Development of Small Scale Paneer Manufacturing System, using Solar Energy Suitable for Milk Producers of Rural Area

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Abstract: ***Paneer is an important acid- coagulated indigenous milk product. Presently heat treatment is given by burning coal or furnace oil (for generation of steam/hot water) which ultimately increases CO_2 or methane component of atmosphere. Solar energy system is unlimited source of energy and it is free of cost because it is naturally occurred. We can use this energy for paneer manufacturing process. The objectives of the present investigation were to develop paneer manufacturing system, to prepare paneer using above system and to assess the sensory quality of paneer. The adopted method involved solar water heating system which was connected to surface heat exchanger, gave temperature of the water in the surface heat exchanger up to 80-85^{0}C. This hot water temperature is used for heating milk for paneer manufacturing. The experimental paneer was compared with control for their chemical, microbial and sensory characteristics. The experimental paneer had 51.73, 24.35, 48.27 and 0.49 per cent moisture, fat, total solid and acidity respectively and was comparable to control. The total and coliform counts were 7.1 x 10^3 and 77 cfu/g; 6.2 x 10^3 and 69 respectively for experimental and control paneer samples and was within the BIS microbial standards specified for paneer. The experimental paneer had significantly ($p<0.05$) higher body and texture (32.7 out of 35) scores, while flavour and colour and appearance scores were comparable to control. Solar water heating system assisted surface heat exchanger (an environmental friendly) system was effectively used to produce good quality paneer without using fossil fuel.***

Keywords: Solar water heater, solar energy, *paneer*, surface heat exchanger, non-renewable energy

1. Introduction

India is the largest milk producer in the world and the present production of milk is about [1]. In India, milk is mostly produced in rural areas. It is quite evident that if treated and processed properly, it can be a good source of income [2]. Traditionally, fossil fuels (coal, gas, diesel etc.) are utilized to generate heat to produce steam/hot water and are subsequently used as a heating medium. In contrast, solar energy is an unlimited, renewable, naturally available, environmental friendly, cost free energy source which could be utilized for various heating purposes.

In areas where sunlight is plenty, its use to pasteurize contaminated water and milk [3]. Solar energy is utilized for heating of milk and is confined to pasteurization of milk only. If solar energy is utilized for achieving higher temperature, it can be subsequently used for *paneer* making. Therefore, the investigation was carried out to develop *paneer* manufacturing system, to prepare *paneer* using above system and to assess the sensory quality of *paneer*.

2. Traditional Method of *Paneer* Production

Milk (preferably buffalo milk) is heated to 82°C for 5 min. and coagulated at 70°C [4] using citric acid. Whey is drained through muslin cloth and then the coagulant is filled and pressed in hoops to form block thus are dipped in chilled water for firming their body. The product obtained is *paneer*. Traditionally milk is heated with fossil fuels which ultimately increase environmental pollution as well as cost of production. Thus for reducing both, solar energy was used for heating of milk.

Table 1: Specifications of the surface heat exchanger

No.	*Components of the surface heat exchanger*		*Item/ Units*	*Dimensions*
1.	Heat exchanger	1.	Overall height	165 cm
		2.	Overall length	137 cm
		3.	Overall breadth	18 cm
2.	Tubes	1.	No. of tubes	36
		2.	Overall length	120 cm
		3.	Inner diameter	2.31 cm
		4.	Outer diameter	3.55 cm
		5.	Thickness of tube wall	0.62 cm
3.	Tray (for collecting heated milk)	1.	Length	115 cm
		2.	Breadth	35 cm
4.	Volume of the tubes	1.	Volume of single tube	144.84 cm^3
		2.	Total volume	5214.30 cm^3
5.	Surface area of the tube	1.	Surface area of single tube	467.23 cm^2
		2.	Total surface area	16820.35 cm^2

Solar water heating system works on the principle of "thermosiphon". In an entirely passive solar water heating system, water can move through the solar water heater only by natural convection – a movement produced only by the small difference of gravitational force acting on the density difference between warmer and cooler parts of the water.

The Fig. 1 (a) and (b) shows the line diagram of solar water heating system assisted surface heat exchnager and the view of solar water heating system. The Fig 2 shows the view of collection of hot milk from surface heat exchanger (SHE). SHE is a type of heat exchanger which is generally used for cooling of milk and milk products like ice cream mix etc. It is made up of stainless steel tubes. The solar water heating system was connected to SHE using an insulated pipe. The hot water was allowed to enter at the base and flow through the pipe, while the medium to be heated (milk) was admitted to flow from top to bottom.

Slight modification (standardization to fat: SNF ratio 1:1.65 and heating of milk to 80-82°C for 5 min.) was adopted for manufacture of control as well as experimental *paneer* [5]. Samples were analyzed for sensory qualities [6]. Statistical analysis of *paneer* samples were carried out using t-test.

