PULSE ELECTRIC FIELD APPLICATION FOR INACTIVATION OF MICROORGANISMS IN LIQUID FOODS: A REVIEW

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Abstract

The world's perishable and imperishable food production is rising as a result of agricultural technological advancements, but the production is greatly influenced by the cyclical nature of the world's seasons. As a result, civilised society has adopted food processing and preservation techniques to preserve such seasonal food and supply consumers all year long. Although thermal preservation techniques have been around for a while, they significantly modify the food being preserved, especially its flavour. Demand for alternative food processing processes is rising internationally due to healthy eating trends and desires for high-quality foods. The growing demand for high-quality, fresh-like food items has led to research on non-thermal food processing techniques. An novel method for improving food quality that replaces traditional thermal methods is called pulsed electric field (PEF). PEF technology benefits include shorter processing times, lower process temperatures, and environmental friendliness. The PEF procedure works by exposing a food product to a pulsed electric field in a treatment zone. PEF causes a trans-membrane potential to be produced between cell membranes, which results in cell death when a microbe is exposed to it. The effectiveness of the PEF therapy may be determined using both biological and electrical data, such as cell size and structure, such as voltage amplitude, pulse width, and frequency. Since the PEF technology's parameters are interdependent, it is possible to study the impact of each parameter alone as well as in conjunction with the others. If the electrical energy transmitted to the food product is increased, the bacteria may be greatly inactivated newline.

Keywords: PEF, Inactivation, Microorganisms, Shelf life, Perishable.

Introduction

Commercially, liquid food is preserved using a quick, high-temperature method (HTST). Although the heat treatment lengthens the shelf life of liquid food, it also alters the flavour, chemical makeup, and nutritional quality. As a result, non-thermal food processing technology is needed, and among all other non-thermal food processing methods, the PEF method emerges as a potential technique. PEF treatment is a desirable technology that has recently received attention due to research into how it affects cell membranes in the biotechnology and food industries (Haberl et al. 2013; Kotnik et al. 2015; Puertolas 2012).

The first researchers to explain how bacteria are inactivated by PEF were Sale & Hamilton in 1967. They provided results that encouraged researchers to further their PEF technology research. Following that, numerous news about the deactivation of microorganisms using the PEF method were published. The varying outcomes of PEF study

by different researchers may be explained by a number of related aspects. While comparing the contrast results obtained by various research teams is very challenging, it is possible by taking into account generic parameters like the efficiency determinant factors in the PEF treatment. The PEF technique is now at the research stage alone due to technological restrictions. Unreliable industrial equipment is in fact a significant factor in the system's inability to be upgraded (Toepfl, 2012). Poor operating procedures, treatment condition control, and monitoring are the other important factors. Therefore, more information is needed for the commercial applications of PEF technology in order to improve the treatment's reproducibility.

Major factors affecting PEF affecting PEF treatment efficiency

Several variables affect how well the bacterium is inactivated. The elements may be categorised into three groups: PEF processing factors, biological elements, and treatment medium characteristics. In addition to the aforementioned variables, the efficiency is also impacted by the PEF equipment used for the procedure. The following are brief explanations of the parameters that are used to calculate PEF efficiency.

PEF Processing Parameters

The electrical pulse amplitude, electric field strength, treatment duration, pulse width, number of pulses, pulse frequency, and pulse type energy, and pulse incidence are typical process variables that affect PEF therapy effectiveness.

Intensity of the electric field

Field strength created in the food therapy room is determined by the electric field intensity. It is reliant on on the applied voltage in the conduct chamber's space between the electrodes geometry, the size, shape, and distribution of the liquid food's dielectric characteristics between the electrodes.

For parallel plate electrode arrangement the uniform electric field, with the exception of its minor electrode edge effects inside the treatment chamber (Donsi et al. 2007). However, a non-homogeneous electric field is experienced in various chamber arrangements, such as co-linear electrode configuration.

