heat consumption highest in shift B and lowest in shift A, in November (2016). Where as in highest in shift B, lowest in shift A in December (2016) and January (2017) the highest in shift C, lowest in shift A.

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