Milk preservation using pulsed electric field – an alternate to pasteurisation

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MILK PRESERVATION USING PULSED ELECTRIC FIELD – AN ALTERNATE TO PASTEURISATION

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Abstract:

Raw milk is not commercially available. Pasteurisation of raw milk not only kills harmful bacteria but also kills the beneficial bacteria. Several of milk’s natural components including beneficial bacteria, food enzymes, natural vitamins and immunoglobulin are heat sensitive. These health – promoting components of natural raw milk are destroyed by heating and therefore not present in pasteurised milk. All health – promoting components in milk are retained when it is processed in pulsed electric field where there is no generation of heat. Voltage pulses of 35KV/cm, 400 square pulses of 2.5 microseconds pulse width were applied to the raw milk filled in a parallel plate pulsed electric field processing chamber. Physico chemical parameters (pH, acidity, TSS), microbiological parameters (SPC, coliform), were studied before and after processing. Sensory attributes and shelf life studies were conducted after treatment. It was found that there was no change in physico chemical parameters before and after treatment. It was found that the SPC count was less than 15000 cfu/mL and no coliforms were found. The shelf life of milk at 4°C could be extended to 28 days.

Key words: Raw milk, PEF treatment, Pulses, Shelf life.

1. Introduction:

Currently, raw milk is not commercially available and cannot be used for controlled intervention studies because of the potential presence of pathogenic microorganisms. Alternative milk-processing technologies are needed to preserve immune active milk proteins that can improve immunity in children [10, 13]. The various forms of electrical pasteurisation method include ohmic heating, microwave heating, low electric field stimulation, high – voltage arc discharge, low voltage alternating current and high intensity PEF [3, 8]. All the above except PEF involve passage of electrical current which intends to heat food [11]. In PEF technology, electrical energy is applied in the form of short pulses, which destroys the bacterial cell membrane with no significant heating of food. The goal of this work was to investigate the effectiveness of electrical (square) pulses of 35KV magnitude, pulse width of 2.5 micro seconds on microbial inactivation for a variety of raw milk samples collected from 6 different villages in and around Koduvalli village near Redhills, Chennai. The raw milk is processed through the developed lab scale PEF processing parallel plate batch treatment chamber.

2. Material and methods:

2.1 PEF treatment system

The experiment setup of PEF system is shown in the figure below.
Figure (1) shows a High Voltage DC (HVDC) power supply rated for 35KV. Figure (2) shows a pulse forming network (PFN) which consists of 10 stages of Inductance and Capacitance which produces a square shaped waveform. The values of capacitance $C_1$ to $C_{10}$ are 1nF/150KV and Inductors $L_1$ to $L_{10}$ are 2.5µH/150KV. Energy stored is given by the formula $E = \frac{1}{2}CV^2 \times 10^n$, where $n$ is the number of stages in a PFN system[15]. PFN ensures a smooth square waveform.

Figure (3) shows the block diagram of the lab model PEF system which was used to pasteurise the raw milk. The system consists of an inbuilt trigger generator and a timer. The timer is set initially before the HVDC supply is turned on. The system is designed in such a way that after application of the set pulses, the HVDC supply automatically turns off after set time is completed. The spark gap is adjusted to ensure application of pulses at a voltage magnitude of 35KV/cm to the electrodes which are embedded in the processing chamber [9]. The distance between the electrodes are adjustable which enables application of different voltage gradients to the raw milk at different treatments [2].

2.2 Procurement and treatment of raw milk samples
Fresh raw milk was procured from 6 nearby villages in and around Alamathy, Thiruvallur district, Chennai. The samples were collected in sterile containers. The PEF processing chamber
was washed and rinsed in distilled water and kept in autoclave for 1 hour. The raw milk samples were pumped in to the chamber kept in a sterile room. The distance between the electrodes is set to 1cm. The timer and number of pulses are set before HVDC supply is turned on. 400 pulses of 2.5 microseconds pulse width were set and HVDC supply is turned ON. Gradually the voltage is increased to 35KV/cm. At this point the spark gap is fired by pulses which can be noticed in the sparkgap window. The frequency of pulses is varied using a frequency modulator. The experiments were conducted in triplicate by varying the distance between electrodes, varying number of pulses and pulse rate. The characteristics of electric pulses delivered such as shape, polarity, width, difference of potential were monitored using a digital storage oscilloscope (Tektronix TDS 2022B, two channel 200 MHz).

2.3 Collection of treated samples:
The processed samples were collected in sterile containers and stored in 5°C cold room. Figure (4) shows the raw milk collected from the farm. Figure (5) shows the PEF processed milk in sterile containers.