To inactivate the bacteria, the intensity of the electric field typically must be between 4 and 14 kV/cm (Castro et al. 1993). Though, certain literature have shown that using electric fields up to 100 kV/cm on food for a continuous treatment procedure is feasible (Smith et al. 2002).

Treatment time

Time of treatment, that is figured out by multiplying the pulses given to the food product by the width of pulse, is the length of time that microorganisms are efficiently treated. Increasing quantity of pulses or the pulse breadth often raises the inactivation level. The pulse shape affects the pulse width. Exponential or square wave pulses with either unipolar or bipolar polarities are the most often employed pulse types in PEF therapy (Barbosa et al. 1999; Sale & Hamilton 1967; Aronsson et al. 2001b).

Pulse width

The length of time the voltage is maintained at its greatest level is known as the pulse width. Due to the low impedance of the food, when pulses of highest voltage are given to the product, voltage and current waveforms are changed, necessitating constant monitoring during the treatment. Width of pulse is define as the amount of time required to drop the voltage to 37% of its maximum in the event that pulses or pulse distortions occur during therapy. For the pasteurisation of food, a pulse width between microseconds and milliseconds is often used. Nevertheless, just a few studies have shown the inactivation impact of nanosecond pulses (Schoenbach et al. 1997). 2.2.1.4 pulsation rate

Applied pulses quantity per unit of time is referred to as pulse frequency. The quantity of electrical energy provided to the food product within the chamber of treatment per unit of time is determined by pulse frequency, which is why it is crucial. Additionally, the PEF approach has recently discovered the pulse frequency as a crucial element in food technology.

Energy density

Energy density is the amount of electrical energy that a food product receives per each pulse. Energy multiplication density divided by the total number of pulses applied will provide the total intake of precise energy. According to a few studies, the electrical energy density is an appropriate metric for comparing the data that the researchers collected under various PEF treatment circumstances (Heinz et al. 2002).

Temperature

Despite the fact that it degrades food quality, temperature is a significant component that affects the pace at which microorganisms are inactivated. The temperature is elevated dramatically as a outcome of the strength of the electric field, pulse frequency, and pulse breadth. To reduce the associated heating impact, a research is needed before these parameters may be optimised. In the event of batch treatment, the temperature must be measured both before and after the PEF treatment. If the action is continuous, the temperatures at the input and output should be recorded.

Biological Factors

When placed under the same PEF treatment settings, various microorganism kinds exhibit varying degrees of inactivation. This may be as a result of their various sizes and forms (Sale & Hamilton 1967, 1968; Lado & Youcef 2003). According to reportsthe essential electric field has to be inactivate the microorganism relies on the size and orientation of the cells in relation to the strength of the electric field (Heinz et al. 2002).

The structure of the cell outer sheath is crucial in the therapy of PEF because the cell outer sheath shields the cell against PEF due to its resistive nature. Gram-positive microbes are more resilient to the PEF because their walls are thicker and more robust than Gram-negative germs. The administration of PEF causes the cell membrane to break, which causes the cell to bleed its tiny chemicals outside and become inactive. The culture of the microorganisms should be consistent since the preparation of the microbe might considerably alter its susceptibility to PEF.

PEF is more likely to affect microorganisms in their exponential development phase than in their stationary phase (Alvarez et al. 2002; Rodrigo et al. 2003). The efficiency of the PEF action is also impacted by the amount of bacteria on the food to be treated (Barbosa et al. 1999). For the same electric field intensity, Jayaram et al. (1992) gave an explanation for why trans-membrane potential is larger across cell clusters than it is across individual cells.

