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Physico-Chemical and Microbial Analysis of Solar Processed Milk

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A B S T R A C T

This paper investigates physico - chemical and microbial analysis of solar powered milk processor which involves application of solar energy in pasteurisation of milk in batch processor. Photovoltaic (PV) cells were used to convert solar energy in to electrical energy through photoelectric effect. The batch processor was designed for 40 Litres capacity using Auto Cad Inventor software and developed using SS 304 material with water level indicator and temperature control circuit. Suitable trials were conducted to validate the developed equipment by conducting physico - chemical and microbial analysis for the processed milk samples. Comparative studies were made between conventional processing and solar processing of milk. The shelf life of the solar processed milk was compared with the conventional pasteurised milk. It was observed that there was no significant difference ($p>0.05$) difference in shelf life between the control samples and solar processed milk samples. The standard plate count in solar processed milk samples was observed to be (4.00±0.00) for all treatments and was found to be within limits. No coliforms were present in all the processed samples.

Introduction

The milk and its products are fundamental food in human nutrition. It can be used as an important part of diet throughout the lifetime. The milk is a perishable foodstuff because it is an excellent medium for the growth of microorganisms which cause spoilage. Heating milk to a specific temperature for a specific period, leads to destruction of harmful microorganisms. This is achieved by pasteurization which requires large amount of thermal and electrical energy involving high operational cost. Solar energy is the renewable source of energy, and it is freely available. Utilisation of solar energy is growing and studies have shown that solar energy can supply about 1,000 times more energy than the world's demand. However, only 0.02% of its full potential is currently being used (Manton *et al.*, 2015).

All the solar systems use solar panels, solar inverter and a switch board. Solar panels are made up of silicon cells or photovoltaic (PV) cells which generate direct current (DC) electricity from sunlight. The individual PV cells are linked together within the solar panel and connected to adjacent panels using cables. The most common form of solar energy is PV

cells where sunlight is converted into electricity using PV cells to separate electrons from their atoms and increasing their speed through a conductor (Manton *et al.*, 2015). This can be achieved by installing grid connected solar on the roof – top.

As one kilowatt ON - grid solar panel with inverter generates 4 – 5 units of electricity per day, a well-designed solar system could quite easily meet the requirements of processing milk in a batch mode which is the simplest and oldest method for pasteurising milk. Hence this work is envisaged to pasteurise milk in batch processor using solar energy and to analyse the physico - chemical and microbial analysis of the solar processed milk.

Materials and Methods

The study was carried out at College of Food and Dairy Technology (CFDT), Koduvalli, and the following materials were used and methods were adopted for the study. Raw milk samples were collected from different places around Alamathy village, Chennai. Sterile glass bottles 200ml capacity was used to pack and store the processed milk. The media, broth, reagents and chemicals for bacteriological work were obtained from M/s. Hi Media Laboratories Pvt. Ltd., Mumbai, India. Pasteurization of milk samples were done with the following treatments for heating and cooling process.

Heating process

Milk was heated with four treatments. In treatment 1 the milk was heated without agitation and without regenerative action. In treatment 2 the milk was heated with agitation and without regenerative action. In treatment 3 the milk was heated without agitation and with regenerative action. In treatment 4 the milk was heated with agitation and with regenerative action.

Cooling process

The hot milk at 63ºC for 30 minutes was cooled by six treatments. In Treatment 1 the temperature of milk was brought to ambient/room temperature by circulating normal water without agitation of the milk. In Treatment 2 the temperature of milk was brought to ambient/room temperature by circulating normal water with agitation of the milk. In Treatment 3 the temperature of milk was brought to ambient/room temperature by circulating chill water without agitation of the milk. In Treatment 4 the temperature of milk was brought to ambient/room temperature by circulating chill water with agitation of the milk. In Treatment 5 the temperature of milk was brought to ambient/room temperature by circulating brine water without agitation of the milk. In Treatment 6 the temperature of milk was brought to ambient/room temperature by circulating brine water with agitation of the milk. The processed samples in all the above treatments were collected in sterile glass bottles and stored in 5 ºC. To optimise the treatments (T_1 to T_6) the processed samples were subjected to shelf life studies.

Clot on boiling test used as platform test was conducted daily in triplicate to check the quality of the milk.

Clot on boiling

Five milliliters of sample was taken in a test tube and placed in boiling water bath for five minutes. Appearance of flakes/clots on the walls of the test tube indicated positive for the test (FSSR, 2011).

Determination of pH

pH was determined with a digital pH meter at room temperature. The pH meter was standardized using pH buffer of 4.0, 7.0 and 9.2 (FSSR, 2011).

Determination of total titratable acidity

Titratable acidity (as % lactic acid) of pasteurized milk samples were estimated as per IS: 1166 – 1973 Specification for milk, Bureau of Indian Standards (BIS), New Delhi. 10 ml of Pasteurized milk sample was taken in a beaker and water (10ml) was added into it. The content was mixed well followed by addition of few drops (2-3) of phenolphthalein indicator. The sample was titrated against 0.1N NaOH till the appearance of light pink tinge, which persisted for 30 seconds in the solution. The titratable acidity was calculated by the following formula and was expressed as percent lactic acid.

$$\text{Titratable Acidity (\% Lactic acid)} = \frac{9 \times A \times V}{W}$$

Where,

V = Volume of 0.1 N NaOH required for titration,

A = Normality of NaOH solution,

W = Weight of sample taken for the titration (g)

Enumeration of standard plate count

Standard plate count was assessed daily in triplicates for the processed and control samples for period of ten days. The samples were analysed for standard plate count following by the method described by American Public Health Association (APHA, 1998).

Enumeration of coliform

Coliform was assessed daily in triplicates for the processed and control samples for period of ten days. The samples were analysed for coliform following the method described by American Public Health Association (APHA, 1998).

Statistical Analysis

One-way analysis of variance (ANOVA) was carried out to find the optimum treatment combination for time and temperature, energy consumed and shelf life for the solar powered processed milk.

Results and Discussion

Table 1 shows the shelf life of control and solar processed milk (SPM) samples stored at 5ºC. Mean values of 6.83±0.17, 6.83±0.17, 6.83±0.17, 6.83±0.17, 6.83±0.17, 6.83±0.17 were obtained respectively for various treatments T_1-T_6 in control milk samples. Mean values of 7.00±0.00, 7.00±0.00, 7.17±0.17, 8.67±0.17, 7.33±0.21, 8.33±0.21 were obtained respectively for various treatments T_1-T_6 in solar processed milk samples. It was observed that there was no significant difference ($p<0.05$) between the control and SPM samples in all treatments. It was also observed that there was significant difference ($p>0.01$) in shelf life between treatments in both control and SPM samples.

As the control sample was pasteurised milk, the shelf life of the control sample was 7 days and the mean values represented in table 1 had no significant difference ($p>0.05$) for all treatments. It was also observed that there was significant difference ($p<0.01$) between treatments. Duncan's analysis revealed that treatments t4 and t6 significantly differed ($p<0.01$) from other treatments as it formed different subsets. It was also observed that there was no significant difference ($p>0.05$) between control samples and solar processed milk samples for treatments t1, t2, t4 and t5 which had the same shelf life as control samples. However a significant difference was observed between control and solar processed

samples for treatments t4 and t6, as regenerative action was incorporated for heating process and chill water and brine was used for cooling process. Moreover the milk was agitated both during the heating and cooling period to ensure uniform distribution of temperature to the milk particles Modi and Prajapat (2014).

Determination of pH of solar processed milk

Table 2 shows the values of pH in control and solar processed milk samples during the storage period at 5^{o}C. It was found that there was significant difference ($p<0.01$) during the storage period as decreasing trend in pH values were noticed in control and in all treatments t1 – t6. It was observed that there was no significant difference ($p>0.05$) between the control and solar processed milk during the 0th day of storage. This might be because of the fact that in solar processing the temperature of the milk was increased to 63^{o}C and maintained at the same temperature for 30 minutes as in conventional processing. But a significant difference was observed during the subsequent days till 8th day of storage between control and solar processed samples. The control sample and solar processed milk samples in treatments t1, t2, t3, t5 offered a sour flavour during the 7th day and spoiled during the 8th day of storage. The solar processed samples in treatments t4 and t6 had a shelf life of 8 days and spoiled during the 9th day of storage. This coincides with the findings of Bandler and Barnard, (1984) who stated that a drop in pH below 6.4 in milk is subjected to increase in acidity causing sour flavour and results in spoilage of milk.

Determination of total titratable acidity of solar processed milk

Table 3 shows the total titratable acidity values for control and solar processed milk samples. A significant difference ($p<0.01$) in mean values were observed for control and solar processed milk samples during the storage period at 5 ^{o}C. During the 0th day of storage it was found that there was no significant difference ($p>0.05$) between the control and solar processed milk. But a significant difference in mean values of acidity was observed between control and various treatments (t1 – t6) during the storage period. This might be due to various methods used in cooling the milk to reduce the temperature to ambient temperature. However, the control sample and solar processed milk samples in treatments t1, t2, t3, t5 developed a sour flavour with acidity during 7th day of storage and spoiled during the 8th day of storage period at 5^{o}C. But solar processed milk samples in treatments t4 and t6 spoiled during the 9th day of storage. This might be due to chill water and brine used for treatments t4 and t6 which took lesser time to bring the temperature to ambient temperature along with regenerative action. This correlates with findings of Saxena and Rai, (2013) who found that an average acidity of pasteurised milk ranged from 0.179 to 0.2 during six days of storage.

