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The Application and Effect of Pulsed Electrical Fields in Milk Pasteurization

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ABSTRACT

Today, with the increasing demand for products with minimum loss of nutrients and flavors, the use of non-thermal processes has been considerably addressed in food processing technologies. Pasteurization by heating is one of the most common methods for increasing milk shelf life. But it is obvious that milk is sensitive to heating and its nutrients and sensory properties are affected by temperature variations. On the other hand, serious needs for environmentally friendly technologies promoted alternative methods for heating processes in the maintenance and preservation of milk: one of the most innovative and latest technologies in processing heat-sensitive products, especially milk, is application of pulsed electrical fields (PEF). This process is carried out at low temperature and minimal thermal damage may occur in milk and its sensory properties while its nutritional quality is maintained. Moreover, the destruction of harmful micro-organisms and undesirable enzymes increases the shelf life of milk.
KEYWORDS: non-thermal processes, pulsed electrical fields, milk shelf life

1. INTRODUCTION

Milk is one of the most important and a complete and nutritional source in natural foods. It is used as a source of calcium with different types of dairy products. However, given the structure of this product, it provides a suitable environment for a wide range of micro-organisms such a Coliforms, Psychotropics and Endo spores which cause rapid corruption of milk and can be harmful to human health (Ribeiro et al., 2011). Therefore, immediately after milking until the time of use, it is necessary to perform suitable actions for preventing rapid corruption. Thermal processing of pasteurization and sterilization has long been used as a business process to reduce the microbial load and increase the shelf life of milk. This process in addition to removing micro-organisms enhances the maintenance of milk for three weeks at refrigerator temperature; however, this process reduces the nutritional value and sensory properties of milk (Sepulveda et al., 2009). Nowadays, the increasing consumer demands for products with higher nutritional value and sensory properties have directed food industry towards processes with minimum nutritional values. One of these processes is pulsed electric fields (PEF) (Ribeiro et al., 2011). PEF process is one of the non-thermal pasteurization methods for foods and in recent years, they have developed to reach sufficient microbial load while maintaining the quality of the food (Lebovka et al, 2004). Today, PEFprocess is normally used for liquids and beverages pasteurization and preserves the quality and freshness of beverages such as fruit juices (Sale & Hamilton, 1967). In this process, electrical fields with short pulses and a time scale between microseconds and millisecond are applied in the processing chamber between electrodes. At normal temperature, this process is performed in less than one second resulting in minimizing the amount of nutrients loss (Huang & Wang, 2009).

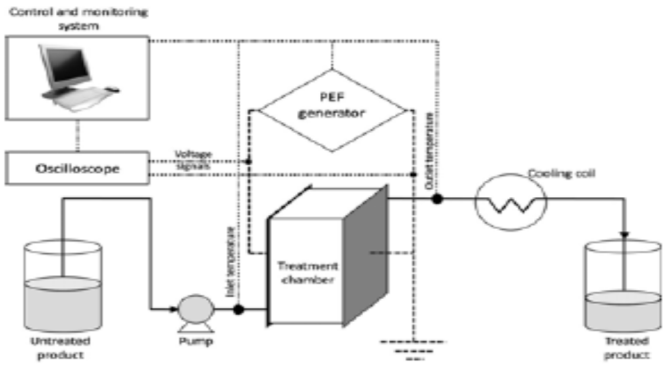

Figure 1- PEF process schema for products that can be pumped

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This method is based on applying electric energy using electrical fields and creating pores in cell membranes that is called electroporation. This electroporation can be reversible or irreversible (Barbosa-Cánovas et al., 1999). Reversible processes are applied in cell stimulation, gene transfer and increasing metabolic activity of cells and irreversible pores are used in three major categories of food processing: 1- Removal of micro-organisms implementing pasteurization processes and sterilization without applying temperature, 2- In extracting processes of intracellular components of plants and animals, and 3- Dehydration and drying food water (De Vitoet al., 2008). Additionally, this process contains germicidal effects. Bactericidal effect of electric current was examined by a group of scientists in the late 19th century. One of the first attempts to use electricity formilk pasteurization was conducted using 220v (AC) electricity (non-pulsed) (Toepfl et al., 2008).