Characteristics of the Treatment Medium

The medium of analysis chemical and physical characteristics have an impact on how well the microorganism grows. For each food processing method, the treatment medium must be carefully determined since the food processing procedures also have a significant influence on it.

among the most crucial elements in the PEF food treating process is the medium's conductivity. Typically, it depends on the medium's temperature (Reitler et al. 1990). The trans-membrane potential is raised by the presence of ions (Bruhn et al. 1997). Low conductivity food, as compared to high conductivity medium (food), rises the alteration between the cell's conductivity and medium. As a result, when the voltage is applied, the stress on the cell membrane rises, enhancing electroporation. However, when the conductivity rises due to the process temperature, so does the amount of electrical energy needed to inactivate the cells. Intensity of the electric field, temperature, and medium conductivity therefore have a dynamic connection. According to reports, increasing the inactivation level of the microbe is more challenging when it's suspended in a complicated food substance like milk than it is when it's in a buffer solution or a simple food substance (Ho et al. 1995; Dutreux et al. 2000).

In relation to recent research, the pH level also influences how sensitive an organism is to certain therapies. The cell membrane is put under extra stress by the acidic and alkaline pH values, which raises the inactivation level. Similar to this, when using the PEF technique, a drop in the food's water activity similarly decreases the microorganism's degree of inactivation (Aronsson & Ronner 2001a).

PEF Equipment and Treatment Chamber

PEF generators come in a variety of varieties, and they have been around for a while. A source of high voltage, a power reserve component, a pulse converter, and a treatment chamber make up the fundamental PEF generator. Food processing methods include batch processing and continuous systems. The batch system is appropriate for investigations at the laboratory size, while the continuous system is appropriate for operations at the industrial scale.

Two electrodes that surround the meal make up the therapy chamber. The electrodes might be set up as co-linear or parallel plates. The design of a parallel plate layout is the simplest and results in an evenly distributed a magnetic field inside the treatment area. Because of the broad electrode surface, it has low inherent resistance and runs at a high current, which causes unwanted electrochemical phenomena at the electrode borders. The co-linear arrangement creates a non-uniform electric field over the treatment zone using tubular electrodes. Because of the small effective area, it delivers a high inherent resistance and runs at a lower current. Therefore, to achieve equal electric field distribution, a well built chamber is necessary.

Inactivation of microorganisms in juices by PEF process

PEF application is regarded as a promising non-thermal food processing equipment for fruit juice pasteurisation. PEF technology has been particularly successful among liquid goods utilised the most for the treatment of apple juice, orange juice, milk, liquid eggs, and brine solutions. According to the investigations done thus far, a number of pathogenic microorganisms have sufficient levels of inactivation. According to studies, PEF has little impact on the nutritive value and worth of juices (Giner et al. 2001; Ayhan 2001). The strength of the electric field that is being used, rather than the byproducts of electrolysis or the temperature alone, is likely to be the basis of the inactivation of vegetative bacteria and yeasts by PEF (Evrendilek & Zhang 2003; Heinz et al. 2003). In addition, juices treated with PEF showed less colour change than untreated juices. In

Microbes' inactivation and the lengthening of the post life of treated orange juice have both been the subject of numerous studies. Sale & Hamilton's (1967; 1968) findings demonstrate 2 log10 reductions at 19.5 kV/cm for 20 s with a 10 C temperature increase. By applying 30 and 50 kV/cm for 12 s at 55 C in orange juice, McDonald et al. (2000) reported the effect of PEF to inactivate Leuconostoc mesenteroides (L. mesenteroides) and achieved 4.75 and 6.2 log10 reductions, respectively. E. coli O157:H7 suspended in orange juice was inactivated by PEF, as shown by Gurtler et al. (2010), who reported 1, 2.4, and 3.4 log10 reductions for 75 s at 13.1, 19.7, and 23.7 kV/cm at 55 C, respectively.

