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Study on thermal energy scenario for in selected dairy products

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ABSTRACT : A case study on the thermal energy analysis was performed for selected dairy products at commercial dairy plant. The purpose of the analysis was to determine the thermal energy usage in the processing line. This will ultimately leads to ensure efficient process with his her productivity and to improve productivity. Engineering services in dairy plants are considered as the area where simple plant optimization measures can lead to substantial and almost immediate savings. In general dairy plant is considered as the heat and mass transfer industry where thermal energy is the main energy utilized for dairy processing. In dairy processing plant, steam was utilized in liquid milk processing, cream pasteurization, cheddar cheese, mozzarella cheese, paneer, ice cream, basundi and ghee processes were found as 1.46, 3.00, 46.66, 87.21, 81.71, 8.83, 88.72, and 64.62 kg per 100 kg product, respectively and condensate losses were 7.25, 7.96, 6.97, 7.14, 7.25, 6.06, 9.52, and 6.88 per cent, respectively of the total heat per 100 kg product processing.

KEY WORDS : Thermal energy, Dairy processing, Consumption, Steam, Industry, Pressure, Temperature

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Energy is one of the essential requirements for the economic growth of developing countries. India has 8.6 per cent of the world coal reserves and is the fourth largest producer of coal and lignite meet nearly 50 per cent of commercial energy requirements in the country. Natural gas accounts for about 8.9 per cent of energy consumption in the country. The current demand for natural gas is about 96 million cubic metres per day (mcmd) as against availability of 67 mcmd (Desai and Zala, 2010). The major commercial energy consuming sectors in the country are classified into five major sectors namely agriculture, domestic, industry, transport and others. Among these the industry remains the biggest consumer with 49 per cent share in total commercial energy consumption, followed by transport 22 per cent , domestic 10 per cent, agriculture 5 per cent and other remaining 14 per cent (Anonymous, 2006 and Shashi *et al.*, 2007).

The price of fossil fuel is increasing steadily which in turn increases the processing cost and hence, the product cost. The 1976 energy crisis accelerated the research on energy conservation. According to California university task force Report (1974) about 18 per cent of the total energy is used by food production and remaining by food manufacturers, wholesalers, retailers, transporters and consumers. Direct energy is used by food processors and indirect energy is used by food producers, wholesalers, retailers, transporters and consumers.

The dairy industry uses considerable amounts of energy in the form of steam, hot air, electricity etc. in processing of milk and milk products. The cost of energy sources used in the industry is increasing continuously which in turn increase the processing expenses besides product cost. Energy costs constitute 30-35 per cent of overall manufacture cost. It is estimated that on an average 11 per cent of thermal energy and 7.5 per cent of the electrical energy can be conserved. (Mahalingaiah *et al.*, 2008).

A methodology has been proposed by Singh (1978) and instrumentation described by Knopf *et al.* (1978) to conduct energy audits in food plants such as dairy and meat processing. The procedure includes monitoring of energy consumption and mass flow of food materials during regular plant operation. The method was used to measure the ratio of energy to mass of product for fluid milk, cottage cheese and ice cream. The energy used for processing fluid milk, chocolate milk or ice cream was 165-209 kJ/kg product while cottage cheese used 2126 kJ/kg. Of this large amount for cottage cheese, 72 per cent is used for heat.

METHODOLOGY

The present study was carried out at thermal energy analysis was performed for selected dairy products at commercial dairy plant:

Regeneration efficiency of the milk PHE :

Milk was pasteurize in plate heat exchanger. The pasteurizer consists of 1st regeneration, 2nd regeneration, 3rd regeneration, final heating section, holding section; steam/hot water section and chilling section. First all the temperature measuring probes fixed at various section of pasteurizer were checked for their accuracy by comparing them with standard digital thermometer. Pressure gauge was fixed in steam line coming to pasteurizer. Regeneration efficiency was calculated by using the following formula :

$$\text{Regeneration efficiency (R.E.)} = \frac{t_{Reg} - t_R}{t_P - t_R} \times 100$$

t_{Reg} = Temperature of milk coming out of regeneration section and entering heating section (^{0}C)

t_R = Raw milk temperature (^{0}C)

t_P = Temperature of pasteurized milk (^{0}C).

Pasteurizer capacity was calculated by measuring the flow meter and also checks by measuring the change in milk level in silo per unit time. Pasteurizer capacity was found as 11000 l/h.