In this study, the researcher investigated the effect of this process on shelf life and microbial load of milk. Milk transport to distant places is one of the problems of dairy industry. The problem of milk transportation in long routes is that raw milk cannot be stored for a long time; moreover, milk contamination after pasteurization can reduce its shelf life. Raw milk cannot be stored more than 7 hours; as a result, one of the operations that are used for transporting milk to distant areas is the application of a pre-process of heating and pasteurization after transportation. In fact, milk is heated in bulk and is pasteurized by retails. This method of preservation, in addition to increasing production costs can influence nutrients and the sensory properties of milk and may decrease their quality. Sepulveda et al. (2009) conducted a study on milk. In their research, pasteurized milk with HTST (high temperature short time) method was processed with 5 pluses in PEF process and a plus intensity of 36 kw/cm and the time for each pulse was equal to 3/2 µs at 65C° and the processing duration of less than 10 seconds. This process was done in two periods, one immediately after pasteurization and the other 8 days after pasteurization. They concluded that using PEF process immediately after pasteurization increased milk shelf life for 60 days while using PEF after 8 days of heating treatment improved the shelf life of milk up to 78 days. In this process, all Psychotropic and Entro bacteria were removed and the number of thermophilic bacteria reduced greatly. The most important remaining bacteria were Bacillus spp which can start the germination process after a definite time(Sepulveda et al., 2009).

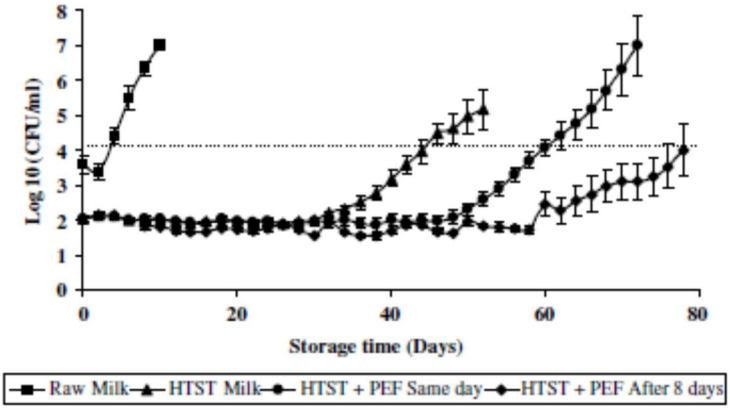

Figure 2- Mesophill bacteria population in maintained milk at 4C° after 80 days(Sepulveda et al., 2009)

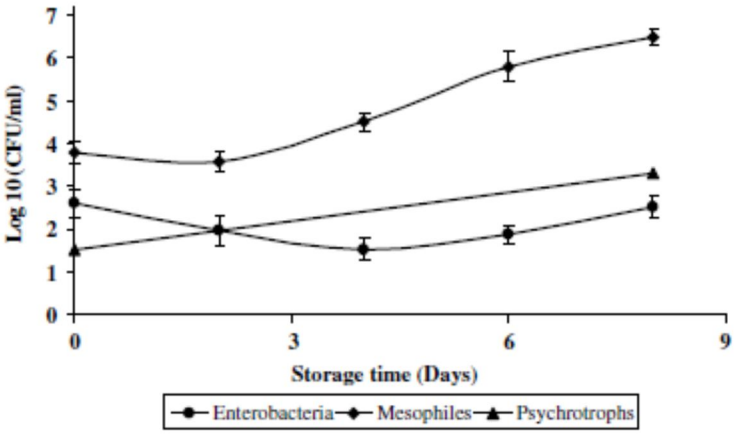

Figure 3- Microbial flora in raw milk stored at 4C° during 8 days of preservation(Sepulveda et al., 2009)

1-Effecting Milk Micro-organisms

Normally, due to the accumulation of opposite charges on both sides of the membrane about10mv electrical potential difference was generated. In this case, the membrane was exposed to electrical field and the equilibrium potential of dielectric on both sides will impair and the membrane can endure this change to some extent but if it passed from a point (more than 1V), it may cause a permanent destruction of membrane. Therefore, PEF process can impair the material transfer system in the membrane by creating pores in membranes of vegetative cells and bacterial Endospores and eventually remove micro-organisms (Soliva-Fortuny et al., 2009).