Heinz et al. looked into the outcome of temperature on the inactivation of E. coli in apple juice for the temperature sort of 35 to 70 C. (2003). In this study, when the temperature was raised from 40 to 50 C, a maximum of 7 log10 reductions of E. coli were accomplished at 24 kV/cm. It was made very clear that a rise in temperature resulted in a reduction in the amount of energy needed to produce the same log10 reductions in E. coli in apple juice. Saldana et al. (2011) also discussed the impact of temperature increase on the improvement of the inactivation level and found that raising the starting temperature to 20, 30, and 40 C, respectively, resulted in reductions of 0.5, 1.5, and 2.8 log10 of E. coli suspended in apple juice. When the input temperature was adjusted at 0, 50, and 55 C, respectively, Fleischman et al. (2004) found that the inactivation rate of Listeria monocytogenes (L. monocytogenes) inoculated in skim milk rose to 0.3, 1.5, and 4.5 log10 decreases. Salmonella typhimurium (S.typhimurium) was similarly inactivated at rates of 1.5, 2.9, 4, and 5 log10 decreases at temperatures of 15, 27, 38, and 50 C, respectively, at 30 kV/cm (Saldana et al. 2010). Therefore, raising the treatment temperature while increasing the electric field intensity may boost the PEF processing efficiency (Aronsson & Ronner 2001a, Lindgren et al. 2002). When the temperature was below 43 °C, PEF treatment of E. coli and Bacillus subtilis (B. subtilis) produced 2 log10 reductions by applying 15 to 30 pulses sequentially, and 5 log10 reductions were obtained after the temperature was raised to 53–55 °C under the same PEF circumstances (Vega et al. 1997).

Salmonella enteritidis (S. enteritidis) was more effectively inactivated by Korolczuk et al. (2006) when they increased the pulse width from 0.05 to 3 s at 50 kV/cm, 15 C. However, he found no appreciable rise in the inactivation of S.enteritidis. For the pulse breadths of 1, 2, and 5 s that were applied at 25 kV/cm, Abram et al. (2003) studied the effect of pulse width on inactivation of Lactobacillus plantarum (L. plantarum) and demonstrated the effective inactivation of the L. plantarum. On the other hand, during PEF treating at 40 kV/cm, extending the pulse width from 2.5 to 4 s did not increase the inactivation of L.

plantarum in an orange beverage (Sampedro et al. 2007). These conflicting findings might be the result of employing several PEF systems or pulses under various operating circumstances.

More research relating the efficiency of various pulse waveforms have shown that square wave and exponential decay pulses are most proficient in inactivating microorganisms. However, square wave pulses store more energy, which means fewer cooling power is needed (Gongora-Nieto et al. 2002; DeHaan & Willcock 2002; Kotnik et al. 2003). Instead, Qin et al. (2015) evaluated the inactivation of S. cerevisiae using square, oscillating, and non-oscillating exponential impulse waveforms with 67 and 80 kV/cm, and they found that the latter performed better with a maximum of 3 log10 decreases. Additionally, it was claimed that monopolar pulses were less effective in inhibiting microbes than bipolar pulses (Qin et al. 1994; Ho et al. 1995; Elez-Martinez et al. 2004, 2005).

Pathogenic strains are known to commonly be present in unpasteurized orange juices and can cause severe foodborne disease. By using an electric field power of 29 kV/cm for 172 s at 25 C, Evrendilek et al. (1999) found the inactivation threshold of 5 and 5.4 log10 reductions of E. coli O157: H7 and E. coli 8739 in apple juice, respectively. E. coli O157:H7 was reduced by 1.59 log10 at 22 kV/cm for 59 s at 45 C and by 2.22 log10 at 20 kV/cm for 70 s at 55 C, according to Gurtler et al. (2010). Orange juice was found to contain S. typhimurium strains UK-1 and 14028 at decreases of 2.8 and 3.5 log10, respectively, in the same investigation.