2.4 Sensory, chemical and microbial analysis

2.4.1 Sensory analysis
Sensory quality was determined using 9 point Hedonic scale rating. For sensory, colour, flavour/odour, taste evaluation and overall acceptability, 10 untrained panellists were selected. The 100ml samples of all the processed foods were presented to the panellists. The panellists rated the preferred samples in comparison with control.

2.4.2 Chemical analysis
**pH:** The pH was determined with a pH paper. It was also determined with a Digital pH meter at 23°C. The pH meter was standardised using pH buffer of 4.0, 7.0 and 9.2.
**Total Soluble solids:** The total soluble solids (°Brix) were measured using a hand refractometer. The refractometer prism was cleaned with distilled water after each analysis.

2.4.3 Microbial analysis
Microbial analysis was carried out after processing. For the microbial counts, samples were serially diluted, plated in Mueller Hinton agar for total plate counts and MacConky for *E coli*. Plates were incubated at 30°C for 48hrs for Total Plate Counts.
2.5 Statistical analysis
Data were analysed by Mann – Whitney U test. It is a non parametric test that is used to compare two population means that come from the same population. It is used for equal sample sizes, and is used to test the median of two population.

Calculation:

\[
U = \frac{n_1n_2}{2} + \left[\frac{n_2(n_2 + 1)}{2}\right] - \sum_{i=n_1+1}^{n_2} R_i
\]

\(U = \) Mann – whitney U test
\(n_1 = \) sample size one
\(n_2 = \) sample size two
\(R_i = \) Rank of the sample size

3. Results and discussions:
3.1 Statistical analysis for sensory evaluation
The sensory attributes (colour, odour and Overall acceptability) revealed that there is no significant difference between the PEF processed milk and unprocessed milk sample [1,6].

<table>
<thead>
<tr>
<th>Properties</th>
<th>200 pulses</th>
<th>400 pulses</th>
<th>Comparison between 200 pulses and 400 pulses of 2.5 µs PW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td>Control</td>
<td>Processed</td>
<td>Processed</td>
</tr>
<tr>
<td>Colour</td>
<td>8.17±0.408</td>
<td>8.17±0.408 (U = 18)</td>
<td>8.17±0.408 (U = 18)</td>
</tr>
<tr>
<td>Odour</td>
<td>8.5±0.55</td>
<td>8.5±0.55 (U = 18)</td>
<td>8.67±0.52 (U = 18)</td>
</tr>
<tr>
<td>OAA</td>
<td>8.5±0.55</td>
<td>8.5±0.55 (U = 18)</td>
<td>8.67±0.52 (U = 18)</td>
</tr>
</tbody>
</table>

Table (1)

The U – value is 18. the critical value of U at p ≤ 0.05 is 5. This indicates that there was no significant difference in sensory attributes between control and processed samples.

3.2 Microbial analysis
Shelf life of PEF processed milk was determined based on the microbiological quality of food. The processed samples were tested periodically for their microbiological quality and physical and chemical changes. It was found that standard plate count was less than 15,000 cfu/ml till 28 days and E.coli was found nill [4, 5, 14]. Table (2) shows the percentage reduction in total microbial load for control and immediately after processing.
Results are expressed as mean (±SE) in triplicates (cfu/mL)

3.2.1 Parameters comparison between control and processed samples collected from six different places in and around Alamathy

<table>
<thead>
<tr>
<th>Type</th>
<th>Log\text{\textsubscript{10}} cfu/ml</th>
<th>Percent Reduction A-B X 100 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (A)</td>
<td>11±0.24</td>
<td>-</td>
</tr>
<tr>
<td>100 (B)</td>
<td>7.60±0.17</td>
<td>30.9%</td>
</tr>
<tr>
<td>300 (B)</td>
<td>3±0.04</td>
<td>72.7%</td>
</tr>
<tr>
<td>400 (B)</td>
<td>-</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table (2)

3.3 Chemical analysis
pH meter and pH paper were used to measure pH and hand refractometer was used to measure Total soluble solids in all the liquid foods.

<table>
<thead>
<tr>
<th>Food Product</th>
<th>pH Before</th>
<th>pH After</th>
<th>TSS Before</th>
<th>TSS After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>6.8</td>
<td>6.8</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

Table (3) shows pH and TSS before and after PEF processing. It was observed pH and TSS remain unchanged [3].

4. Conclusion:
Trials on raw milk samples collected from six different villages in and around Alamathy village were conducted with the designed PEF system. Sensory, Chemical and microbial analysis were made. It was found that there was no significant difference in sensory attributes between
processed and unprocessed raw milk. Microbial analysis revealed that there was 9 log reduction (approx) in microbial load after processing (PEF Treatment) It was also found that there is no change in pH and TSS before and after processing. Temperature was also recorded using analog thermometer. It was also found that there was no increase in temperature even after the application of 400 pulses of 2.5 µsec duration [12].

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6. References:


