Energy consumption during pasteurization of milk

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Abstract

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. 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 and specific heat. The data was analyzed of November 2016, December 2016, and January 2017 for Gea pasteurizer in Parag Dairy, Meerut. The highest average quantity of milk, electricity consumption and thermal energy in shift C of November was 4001.83 kg., 133.49 (KW) and 1108.58(KJ×10³) respectively. The lowest average quantity of milk, electricity consumption and thermal energy in shift A of November was 1666.33 kg., 55.58 (KW) and 462.50(KJ×10³). The highest average quantity of milk, electricity and thermal energy consumption in December was 2059.51 kg., 68.70 (KW) and 569.68 (KJ×10³) in shift B and the lowest collection of milk 954.03 kg., average electricity consumption 31.82 (KW) and thermal energy consumption 261.98 (KJ×10³) in shift C of Gea pasteurizer. Gea pasteurizer's highest average quantity of milk in January (2017), 680.64 kg., electricity consumption average was 22.70 (KW) and thermal energy consumption 190.10 (KJ×10³) in shift B while lowest average collection of milk, electricity, and thermal energy consumption was 281.93 kg., 9.40 (KW) and 78.44 (KJ×10³) in shift A respectively.

Keywords: Energy, milk, pasteurization, pasteurizer, specific heat, thermal energy.

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Introduction

Milk production during 2014-15 and 2015-16 is 146.3 million tons and 155.5 million tons respectively showing an annual growth of 6.27%. The per capita availability of milk is around 337 grams per day in 2015-16. (Source: Department of Animal Husbandry, Dairying & Fisheries Ministry of Agriculture & Farmers Welfare Government of India). Pasteurization is the process of heating a liquid to below the boiling point to destroy microorganisms. Pasteurization of these products (in case of milk) may be three types there are the low temperature long time(LTLT) at 63°C for 30 min, high tempter short time(HTST) at 72°C for 15 sec and

flash heating at 85-90°C for 1-4 sec milk is heated. Generally in the dairy HTST processes of milk pasteurizer is used (Modi and Prajapati, 2014). In the milk pasteurization the killing effect in the temperature range up to 90°C has not been elucidated Pasteurization temperatures of 50°C, 60°C, 72°C, 84°C and 90°C and pasteurization units of 0; 15; 80 and 500 PU were used. The chemical tests were measured and included determination of moisture, fat, lactose, ash and protein (Al-Hilphy and Ali (2013). 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 number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program (Sreejith *et al.*, 2014). Many authors have proposed systematic approaches to performing energy audits. The level and type of the energy audit is usually determined by the cost of the audit, and therefore the duration and the type of measurements (Thumann, 1995). According to the ambition of the energy audit, the results can be more or less precise. The IPPC directive (Integrated Pollution Prevention and Control) defines the energy audit as an energy usage analysis to identify the main consuming operations and types of energy used, where it can also lead to identifying cost effective energy saving opportunities (IPPC, 2006). Two essential parts define the energy audit data acquisition and data analysis (Thumann 1995). The accuracy of the results depends on the type of the energy audit performed. The energy analysis as defined above is the data analysis leading to the proposed solutions.

Material and Methods

The work was carried out in Gangol Sahkari Dugdh Utpadak Sangh(Parag Dairy) Meerut and data analyzed in the Department of Agricultural 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. Gea pasteurizer was available in Parag Dairy. The work was done in three shifts (A, B and C) in 24 hours. Data was collected manually and then were analyzed using various formulas.

Gea pasteurizer: Gea pasteurizer is widely appreciated all over the nation for its salient

features. The standard units are built to operate at heating temperatures range of 72–85°C. However, equipment to cope with higher pasteurization temperatures can be delivered on request. System heat recovery levels of > 90% for milk and milk-mix products, and >85% for cream, are guaranteed, offering capital and running cost benefits. For applications including consumer milk, milk-mix drinks, cream, yoghurt, cheese and sour milk products, ice cream mixes and whey products. Gea pasteurizer is mostly used for milk industry and liquid foods; this pasteurizer manufactured by company “Gea Eco Flex India Pvt. Ltd.” In this pasteurizer, plate heat exchange mechanism is used for exchange the heat one place to another. The system is compact, requires minimal space and is very easy to expand capacity by adding additional plates. It has adjustable temperature and pressure. The design temperature up to 110°C & pressure up to 5.00 bars. The capacity of the Gea pasteurizer has 20,000 lit/hr.

Parameters Analyzed:

1. Thermal energy: Thermal energy is energy possessed by an object or system due to the movement of particles within the system. It was calculated by following formula:

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

Where,

Q = Thermal energy (KJ)
 m = Quantity of milk (kg)
 Cp = Specific heat (KJ/kg K)
 ΔT = Temperature difference (°K)

2. Specific heat: specific heat of the milk samples were calculated by using formula as follow:

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

Where,

Cp = Specific heat (KJ/kg K)
 F = Fat (%)
 SNF = Solid not fat (%)

M = Moisture (water) (%)

3. Electricity: amount of electricity was calculated by using formula as follow:

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

Results and Discussion

Thermal properties of milk and energy consumption during pasteurization

November (2016): In November 2016, the Gea pasteurizer, pasteurized average highest quantity of milk 4001.83 kg/day in shift C followed by 3087 kg/day in shift A and lowest 1666.33 kg/day in shift B (Table1). Electricity consumption was depends upon quantity to be pasteurized. In November it was calculated highest in shift C (133.49 KW) followed by shift A (102.97 KW) and lowest in shift B (55.58 KW). Average specific heat used was calculated highest in shift C (3.18 KJ/kg K) followed by shift A (2.94 KJ/kg K) and lowest in shift B (1.96 KJ/kg K). Thermal energy consumption in milk pasteurization was highest in shift C (1108.58×10^3 KJ) followed by shift A (857.08×10^3 KJ) and lowest in shift B (462.51×10^3 KJ).

December 2016: In December 2016, the Gea pasteurizer pasteurized average highest milk 2059.51 kg/day in shift B followed by 1974.19 kg/day in shift A and lowest 954.03 kg/day in shift C (Table 2). Electricity consumption was depends upon quantity to be pasteurized. In December was calculated highest in shift B (68.70KW) followed by shift A (65.85 KW) and lowest in shift C (31.82 KW). Average Specific heat used was calculated highest in shift B (2.25 KJ/kg K) followed by shift A (2.25 KJ/kg K) and lowest in shift C (1.53 KJ/kg K). Thermal energy consumption in milk pasteurization highest average in shift B (569.68×10^3 KJ) followed by

shift A (465.07×10^3 KJ) and lowest in shift C (261.97×10^3 KJ).

January (2017): In January 2017, Gea pasteurizer pasteurized average highest milk 680.64 kg/day in shift B followed by 532.90 kg/day in shift C and lowest 281.93 kg/day in shift A (Table 3). Electricity consumption was calculated highest average in shift B (22.70KW) followed by shift C (17.78 KW) and lowest in shift A (9.40 KW). Average Specific heat used was calculated highest in shift B (0.83 KJ/kg K) followed by shift C (0.71 KJ/kg K) and lowest in shift A (0.71 KJ/kg K). Thermal energy consumption in milk pasteurization highest average in shift B (190.10×10^3 KJ) followed by shift C (148.48×10^3 KJ) and lowest in shift A (78.44×10^3 KJ).

Conclusion

All the parameters like, electricity, thermal energy and specific heat consumption are depend on the quantity of milk. If the milk quantity was increase than all parameters were increased or it was decrease then all the parameter were decreased. In November (2016) the milk quantity to be pasteurized was highest in shift C and lowest in shift A. In December (2016) the milk quantity to be pasteurized was highest in shift B and lowest in shift C. During January (2017) the milk quantity to be pasteurized was highest in shift B and lowest in shift A.

Table 1: Date and shift wise date distribution of Gea pasteurizer in November, 2016