Hulsheger et al. (1983) found that Gram-positive germs and yeasts are more resistant to PEF treatment than Gram-negative germs when few pulses were reviewed. On the other hand, at 30 kV/cm for just 5 s (42 C) or 12 s (50 C), McDonald et al. (2000) showed 3.5 and 6 log10 decreases of Listeria innocua (L.innocua). When compared to other microorganisms he took into consideration for the same experiment, he found that L.innocua (Gram-positive) was inactivated most completely with the fewest pulses at the lowest temperature. At 40 kV/cm and 56 C for 100 s, McNamee et al. (2010) recorded 3.9 log10 reductions of L.innocua in orange juice. The different PEF treatment chamber designs, pulse shapes, chemical characteristics of the orange juice, and various bacteria growing techniques might all contribute to this disparity in inactivation level. L.monocytogenes was inactivated in apple juice by smearing 25 kV/cm for 31.5 seconds at 50 degrees Celsius and 37 seconds at 55 degrees Celsius, respectively. However, in sour cherry juice, the same bacterium was inactivated by applying 27 kV/cm for 131 seconds at 20 degrees Celsius (Altuntas et al. 2011). Since Gram-positive organisms are often less responsive to PEF therapy than Gram-negative species, these findings were surprising. Additionally, he discovered that applying 6–7 pulses reduced S. cerevisiae by a maximum of 2.5 log10 at 50 kV/cm, 55 C. He also observed that weaker electric fields and fewer pulses did not result in greater inactivation and discovered reductions of less than 1 log10. Again, this finding ran counter to the information provided by Hulsheger et al (1983). When two pulses were used and the beverage temperature was maintained below 23 °C, the inhabitants of Byssochlamys fulva conidio spores in tomato juice dropped by less than 1 log cycle at a voltage of 30 kV/cm. When 15 pulses were administered under the same treatment circumstances, the inactivation rate rose to 4 log cycles (Raso et al. 1998).

Orange juice that had been PEF-treated was the subject of experiments by Timmermans et al. in 2011. When the juice was analysed 58 days after the PEF treatment, the number of microorganisms was lower. Juice that had been PEF-treated was kept chilled at 4 C. When treated at 29.5 kV/cm for 60 seconds at 30 C, orange juice's shelf life was increased

by 7 months, whereas untreated juice deteriorated within 30 days (Qiu et al. 1998). Yeom et al. (2000b) reported that orange juice treated by PEF under 35 kV/cm for 59 s had a post life of 112 days at 4 C. Alike effects were observed by Min et al. (2003a) with orange juice treated at 40 kV/cm for 97 s at 45 to 65 C in the marketable-scale (500 L/h) PEF treatment, resulting in a shelf life of 196 days at 4 C.

Inactivation of microorganisms in milk by PEF process

The majority of the research activities demonstrated the efficacy of this technique by reporting how PEF treatment affected inactivation of enzymes and microorganisms in milk or SMUF. When the input temperature was between 25 and 50 C, Smith et al. (2002) showed that the total flora in raw skim milk could only be reduced by 1 to 2 log10 at most. Square wave pulses were 9% more efficient than pulses with exponential decay for inactivating S. aureus and E. coli inoculated in Skim milk, according to Pothakamury et al. (1996). When E. coli inoculated in skim milk was subjected to 60 pulses of 2 s at 45 kV/cm and 35°C, its growth was decreased by 2 log cycles (Zhang 1995a). According to Fernandez et al. (2006), an increase in energy input and treatment duration resulted in a greater inactivation of Pseudomonas fluorescens (P. fluorescens) in skim milk. He used an energy input of 128 kJ/L, 33 °C, and 38.9 kV/cm to obtain a maximum decrease of 2.6 log10s.Smith et al. (2002) used a combination of PEF treatment (80 kV/cm, 50 pulses), moderate heat (52 °C), and the addition of both the natural antimicrobials nisin (38 IU/mL) and lysozyme (1638 IU/mL) to obtain a maximum decrease of 7 log10 in bacteria in raw skim milk.