Steam consumption in dairy product :

Milk processing :

Condensate was collected at regular intervals in a insulated container whose volume was pre-determined. Time required to fill up the container was noted. Initial temperature and final temperature of condensate was noted. Then steam consumption per hour was calculated. Daily milk processed was noted by the flow meter and also checked by scale provided inside the silos.

Cream pasteurization :

Cream pasteurizer consists of 1st regeneration, 2nd regeneration, heating section, steam/hot water section and chilling section. Initial temperature and final temperature of cream was noted. Condensate was collected at regular intervals in a insulated container whose volume was pre-determined. Time required to fill up the container was noted. Initial temperature and final temperature of condensate was noted.

Cheddar cheese manufacturing :

Pasteurized chilled milk is transferred to cheese vat. Steam valve is opened to heat the milk. Vat has two agitators which are used for both stirring and cutting purposes. It has a butterfly type curd valve as an outlet. There are provisions in the vat for temperature display, for setting the cooking temperature, for setting RPM of agitator, display of the time elapsed since the starting of cheese making process. It has two spray balls provided for cleaning-in-place.

Steam is used only when during heating of the milk and cooking. Steam consumption is calculated separately for milk heating and cooking by collecting condensate.

Mozzarella cheese production :

Steam is used during milk heating, cheese cooking, preparation of hot water for stretching and preparation of pasteurized chilled water for cooling moulds. Steam consumption was calculated separately for preheating of milk, cooking of cheese, preparation of hot water for starching and preparation of pasteurized chilled water for cooling moulds by collecting condensate for each batch.

Paneer production :

Paneer milk heated in PHE. The pasteurizer consists of 1st regeneration, 2nd regeneration, final heating section and chilling section. The regeneration and chilling sections are not operated during this operation. Steam is used for heating of milk in plate heat exchanger and solution preparation. Steam consumption was calculated for milk heating in plate heat exchanger by collecting condensate for each batch.

Ice cream production :

Steam is used only when preparation of mix and pasteurization of ice cream mix. Steam consumption was calculated separately for preparation of mix and pasteurization of mix by collecting condensate for each stage.

Basundi production :

Steam is used during preparation of the basundi. Steam consumption was calculated from the bottom of the steam trap by collecting condensate for each batch.

Ghee production :

Condensate coming out from the ghee melting vat and ghee boiler was collected for entire batch during ghee preparation. Steam condensate temperature was noted at regular intervals.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Milk pasteurization :

Table 1shows the value of specific steam consumption and regeneration efficiency along with the steam pressure and pasteurization temperature. Steam consumption per hour was found as 156.59 kg. Pasteurizer capacity was 11,000 litres/ hour. Regeneration capacity of pasteurizer was calculated and average value was estimated as 89.85 per cent. The specific steam and fuel consumption per 100 kg of milk processed were 1.46 kg and 0.13 m^3, respectively. During the milk processing condensate and unaccountable losses were found as 7.25 per cent and 18.13 per cent, respectively. Thermal energy consumption per 100 kg of milk processing was found as 4066.05 kJ.

Cream pasteurization :

Table 2 shows the value of specific steam consumption with respect to initial and final temperature of cream and time duration required for cream pasteurization in H.T.S.T pasteurizer. The average steam consumption per 1000 kg (1 Batch) of cream was found as 30 kg. Specific steam consumption and fuel used per 100 kg cream pasteurization were found as 3.00 kg and 0.27 m^3, respectively. During the cream pasteurization condensate and unaccountable losses were 7.96 per cent and 6.11 per cent, respectively. Thermal energy consumption per 100 kg of cream pasteurization was found as 817.77 kJ.

Cheddar cheese :

Table 3 Shows value of total steam consumption and fuel consumption during cheddar cheese manufacturing. Overall steam consumption and fuel consumption per 100 kg cheddar cheese during pre heating and cooking were found as 46.66 kg and 4.23 m^3, respectively. During the cheese manufacturing, condensate and unaccountable losses were found as 6.97 per cent and 11.60 per cent, respectively. Thermal energy consumption per 100 kg of cheddar cheese was 126595.76 kJ.