Date	Shift A				Shift B				Shift C			
	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)
01-11-16	4620	154.11	3.75	1308.10	0	0	0	0	7740	258.20	3.75	2197.31
02-11-16	3600	120.09	3.80	1034.48	0	0	0	0	7740	258.19	3.80	2221.19
03-11-16	3600	120.09	3.70	1006.65	60	2	3.71	16.78	780	26.02	3.71	218.11
04-11-16	4620	154.11	3.69	1289.38	0	0	0	0	6400	213.49	3.69	1783.79
05-11-16	6400	213.49	3.71	1791.31	0	0	0	0	400	13.34	3.71	112.10
06-11-16	3600	120.09	3.67	998.50	0	0	0	0	0	0	0	0
07-11-16	0	0	0	0	1600	53.37	3.60	432.72	4620	154.12	3.59	1254.48
08-11-16	4620	154.11	3.70	1291.93	6400	213.49	3.71	1792.07	2300	76.72	3.70	644.02
09-11-16	0	0	0	0	0	0	0	0	6400	213.49	3.58	1734.01
10-11-16	7740	258.19	3.70	2161.72	0	0	0	0	4620	154.12	3.70	1292.04
11-11-16	7740	258.19	3.70	2159.81	60	2	3.70	16.68	2300	76.72	3.70	644.26
12-11-16	1600	53.37	3.70	447.26	2695	89.9	3.71	754.35	0	0	0	0
13-11-16	0	0	0	0	4620	154.11	3.68	1285.40	7740	258.19	3.68	2153.45
14-11-16	1600	53.37	3.70	447.45	0	0	0	0	3600	120.09	3.70	1006.77
15-11-16	3600	120.09	3.65	992.14	2300	76.72	3.66	636.39	10000	333.59	3.66	2759.61
16-11-16	6400	213.49	3.70	1786.85	780	26.02	3.71	218.06	7740	258.19	3.71	2160.97
17-11-16	4620	154.11	3.67	1279.42	0	0	0	0	3600	120.09	3.68	996.95
18-11-16	6400	213.49	3.56	1720.79	0	0	0	0	7740	258.20	3.56	2078.33
19-11-16	3600	120.09	3.59	974.83	0	0	0	0	2300	76.72	3.59	623.64
20-11-16	0	0	0	0	3600	120.09	3.69	1004.84	6400	213.4976	3.69	1781.65
21-11-16	3600	120.09	3.68	1001.04	1935	64.54	3.69	538.06	2300	76.72	3.69	638.71
22-11-16	3600	120.09	3.68	1001.70	6400	213.49	3.68	1773.72	1600	53.37	3.68	445.20
23-11-16	15	0.5	3.69	4.18	6400	213.49	3.69	1783.81	0	0	0	0
24-11-16	0	0	0	0	2300	76.72	3.69	640.33	6400	213.49	3.69	1781.79
25-11-16	1935	64.54	3.61	527.47	0	0	0	0	0	0	0	0
26-11-16	1600	53.37	3.68	445.47	1600	53.37	3.69	444.29	1935	64.55	3.68	538.02
27-11-16	1600	53.37	3.68	443.81	4620	154.12	3.68	1286.62	4620	154.11	3.68	1283.21
28-11-16	2300	76.72	3.60	624.48	0	0	0	0	780	26.02	3.608	211.78
29-11-16	3600	120.09	3.58	973.635	4620	154.12	3.59	1251.15	3600	120.09	3.58	971.05
30-11-16	0	0	0	0	0	0	0	0	6400	213.49	3.57	1724.94
average	3087	102.975	2.94	857.08	1666.3333	55.585	1.96	462.51	4001.8333	133.49	3.18	1108.58
Total	92610	3089.25		25712.49	49990	1667.55		13875.28	120055.00	4138.41		33257.42

Table 1: Date and shift wise date distribution of Gea pasteurizer in December, 2016

Date	Shift A				Shift B				Shift C			
	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)
01-12-16	60	2.00	3.55	16.12	780	26.02	3.55	209.01	6400	213.49	3.55	1714.93
02-12-16	0	0	0	0	3600	120.09	3.67	999.02	3600	120.09	3.67	993.74
03-12-16	7740	258.20	3.65	2126.987	1935	64.55	3.65	451.09	4620	154.12	3.65	1269.56
04-12-16	0	0	0	0	2300	76.72	3.70	644.44	3600	120.09	3.70	1004.70
05-12-16	0	0	0	0	7055	235.34	3.68	1967.41	0	0	0	0
06-12-16	1600	53.37	3.62	436.28	10000	333.59	3.62	2730.41	400	13.34	3.62	109.50
07-12-16	7740	258.20	3.70	2162.38	3600	120.09	3.70	1003.00	0	0	0	0
08-12-16	60	2.00	3.67	16.59	0	0	0	0	0	0	0	0
09-12-16	0	0	0	0	0	0	0	0	0	0	0	0
10-12-16	3600	120.09	3.71	100.82	4620	154.12	3.714	1295.63	0	0	0	0
11-12-16	780	26.02	3.70	217.70	1600	53.37	3.70	446.56	0	0	0	0
12-12-16	0	0	0	0	0	0	0	0	0	0	0	0
13-12-16	6400	213.49	3.71	1792.32	0	0	0	0	0	0	0	0
14-12-16	4620	154.12	3.62	1262.99	0	0	0	0	0	0	0	0
15-12-16	6400	213.49	3.72	180.08	0	0	0	0	0	0	0	0
16-12-16	6400	213.49	3.58	1726.54	1600	53.37	3.58	432.78	2300	76.73	3.58	621.30
17-12-16	7740	258.19	3.72	2166.13	0	0	0	0	0	0	0	0
18-12-16	0	0	0	0	4620	154.12	3.70	1291.21	780	26.02	3.70	218.28
19-12-16	0	0	0	0	7740	258.19	3.69	2161.99	60	2.00	3.69	16.71
20-12-16	400	13.34	3.67	110.50	780	26.02	3.66	215.76	2300	76.72	3.66	635.38
21-12-16	0	0	0	0	6400	213.49	3.72	1808.23	1600	53.37	3.72	449.07
22-12-16	1600	53.37	3.69	446.35	400	13.34	3.69	111.73	15	0.50	3.69	4.13
23-12-16	400	13.34	3.70	111.46	1015	33.86	3.70	283.97	0	0	0	0
24-12-16	60	2.001	3.67	16.60	4620	154.12	3.67	1281.90	0	0	0	0
25-12-16	400	13.34	3.71	111.98	780	26.02	3.71	218.07	0	0	0	0
26-12-16	1600	53.37	3.69	445.63	0	0	0	0	0	0	0	0
27-12-16	3600	120.09	3.57	969.77	400	13.34	3.57	107.89	1600	53.37	3.57	432.15
28-12-16	0	0	0	0	0	0	0	0	0	0	0	0
29-12-16	0	0	0	0	0	0	0	0	0	0	0	0
30-12-16	0	0	0	0	0	0	0	0	2300	76.72	3.75	651.73
31-12-16	0	0	0	0	0	0	0	0	0	0	0	0
Average	1974.19	65.86	2.245	465.07	2059.5161	68.70	2.25	569.68	954.03226	31.82	1.53	261.97
Total	61200.00	2041.57		14417.28	63845.00	21.29.80		17660.26	29575.00	986.59		8121.23