Enumeration of standard plate count (log_{10}cfu/ml) in solar processed milk

Table 4 shows the standard plate count values in log_{10}cfu/ml in control and solar processed milk samples. It was observed that there was a significant difference ($p<0.01$) in standard plate count (SPC) values for both control and solar processed milk samples during the storage period. During the 0th day of storage, it was found that the mean values were same (4.00±0.00) for control and various treatment t1 – t6. This correlates with the findings of Monika *et al.,* (2013) who found that the total viable bacterial count for pasteurised milk smaples ranged between 3.43+ 0.17 and 4.82+0.05 log_{10}cfu/ml.

Table.1 Clot on boiling test in days for control and SPM milk

TREATMENT	CONTROL	SPM	T
T1	6.83±0.17	7.00^{A}±0.00	6.250^{NS}
T2	6.83±0.17	7.00^{A}±0.00	6.250^{NS}
T3	6.83±0.17	7.17^{A}±0.17	1.607^{NS}
T4	6.83±0.17	8.67^{B}±0.17	1.607**
T5	6.83±0.17	7.33^{A}±0.21	1.607^{NS}
T6	6.83±0.17	8.33^{B}±0.21	1.607**
F	NS	17.125**	

Different superscripts in a row (small letters) and column (capital letters) differ significantly
** Highly significant (p<0.01)
NS – Non-significant (p>0.05)
SPM – Solar processed milk
T_1 – Normal Water without Agitation
T_2 - Normal Water with Agitation
T_3- Chill Water without Agitation
T_4 - Chill Water with Agitation
T_5 – Brine Water without Agitation
T_6 - Brine Water with Agitation

Table.2 pH in control and solar processed milk stored at 5°C (Mean±SE)[@]

DAYS	C	T1	T2	T3	T4	T5	T6	F Value
0th day	6.62^{I}±0.01	6.63^{I}±0.01	6.63^{I}±0.00	6.6^{4I}±0.01	6.65^{J}±0.01	6.63^{I}±0.00	6.64^{J}±0.00	2.646^{NS}
1st day	6.58^{aH}±0.01	6.59^{aH}±0.01	6.58^{aH}±0.00	6.59^{abH}±0.01	6.61^{cI}±0.00	6.59^{abH}±0.00	6.60^{bcI}±0.00	4.903**
2nd day	6.54^{aG}±0.01	6.54^{abG}±0.01	6.56^{cG}±0.00	6.57^{cdG}±0.01	6.59^{eH}±0.00	6.55^{bcG}±0.00	6.58^{deH}±0.00	14.772**
3rd day	6.50^{aF}±0.01	6.50^{aF}±0.00	6.53^{bcF}±0.00	6.53^{cF}±0.01	6.56^{dG}±0.00	6.52^{bF}±0.00	6.56^{dG}±0.00	30.459**
4th day	6.46^{aE}±0.01	6.47^{aE}±0.00	6.50^{bE}±0.00	6.51^{bE}±0.00	6.54^{cF}±0.00	6.49^{bE}±0.00	6.53^{cF}±0.00	40.637**
5th day	6.42^{aD}±0.00	6.43^{aD}±0.00	6.47^{bD}±0.00	6.46^{bD}±0.00	6.52^{cE}±0.00	6.46^{bD}±0.00	6.51^{cE}±0.00	93.895**
6th day	6.39^{aC}±0.01	6.40^{aC}±0.00	6.43^{bC}±0.00	6.43^{bC}±0.00	6.49^{cD}±0.01	6.43^{bC}±0.00	6.49^{cD}±0.00	61.432**
7th day	6.36^{aB}±0.00	6.36^{aB}±0.00	6.40^{bB}±0.00	6.40^{bB}±0.00	6.46^{cC}±0.01	6.41^{bB}±0.00	6.45^{cC}±0.01	113.916**
8th day	6.31^{aA}±0.01	6.31^{aA}±0.00	6.35^{bA}±0.00	6.35^{bA}±0.00	6.43^{dB}±0.00	6.35^{bA}±0.00	6.41^{cB}±0.00	149.572**
9th day	-	-	-	-	6.34^{A}±0.00	-	6.34^{A}±0.00	0.172^{NS}
10th day	-	-	-	-	-	-	-	-
F Value	259.429**	418.050**	780.227**	365.135**	391.888**	701.237**	486.902**	