In an experiment, Bermudez et al. (2011) compared the quality of whole milk with skim milk. After being processed by an electric field strength of 30.76 to 53.84 kV/cm, at 20, 30, and 40 °C, for varying numbers of pulses, the physicochemical factors (pH, electrical conductivity, density, colour, solids non-fat) and structure (protein and fat content) were assessed. Inconsequential changes in physicochemical parameters were noticed by the authors. They also observed that when the PEF treatment becomes stronger, the amount of fat and protein in skim milk and whole milk decreases. After 33 days, it was discovered that PEF-treated samples had greater stability at 4 °C with very slight pH fluctuations. The samples that were treated at 21 °C, however, deteriorated more quickly and reached a pH of 4 after only 5 days.

When milk was treated with 35 kV/cm, 64 pulses during a treatment duration of 47 s to 188 s, Michalac et al. (2003) showed an overall log10 decrease of 1.0 in PEF treated raw skim milk.When subjected to the same treatment conditions, Martin et al. (1997a) found that the inactivation of bacteria by PEF was less in effect in skim milk than in a buffer solution. They explained the lower inactivation of microbes by pointing to the complicated makeup of skim milk and the presence of proteins. According to Dutreux et al. (2000), the effect of the medium's physicochemical makeup was responsible for the difference in E. coli inactivation between phosphate buffer and milk is less than 1 log.

When the temperature was raised from 40 to 50 °C, Dunn & Pearlman (1987) observed a S.dublin inactivation in milk increased from 1 to 4 log10 decreases. In skimmed milk ultra-filtration (SMUF), Vega et al. (1996) found that E. coli was more effectively inactivated at pH 5.7 than at pH 6.8.

Mycobacterium paratuberculosis (M. paratuberculosis) cells postponed in 0.1% peptone water and sterilised cow's milk had their vitality reduced by Rowan et al. (2001).

When exposed to an electric field strength of 30 kV/cm, 2500 pulses at 50 C, M. paratuberculosis cells were decreased in number by 5.3 log10 reductions in 0.1% peptone water and 5.9 log10 reductions in cow milk, but only by 1.6 log10 reductions in PEF at 5 C. The findings were compared to those obtained using thermal methods carried out at 50 °C for 25 minutes or at 72 °C for 25 s, which provide decreases in log10 of 0.01 and 2.4, respectively. As a result, it was discovered that PEF treatment at 50 °C was superior than thermal sterilisation for the inactivation of M. paratuberculosis.

Alkhafaji & Farid (2007) used square bipolar pulses of 1.7 s, 200 Hz for the treatment period of 100 to 900 s at electric field strengths of 37 and 43 kV/cm at a flow rate of 2.5 mL/s to observe a extreme of 6.6 log10 falls of E. coli ATCC 25922 suspended in SMUF.

Shamsi et al. (2008) looked at how PEF treated raw skim milk affected the deactivation of enterobacteriaceae, pseudomonads, and the whole microflora at electric field powers of 25-37 kV/cm, 200 Hz, with end product temperatures of 15 °C and 60 oC. Maximum 1 log10 decreases in the total microflora and Pseudomonads count were seen when the PEF electric field strength was in the range of 28–37 kV/cm, while more than 2.1 log10 reductions in the Enterobacteriaceae count were seen when the temperature was 15 oC. PEF treatments resulted in 2.4 log10 decreases in total micro-flora at 25-35 kV/cm, 5.9 and 2.1 log10 reductions in Pseudomonads and Enterobacteriaceae counts, respectively, when the temperature was adjusted to 60 °C. PEF has been shown to be effective in inactivating microorganisms in each of the investigations mentioned above.