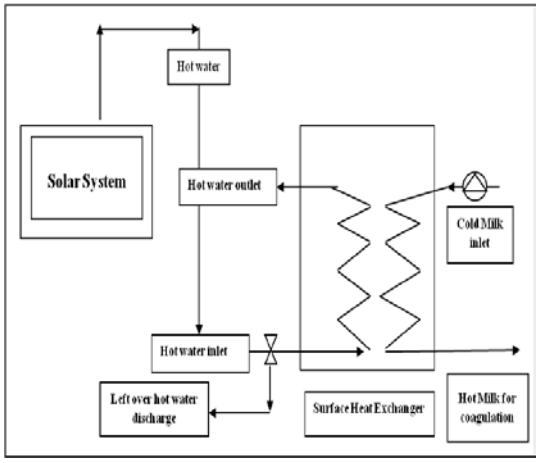

Figure 1: (a) Line diagram of solar water heating system assisted surface heat exchnager

Figure 1: (b) View of solar water heating system

Figure 2: View of collection of hot milk from surface heat exchanger

3. Effect of solar water heating system assisted surface heat exchanger on the quality of fresh paneer

3.1 Chemical quality of *paneer*

The effect of solar water heating system assisted surface heat exchanger on the chemical quality of fresh as well as control *paneer* is presented in Table 2.
The experimental *paneer* had 51.73, 24.35, 48.27 and 0.49 per cent moisture, fat, total solid and acidity respectively and was found statistically comparable with control. Thus it showed no influence of method of preparation on the chemical qualities [7], [8].

Table 2: Effect of solar water heating system assisted surface heat exchanger on the chemical quality of *paneer*

Parameters	*Experimental paneer (Mean± SD)*	*Control paneer (Mean± SD)*	*t-stat*	*t-test*
Moisture	51.73±0.08	51.81±0.096	1.89	NS
Fat	24.35±3.05	24.36±0.025	2.01	NS
Total solids	48.27±0.08	48.19±0.096	-1.90	NS
acidity	0.49±0.02	0.48±2.21	-0.34	NS
Yield	19.35±0.02	19.4±0.063	2.06	NS

NS = Non – significant

3.2 Microbial quality of *paneer*

The effect of solar water heating system assisted surface heat exchanger on the microbial quality of fresh as well as control *paneer* is shown in Table 3.

Table 3: Microbial quality of *paneer*

Parameters	*Cfu/g of paneer* *Experimental paneer (Mean± SD)*	*Control paneer (Mean± SD)*	*t stat*	*t- test*
Standard Plate Count	7.1 x 10^3 ±84.32	6.2 x10^3 ±732.86	-3.01	*
Coliform Count	77±4.71	69±3.27	-4.41	*

*= p≤0.05

The standard plate count and coliforms count were significantly (p≤0.05) influenced by the treatments, the experimental *paneer* had higher SPC and coliforms than control *paneer* sample. The more exposure of milk to atmospheric air as well as higher contact surfaces (coagulation in a separate vessel) might have contributed to higher SPC and coliform counts in the experimental *paneer* than the control. The SPC and coliforms counts of control and experimental *paneer* under the study were in agreement with the values reported by Vaishnavi *et al.* (2001) [9]. However the SPC and coliforms observed in experimental as well as in control *paneer* are within the BIS standards [10].

4. Sensory quality of *paneer*

The effect of solar water heating system assisted surface heat exchanger on the sensory quality of fresh as well as control *paneer* is given in Table 4. The treatment did not show any statistical difference on flavour and colour and appearance scores of *paneer* samples. However, the body and texture score was significantly (p≤0.05) influenced by treatment wherein the experimental *paneer* had the higher score of 32.7 indicating that better body and texture than control *paneer*. This might be due the fact that the milk formed a thin film during heating in solar water heating system assisted surface heat exchanger which ultimately received higher intensity of heat, thus leading to more denaturation of whey proteins and the complex with κ-casein. The extent of whey protein denaturation, influenced by various heat treatments [11]. They observed that increase in temperature has resulted more denaturation of whey protein and interaction with casein micelle.

Table 4: Sensory quality of *paneer* prepared by control and experimental methods

Parameters	*Experimental paneer (Mean± SD)*	*Control paneer (Mean± SD)*	*t stat*	*t-test*
Flavour	43.6±0.67	43.4±0.84	-0.58	NS
Body and Texture	32.7±1.06	31.4±0.52	-3.49	*
Colour and appearance	8.4±0.70	8.3±0.48	0.36	NS

*= p≤0.05; NS = Non- significant

5. Conclusions

It can be concluded that, solar water heating system assisted surface heat exchanger (an environmental friendly) system could be effectively used to produce good quality *paneer*. Hence, this can be utilized at the commercial level for reducing processing cost.

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Author Profile

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