@ average of six trials
Different superscripts in a row (small letters) and column (capital letters) differ significantly
** Highly significant (p<0.01)
NS – Non-significant (p>0.05)
C – Control
T1 - Normal Water without Agitation
T2 - Normal Water with Agitation
T3 - Chill Water without Agitation
T4 - Chill Water with Agitation
T5 - Brine Water without Agitation
T6 - Brine Water with Agitation

Table.3 Total titratable acidity in control and solar processed milk stored at 5°C (Mean±SE)[@]

DAYS	C	T1	T2	T3	T4	T5	T6	F VALUE
0th day	0.120^{A}±0.002	0.122^{A}±0.002	0.120^{A}±0.002	0.120^{A}±0.002	0.117^{A}±0.000	0.120^{A}±0.002	0.117^{A}±0.000	1.098^{NS}
1st day	0.128^{bcB}±0.002	0.129^{cB}±0.002	0.123^{bA}±0.002	0.125^{bcAB}±0.002	0.117^{aA}±0.000	0.125^{bcA}±0.002	0.119^{aA}±0.002	8.333**
2nd day	0.137^{eC}±0.002	0.135^{deC}±0.000	0.131^{bcdB}±0.002	0.129^{bcB}±0.002	0.122^{aAB}±0.002	0.134^{cdeB}±0.002	0.126^{bB}±0.000	12.130**
3rd day	0.146^{dD}±0.002	0.144^{cdD}±0.000	0.132^{abB}±0.002	0.138^{bcC}±0.002	0.126^{aBC}±0.004	0.140^{cdC}±0.002	0.128^{aB}±0.002	13.099**
4th day	0.161^{dE}±0.002	0.159^{dE}±0.002	0.144^{cC}±0.000	0.144^{cD}±0.000	0.131^{aC}±0.002	0.144^{cC}±0.000	0.137^{bC}±0.002	69.136**
5th day	0.173^{dF}±0.002	0.168^{dF}±0.002	0.158^{cD}±0.002	0.155^{cE}±0.002	0.137^{aD}±0.002	0.156^{cD}±0.002	0.144^{bD}±0.000	60.395**
6th day	0.174^{cF}±0.003	0.173^{cF}±0.002	0.167^{bE}±0.002	0.167^{bbF}±0.002	0.144^{aE}±0.000	0.165^{bE}±0.002	0.144^{aD}±0.000	48.366**
7th day	0.182^{eG}±0.002	0.183^{eG}±0.002	0.180^{deF}±0.000	0.176^{cdG}±0.002	0.158^{aF}±0.002	0.174^{cF}±0.002	0.167^{bE}±0.003	21.778**
8th day	0.192^{dH}±0.002	0.192^{dH}±0.002	0.186^{cdG}±0.002	0.185^{cH}±0.002	0.170^{aG}±0.002	0.185^{cG}±0.002	0.176^{bF}±0.003	15.920**
9th day	-	-	-	-	0.185^{H}±0.000	-	0.186^{G}±0.002	10.000*
10th day	-	-	-	-	-	-	-	-
F	195.360**	229.375**	206.843**	175.574**	151.910**	163.014**	201.103**	

@ average of six trials
Different superscripts in a row (small letters) and column (capital letters) differ significantly
** Highly significant (p<0.01)
NS – Non-significant (p>0.05)
C – Control
T1 - Normal Water without Agitation
T2 - Normal Water with Agitation
T3 - Chill Water without Agitation
T4 - Chill Water with Agitation
T5 - Brine Water without Agitation
T6 - Brine Water with Agitation

Table.4 Standard plate count (log_{10}cfu/ml) in control and solar processed milk samples stored at 5°C (Mean±SE)[@]