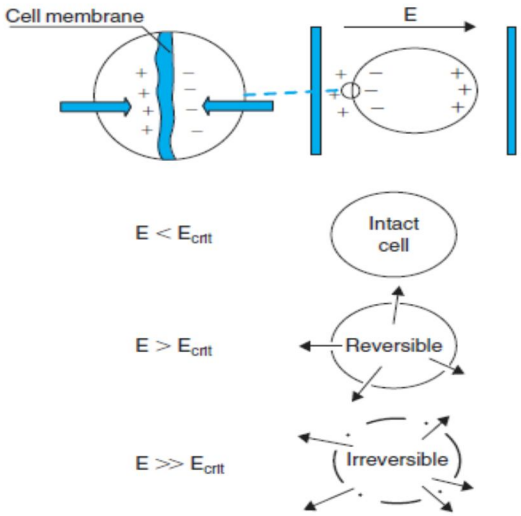

Figure 4- The effect of pulsed electrical field intensity on micro-organisms membrane in PEF process

In addition, Craven et al. (2008) used a combination of PEF process in milk and a mild thermal processing (55C° and less than 10 seconds) and examined the value of Pseudomonas which is one of the chemical corruptive factors in milk. The findings of the study indicated that the highest inactivation value was achieved when PEF process was performed with 31 kw/cm intensity (4.139 Kj/L) (105 CFU/mL) and milk shelf life increased up to 11 to 13 days (depending on the initial inoculum of Pseudomonas that were 103 and 105 CFU/mL, respectively) (Craven et al., 2008).

PEF process can be applied similar to Hurdle process. Rebeiro et al. (2011) compared the two processes and declared that PEF process with 42 Kw/Cm, 612 µs, 815 Kj/L energy and micro-filtration with a flow of 660 L/hm^2 and the pasteurization process at 75C° and 24 s resulted in highest drop regarding the number of micro-organisms for thermal and membrane processing (4.6 and 3.7 log 10 CFU/mL 10) and the lowest drop for PEF process (2.5 CFU/mL 10). However, micro-filtration and PEF were used similar to Hurdle (1.710 CFU/mL). Moreover, germicidal value increased greatly when PEF process was use firstly and micro-filtration was performed later. They stated that when PEF process is applied initially and higher temperature is generated (Sampedro et al., 2005).

3. Influence on Milk Shelf Life

15 to 22 days shelf life was achieved for raw pasteurized milk by 30 pulses withan electric field intensity of 30-50 Kv/cm at 70-80C°. In another investigation skim milk was exposed to 30 pulses for 2 microseconds and electric field intensity of 30-50 Kv/cm and its shelf life was reported as 2 weeks at 4C° temperature. Moreover, when the same process was performed with the temperature (73 or 80C° for seconds), the observed shelf life was 22 days at 4C°. When PEF process was performed on pasteurized milk, the shelf life of 2-3 weeks increased to 60-78 days. More shelf life for milk can be created by pulsed electric fields with a more gentle thermal process. Additionally, this technology can improve shelf life and reduce the number of yeasts and molds in flavored milk and yogurt without causing sensory variations (Sampedro, et al., 2005; Sepulveda et al., 2009;Ribeiro et al., 2011).

4. Influence on Sensory and Nutritional Quality of milk

Milk vitamins such as Thiamine (B_1), Riboflavin (B_{12}), Cholecalciferol (D_3) and Tocopherol (E) remain unchanged after PEF process and only the amount of ascorbic acid would be slightly affected. In addition to vitamins, other chemical aspects of milk that were not affected by electric field intensity of milk of 20-8 Kv/cm are pH, acidity, fat and protein uniformity, calcium distribution, color, moisture and particle size. The research findings

indicated no sensory or physicochemical change by applying 6-7 pulses for 2 microseconds and electric field intensity of 40 Kv/cm for milk with 2% fat. And, shelf life reached to 2 weeks at 4C° compared to thermal processes(Bendicho et al., 2002; Fernandez et al., 2005; Sepulveda et al., 2009).

5. A Comparison of Milk Pasteurization with Pulsed Electric Fields and Thermal Pasteurization

Quality and immunity of milk are influenced and reduced by microbial activities, chemical reactions, and enzymes that are destroyed. Micro-organisms leading to spoilage and natural enzymes can be inactivated by thermal processes such as pasteurization; however, temperature can alter the flavor of milk and reduce the nutrients. In addition, it is followed by undesirable reactions such as browning in milk and its products, leading to undesirable pollutants which can cause the unfavorable enzymes to be inactivated and the micro-organisms (especially vegetative cells) to be removed; in this regard, the chemical PEF is carciogenic. In conclusion this process maintained the flavor and nutritional value of milk and led to less denaturation of milk proteins compared to the thermal processing(Hilton et al., 2007; Sale & Hamilton, 1967; Ribeiro, 2011).

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