Table 1: Date and shift wise date distribution of Gea pasteurizer in January, 2017

Date	Shift A				Shift B				Shift C			
	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)	Quantity of milk (kg)	Electricity used in per day (KW)	Sp. heat (kJ/kg.K)	Thermal Energy $\times 10^3$ (KJ)
01-01-17	0	0	0	0	0	0	0	0	0	0	0	0
02-01-17	0	0	0	0	780	26.02	3.69	216.70	3600	120.09	3.69	1000.15
03-01-17	0	0	0	0	3600	120.09	3.731	1014.88	0	0	0	0
04-01-17	0	0	0	0	0	0	0	0	0	0	0	0
05-01-17	780	26.02	3.70	218.40	2300	76.73	3.71	645.73	0	0	0	0
06-01-17	0	0	0	0	0	0	0	0	0	0	0	0
07-01-17	0	0	0	0	0	0	0	0	0	0	0	0
08-01-17	0	0	0	0	0	0	0	0	0	0	0	0
09-01-17	0	0	0	0	0	0	0	0	400	13.34	3.71	112.19
10-01-17	2300	76.72	3.69	640.04	3600	120.09	3.69	1003.13	60	2.00	3.69	16.74
11-01-17	0	0	0	0	4600	153.45	3.69	1285.24	60	2.00	3.69	16.74
12-01-17	0	0	0	0	0	0	0	0	0	0	0	0
13-01-17	0	0	0	0	0	0	0	0	0	0	0	0
14-01-17	0	0	0	0	0	0	0	0	7800	260.20	3.67	2166.96
15-01-17	1600	53.37	3.68	445.58	0	0	0	0	0	0	0	0
16-01-17	0	0	0	0	0	0	0	0	0	0	0	0
17-01-17	0	0	0	0	0	0	0	0	0	0	0	0
18-01-17	0	0	0	0	0	0	0	0	0	0	0	0
19-01-17	0	0	0	0	1600	53.37	3.70	440.02	0	0	0	0
20-01-17	0	0	0	0	0	0	0	0	0	0	0	0
21-01-17	0	0	0	0	0	0	0	0	0	0	0	0
22-01-17	0	0	0	0	0	0	0	0	0	0	0	0
23-01-17	0	0	0	0	0	0	0	0	0	0	0	0
24-01-17	0	0	0	0	0	0	0	0	0	0	0	0
25-01-17	0	0	0	0	0	0	0	0	0	0	0	0
26-01-17	0	0	0	0	0	0	0	0	0	0	0	0
27-01-17	0	0	0	0	0	0	0	0	0	0	0	0
28-01-17	400	13.34	3.69	111.47	4620	154.12	3.69	1287.51	0	0	0	0
29-01-17	0	0	0	0	0	0	0	0	4600	153.45	3.72	1290.38
30-01-17	60	2.00	3.70	16.79	0	0	0	0	0	0	0	0
31-01-17	3600	120.09	3.67	999.45	0	0	0	0	0	0	0	0
Average	281.94	9.40	0.71	78.44	680.64	22.70	0.83	190.10	532.90	17.77	0.71	148.49
Total	8740.00	291.54	22.13	2431.73	21100.00	703.87	25.90	5893.21	16520.00	551.08	22.17	4603.16

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