DAYS	C	T1	T2	T3	T4	T5	T6	F VALUE
0th day	4.00^{A}±0.00	4.00^{A}±0.00	4.00^{A}±0.00	4.00^{A}±0.00	4.00^{aA}±0.00	4.00^{A}±0.00	4.00^{aA}±0.00	-
1st day	4.00^{A}±0.00	4.00^{A}±0.00	4.00^{A}±0.00	4.00^{A}±0.00	4.00^{aA}±0.00	4.00^{A}±0.00	4.00^{aA}±0.00	-
2nd day	4.30^{B}±0.00	4.30^{B}±0.00	4.30^{B}±0.00	4.30^{B}±0.00	4.00^{aA}±0.00	4.30^{B}±0.00	4.00^{aA}±0.00	299.630**
3rd day	4.47^{cC}±0.00	4.47^{cC}±0.00	4.33^{bB}±0.03	4.30^{bB}±0.00	4.00^{aA}±0.00	4.30^{bB}±0.00	4.00^{aA}±0.00	20.618**
4th day	4.75^{cD}±0.05	4.63^{bcD}±0.07	4.54^{bC}±0.06	4.48^{bC}±0.00	4.15^{aB}±0.07	4.48^{bC}±0.00	4.10^{aA}±0.06	30.545**
5th day	4.88^{cE}±0.01	5.87^{cE}±0.00	4.73^{bcD}±0.06	4.77^{bcD}±0.05	4.28^{aC}±0.06	4.68^{bD}±0.05	4.20^{aB}±0.06	92.134**
6th day	5.01^{cF}±0.01	5.00^{cF}±0.00	4.90^{bE}±0.04	4.88^{bE}±0.03	4.48^{aD}±0.00	4.85^{bE}±0.04	4.48^{aC}±0.00	97.436**
7th day	5.06^{bG}±0.01	5.05^{FG}±0.01	5.03^{bF}±0.01	5.01^{bF}±0.01	4.68^{aE}±0.03	5.01^{bF}±0.01	4.68^{aD}±0.03	21.343**
8th day	5.12^{bH}±0.01	5.10^{bG}±0.01	5.09^{bF}±0.01	5.09^{bG}±0.01	4.89^{aF}±0.04	5.10^{bG}±0.01	4.87^{aE}±0.05	0.294^{NS}
9th day	-	-	-	-	5.01^{G}±0.01	-	5.02^{F}±0.01	-
10th day	-	-	-	-	-	-	-	-
F	598.230**	401.982**	159.866**	385.546**	79.241**	359.512**	79.008**	

@ average of six trials
Different superscripts in a row (small letters) and column (capital letters) differ significantly
** Highly significant (p<0.01)
NS – Non-significant (p>0.05)
C – Control
T1 - Normal Water without Agitation
T2 - Normal Water with Agitation
T3 - Chill Water without Agitation
T4 - Chill Water with Agitation
T5 - Brine Water without Agitation
T6 - Brine Water with Agitation

This might be due to heating the milk to 63^{o}C and holding it at the same temperature for 30 minutes in solar processing similar to conventional pasteurisation.

The mean values show an increasing trend during the storage period in control and various treatments.

However, the during the 8th day of storage,

The mean values of control and various treatments are in the range of 5.09±0.01 to 5.12±0.01 except treatments t4 and t6 which had 4.89±0.04 and 4.87±0.05 respectively.

The control samples and various treatments t1, t2, t3, t5 developed a sour flavour during the 7th day of storage and spoiled during the 8th day of storage.

But the solar processed sample in treatments t4 and t6 spoiled during the 9th day of storage.

This is in accordance with Monika *et al.*, (2013) who also stated that initial average total viable count increased from 3.43±0.17 log_{10}cfu/ml to 4.82±0.05 log_{10}cfu/ml after six days of storage.

It was also observed that the coliforms were absent in all control and solar processed milk samples in all treatments.

This is in accordance with Wayua *et al.*, (2012) who observed that the coliform counts were negative in all milk samples processes in a solar batch processor.

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References

American public health association (APHA), American water works association and water environment federation 1998. Standard methods for the examination of water and waste water, 20th ed. L.S, Clesceri, A.E, Greenberg, A.D. Eaton (eds). Washington DC.

Bandler, D. K., and Barnard, S. E. (1984). *Milk Flavor and Qualityfrom Cow to Consumer*. Cornell University.

FSSR 2011. Food safety and standard regulations. Gazetted notification.

Manton, A. 2015. Solar Energy: A Renewable Resource with Global Importance. *ESSAI*, 13(1): 26.

Modi and Prajapat, R. (2014). Pasteurization process energy optimization for a milk dairy plant by energy audit approach. *International Journal of Scientific and Technology Research*, *3*(6), 181-188.

Monika, S., and Poonam, R. (2013). Microbiological and Chemical Analysis of Raw, Pasteurized and UHT Milk during Preservation In India. *International Journal of Chemical Technology Resources*, *5*(6), 2804-2809.

Saxena, M., and Rai, P. (2013). Microbiological and chemical analysis of raw, pasteurized and UHT milk during preservation in India. *International Journal of Chem Tech Research*, *5*(6), 2804-2809.

Wayua, F. O., Okoth, M. W., and Wangoh, J. (2012). Design and performance assessment of a flat- plate solar milk pasteurizer for arid pastoral areas of Kenya. *Journal of Food Processing and Preservation*, *37*(2), 120-125.

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