Mozzarella cheese :

Table 4 Shows value of total steam consumption and

Table 1 : Performance study of milk pasteurization

Sr. No.	Steam pressure (kg/cm^2) Abs	T_R (°C)	T_P (°C)	T_{R3} (°C)	T_C (°C)	$T_{cond.}$ (°C)	Regeneration efficiency (%)	Specific steam consumption per 100 kg milk processed (kg)
1.	2.21	2.2	77	69	3.3	71	89.30	1.45
2.	2.31	2.8	78	70	3.5	73	89.36	1.48
3.	2.21	3.2	77.5	70	3.2	71	90.90	1.44
Avg.	2.24	2.73	77.5	69.66	3.33	71.66	89.85	1.46

Table 2: Performance data for pasteurization of cream (Batch size 1000 kg) (Steam pressure, 2.41 kg/cm^2, Abs)

Sr. No	Time for cream pasteurization (min)	Temperature of cream		Condensate temp. (°C)	Qty. of steam (kg)	Steam consumption/ 100kg cream (kg)
		Initial (°C)	Final (°C)			
1.	25	38	85	78	30	3.0
2.	30	39	83	76	28	2.5
3.	34	40	84	79	34	3.4
Avg.	29.66	39	84	77.66	30	3.0

Table 3 : Thermal energy and fuel consumption at various stages of cheddar cheese processing (Per 100 kg cheddar cheese base)

Stage	Steam			Fuel consumption (m^3)
	Pressure (kg/cm^2), Abs	Quantity (kg)	Thermal energy (kJ)	
Pre heating	2.31	36.57	99203.43	3.32
Cooking	2.41	10.09	27392.33	0.91
Total	–	46.66	126595.76	4.23

Table 4: Thermal energy and fuel consumption at various stages for mozzarella cheese processing (Per 100 kg of mozzarella cheese base)

Sr. No	Stage	Steam			Fuel consumption (m^3)
		Pressure (kg/cm^2), Abs	Quantity (kg)	Thermal energy (kJ)	
1.	Pre heating	2.11	37.14	100601.11	3.37
2.	Cooking	2.21	9.85	26700.3	0.89
3.	Hot water for stretching	2.21	26.68	72321.47	2.42
4.	Pasteurize water for mould dipping	2.11	13.54	36675.79	1.22
	Total		87.21	236298.67	7.91

fuel consumption during mozzarella cheese manufacturing. Overall specific steam and fuel consumption per 100 kg mozzarella cheese were found as 87.21 kg and 7.91 m^3, respectively. During the mozzarella cheese making condensate and unaccountable losses were found as 7.96 per cent and 6.11 per cent, respectively. Thermal energy consumption per 100 kg of mozzarella cheese was 236298.67 kJ.

Paneer :

Table 5 Shows value of the specific steam consumption with respect to initial and final temperature of milk and time duration required for preheating of milk during paneer manufacturing. The average steam consumption per 217.66 kg of paneer was found as 176.66 kg. Steam consumption per 100 kg paneer was 81.16 kg. During citric solution preparation, steam consumption per 100 kg paneer was 0.55 kg. Total Specific steam and fuel consumption per 100 kg paneer was found as 81.71 kg and 7.30 m^3, respectively. During the paneer manufacturing, condensate and unaccountable losses were found as 7.25 per cent and 5.35 per cent, respectively. Thermal energy consumption per 100 kg of paneer was 99704.12 kJ.

Ice cream :

Table 6. Shows value of thermal energy consumption and fuel consumption per 100 kg of ice cream mix preparation during the ice-cream manufacturing. Overall steam consumption and fuel per 100 kg of mix during mix preparation and pasteurization were found 8.83 kg and 0.80 m^3, respectively. During the ice cream manufacturing, condensate and unaccountable losses were found 6.06 and 6.63 per cent, respectively. Thermal energy consumption per 100 kg of ice cream mix pasteurization was 23937.99 kJ.

Basundi :

Table 7 Shows value of specific steam consumption during basundi manufacturing. The average steam consumption per 242.33 kg (1 Batch) of basundi was found as 215 kg. Specific steam and fuel consumption per 100 kg basundi were found as 88.72 kg and 8.05 m^3, respectively. During the basundi manufacturing, condensate and

Table 5: Performance data of paneer preparation

Sr. No.	Time for heating the milk	Quantity of milk (kg)	Temperature of milk		Condensate Temp (^{0}C)	Qty. of steam (kg)	Qty. of paneer (kg)	Steam consumption/100 kg paneer (kg)
			Initial (^{0}C)	Final (^{0}C)				
1.	1 hr 10 min	1500	6	82	73	175	216	81.01
2.	1 hr 20 min	1550	8.2	84	74	182	220	82.72
3.	1 hr 5 min	1425	7.5	82	72	173	217	79.72
Avg.	1 hr 12 min	1491.66	7.23	82.6	73	176.66	217.66	81.16

Table 6 : Thermal energy and fuel consumption at various stages of ice cream processing (Per 100 kg of ice cream mix)