Quality aspects of PEF-Treated liquid foods

In freshly squeezed orange juice, Yeom et al. (2000a) investigated the scent loss, browning index, colour, fluctuation of soluble solids, and pH. The orange juice was treated with pulses lasting 59 seconds at 35 kV/cm while keeping the temperature at 94.6 C. In comparison to heat-treated juices, PEF-treated juices were shown to retain volatile chemicals (-pinene, myrcene, octanal, d-limonene, and decanal) better at 4 C. Juices that had been PEF treated, however, showed reduced browning and hardly any changes to the pH or the amount of soluble solids. Citrus juices prepared from grapefruit, lemon, orange, and tangerine had no variations in their physical or chemical characteristics between the PEF-treated and untreated samples, according to Cserhalmi et al. (2006). It's interesting to note that the volatile components in PEF-treated juice were almost identical to those in untreated juice. Elez-Martinez et al. (2006) found that juice that had undergone PEF treatment (35 kV/cm, 1000 s, bipolar 4 s at 200 Hz) maintained its colour better than juice that had undergone heat treatment, with no alterations in pH or acidity. According to Zarate et al. (2000), there were no variations in the soluble solids, pH, or acidity of apple juice treated with PEF. Additionally, Evrendilek et al. (2000) discovered no changes in the volatile components in apple juice treated with PEF. In comparison to heat-treated juice, Aguilar et al. (2007) found that PEF-treated apple juice saw less alterations in volatile components.

PEF-treated tomato juice was discovered to have superior physical, chemical, and sensory properties over heat-treated juice in the areas of colour, pH, acidity, soluble solids, viscosity, and smells (Min & Zhang 2003; Min et al. 2003b; Aguilo et al. 2008). Additionally, tomato juice that underwent PEF processing was more well accepted than juice that underwent thermal treating (Min et al. 2003b).

The efficiency of a strawberry juice's viscosity was proved by Aguilo et al. (2009) using PEF processing variables including pulse polarity, width, and frequency. Additionally, they noticed that PEF treated watermelon juice had superior colour attributes reduced than thermally treated juice. The sourness and pH of milk were unaffected by the PEF treatment (Serrano et al. 2006). Evrendilek et al. (2001) used PEF and hurdle PEF-Thermal techniques to perform research on the colour, pH, soluble solids, and conductivity changes in milk with chocolate during storage. The outcomes were contrasted with an untreated sample's. Both procedures did not reveal any changes in the treated milk.

Melgar et al. (2008c) examined juices from melon and watermelon that had been thermally treated but not PEF-treated and found no discernible changes in odour, colour, taste, or overall characteristics. By using a variety of treatments, including PEF-therapy (30 to 50 kV/cm, 4 Hz, 40 to 65^{o}C), orthodox heating at 60 or 65 °C for 21 s, and the combination of PEF treatment with heat or organic acids, Fernandez et al. (2005a, b, c) studied the shelf life of skim milk (acetic or propionic acids). PEF may be used in conjunction with heat or organic acids to obtain a upper degree of microbial inactivation in milk, according to all three studies, which found that the combination of PEF and organic acids had the greatest impact on the inactivation of microbes.

Sepulveda et al. (2005) sought to use PEF treatment to prolong the post life of HTST pasteurised milk. The PEF treatment was applied right away after the first HTST pasteurisation, and it was applied again following the storage of HTST pasteurised milk for 8 days at 4 C. Two pulses, 2.3 seconds, and a 35 kV/cm electric field power were used. It was shown that applying PEF right away after pasteurisation might prolong milk's shelf life at 4 C by up to 60 days, whereas processing PEF after an 8-day storing period produced a post life of 78 days.

Conclusion

PEF has been researched as a viable non-thermal food safeguarding strategy, however there are several variables that affect how well PEF inactivates microorganisms. A thorough understanding of the crucial elements is determined to be important for generating high-quality PEF-treated food based on all the research that are currently available. PEF pasteurisation involves a large number of factors, many of which have undergone extensive testing by several research teams. However, it could still be hard to identify the factor that affects the degree of bacterial inactivation. In any case, the use of PEF offers a great deal of promise for the preservation of premium goods at lower temperatures while maintaining fresh-like goods.

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