Stage	Steam			Fuel consumption (m^3)
	Pressure (kg/cm^2), Abs	Quantity (kg)	Thermal energy (kJ)	
Mix preparation	2.21	7.58	20547.10	0.68
Mix pasteurization	2.31	1.25	3390.89	0.11
Total		8.83	23937.99	0.80

Table 7 : Performance data of basundi preparation

Sr. No.	Quantity of mix (kg)	Temperature of basundi		Condensate temp (^{0}C)	Qty. of steam (kg)	Qty. of basundi (kg)	Steam consumption/ 100 kg basundi (kg)
		Initial (^{0}C)	Final (^{0}C)				
1.	400	10	96	88	210	242	86.77
2.	425	8	95	86	230	245	93.87
3.	400	12	96	89	205	240	85.41
Avg.	408.33	10	95.6	87.66	215	242.33	88.72

Table 8 : Thermal energy and fuel consumption at various stages of ghee preparation (Per 100 kg of ghee)

Stage	Steam			Fuel consumption (m^3)
	Pressure (kg/cm^2), Abs	Quantity (kg)	Thermal energy (kJ)	
Butter melting	2.81	52.17	141985.87	4.73
Heating ghee	3.00	12.45	33922.51	1.13
Total		64.62	209792.30	5.86

unaccountable losses were found 7.25 per cent and 9.52 per cent, respectively. Thermal energy consumption per 100 kg of basundi was found 242287.51 kJ.

Ghee :

Table 8 Shows value of thermal energy consumption and fuel consumption with respect to two different stages via. butter melting and heating during the ghee manufacturing. The average steam consumption per 1200 kg butter and 100 kg ghee were found to be 512.66 kg. and 52.17 kg, respectively. Average steam consumption per 982.66 kg of ghee was found 122.33 kg during heating of ghee in ghee boiler. Specific steam and fuel consumption per 100 kg ghee were found as 64.62 kg and 5.86 m^3, respectively. During the ghee manufacturing, condensate, convection and radiation (C and R) and unaccountable losses were found as 6.88 per cent, 10.85 per cent and 6.11 per cent, respectively. Thermal energy consumption per 100 kg of ghee preparation was 209792.30 kJ (Abichandani and Sarma, 1978 and Abichandani *et al.*, 1978) .

Specific thermal energy consumption :

Fig. 1 shows value of the specific thermal energy consumption during manufacturing of various dairy product via pasteurized milk, pasteurized cream, cheddar cheese, mozzarella cheese, paneer, ice cream, basundi and ghee. Specific thermal energy consumption per 100kg product were found as 3957.62 kJ, 8144.4 kJ, 126595.76kJ, 236298.67kJ, 221327.87kJ, 23937.99kJ, 238541.6kJ and 209792.3 kJ for same above dairy products, respectively (Balasubramanian and Puri, 2009 and Biziak *et al.*, 1985) .

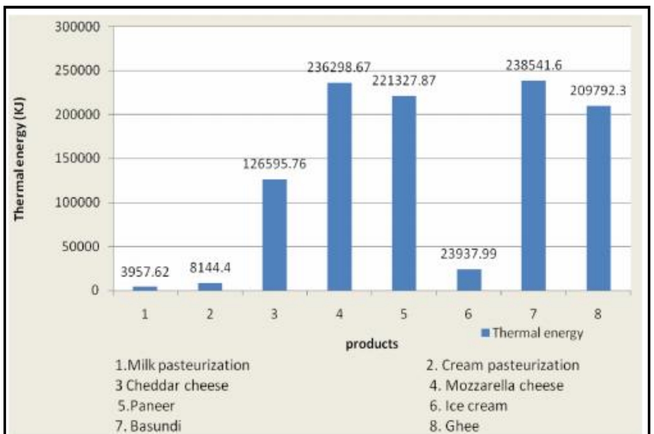

Fig. 1 : Thermal energy consumption per 100 kg product

Conclusion :

Total thermal energy used in the eight products was 1064284 kJ per 100 kg. Among these, Ghee, mozzarella and basundi were major contributors of total thermal energy as about 19.71, 22.20 and 22.41 per cent, respectively. 64.32 per cent. Here it is suggested that these three process are energy intensive. Hence, these processes are required to monitor for the energy conservation.

The overall condensate loss observed was 7.06 per cent of the total thermal energy input. It is suggested that the condensate recovery system should be planned to conserve the thermal energy and reuse it as the boiler feed water which will reduce the cost of water softening as well as will improve the boiler efficiency.

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