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The Influence of Extremely Low Frequency (ELF) Waves for Pasteurization of Cow Milk

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ABSTRACT

The extremely low frequency (ELF) magnetic field exposure technology for food processing and preservation is a future technology that produces better food quality. This research aims to examine the exposure of extremely low frequency (ELF) magnetic field waves to pasteurized cow milk and its effect on pH, chemical content, total microbial count, and sensory tests. This research was carried out by exposing ELF waves of 834.8 micro Tesla (µT) for 90 minutes to fresh milk and pasteurized milk. Samples were stored at room temperature then observed at 0, 2, 6, and 21 hours. Each treatment was repeated three times. The results showed that exposure to ELF waves had no effect on chemical content (P<0.05). The pH measurement shows that exposure to ELF waves could maintain the pH value. The total microbial count showed that exposure to ELF waves had an effect on reducing the total microbial count. The organoleptic test showed that pasteurized milk exposed to ELF waves had a smaller level of change. Based on observations, exposure to ELF waves has the potential to be developed in pasteurization, storage of cow milk, and retain its nutritional content.

1. INTRODUCTION

Cow milk is a product that is consumed by many people. Cow milk production needs to be increased because annual consumer demand continues to increase 16.7 L/capita (BPS, 2017). The high nutritional content in cow milk makes it easy for bacteria to grow. One of the processing of cow milk is pasteurization to kill pathogenic bacteria and is safe for consumption. Pathogenic microbes can cause poisoning due to infection and intoxication, infection occurs due to consuming milk contaminated with bacteria, while intoxication occurs due to consuming milk containing toxins.

Conventional milk pasteurization process is usually carried out by heating at a temperature of 63–66 °C for a minimum of 30 min or at 72 °C for a minimum of 15 s. Currently, pasteurization of milk is being developed by exposure to an extremely low frequency (ELF) magnetic field. Muharromah *et al*. (2018) explain that ELF magnetic field is a subset of electromagnetic waves. The ELF magnetic field can be used in everyday life, one of which is the food sector as food or beverage preservation. ELF waves produce a non-thermal effect on the applied biological target, so that they do not cause a change in temperature when inducing a medium (Ahmed, 2013), because ELF electromagnetic wave radiation is classified as non-ionizing radiation, the energy beam does not cause ionization processes in molecules at a medium (Alatas & Lusiyanti, 2001).

Fresh cow milk at room temperature does not last long because bacterial growth is influenced by environmental conditions (Arini, 2017). Muslim *et al*. (2013), milk contains high nutritional value resulting in milk becoming a growth medium and bacterial development. Gurtler *et al*. (2010) explained that *Salmonella sp.* in food ingredients that contain cryoprotectant compounds such as protein and fat will be more resistant to physical and mechanical treatment. the inhibitory resonant frequency of ELF-EM waves that aggravates Salm. typhi growth would be a promising method for the treatment of Salm. typhi infection both in vivo and in vitro (Fadel *et al*. 2010).

The utilization of ELF magnetic field radiation shows promise for advancing bacterial sterilization technology. This type of radiation, characterized by its nonionizing nature and low energy levels, holds potential for enhancing food security technology while posing minimal safety risks. (Sudarti *et al*., 2022; Ghausia, 2017). Gaafar *et al*. (2006) explains that the induced current that arises in ELF magnetic fields can cause changes in the speed of movement of extracellular Ca2+ ions pass through the cell membrane. Sudarti (2016) explained that ELF magnetic field radiation has the potential as an alternative to sterilization cheap and safe method of fresh food from *Salmonella typhimurium*, exposure to a ELF magnetic field with an intensity of 646.7 µT for 30 minutes has been proven to reduce the population of *Salmonella typhimurium* in fresh "Gado-Gado" food. The results of the study on the effect of exposure to ELF waves on fresh cow milk, among others (Resnawati, 2020) explained that the process of processing by simple sterilization with pasteurization can maintain the quality of milk for up to 48 hours, with storage at room temperature. Heating time, storage time and type of packaging affect the acidity value. Magnetic field technology is a non-thermal preservation method using the process of providing a magnetic field. Magnetic field technology utilizes the magnetic field generated by the current entering the coil to kill pathogenic microbes in food (Sari *et al*., 2012).

Sudarti *et al*. (2022) outlined that being subjected to magnetic fields of 300 µT and 500 µT did not preserve the quality of cow milk. Exposing the milk to a magnetic field of 500 µT for 60 minutes, however, significantly ($p < 0.05$) decreased the population of Salmonella sp., but not Escherichia coli. Despite maintaining the physical attributes such as color and odor resembling fresh milk, clumps did not manifest until after the 10th hour. Widjayanti *et al*. (2021) the ELF had an effect on the pH of soy milk, which the exposure intensity 500 µT with an exposure 60 minutes had the potential to inhibit pH decline of soy milk. Exposure ELF magnetic field intensity 500 µT exposure time 72 h after tape fermentation influence on the highest reduction in the number of microbes, namely of 0.50 x1013 cells/mL (Sadidah *et al*., 2015).

The results of the study (Muharromah *et al*., 2019) showed that exposure to an ELF magnetic field with an intensity of 800 µT for 45 minutes had an effect on the pH of fresh cow milk. Judging from the pH value of cow milk, it shows that control cow milk fulfills the quality requirements for up to 8 hours, while cow milk exposed to ELF waves fulfills the quality requirements for up to 9 hours. The organoleptic properties studied based on the color and texture of fresh cow milk did not change significantly from the control group and the experimental group. Based on the description of previous research, exposure to the ELF magnetic field in food has great benefits in inhibiting microbial growth, so that it can preserve food in an environmentally friendly way. In this study, a study was conducted to determine the effect of using an extremely low frequency magnetic field on pasteurized cow milk, to determine the shelf life and quality in terms of pH, chemical content, total number of microbes and sensory tests. Nurhasanah *et al.* (2018) reported that exposure to ELF waves of 730.56 µT for 2 x 30 min affected the pH value of milkfish so that it could inhibit the increase in pH value.

While the results of research on the effect of exposure to ELF waves on pasteurized cow milk, among others on research (Saleh *et al*., 2022) explained that exposure to ELF waves of 801 µT for 90 minutes affected the type of milk and total microbes. The total microbe in fresh milk was 20,000 (CFU/mL) and after exposure to ELF waves was 4,700 (CFU/mL), whereas in pasteurized milk it was 430 (CFU/mL) and after exposure to ELF waves was 63 (CFU/mL). This study aims to further investigate the effect of exposure to an extremely low frequency (ELF) magnetic field of 834.8 µT for 90 minutes on pasteurized milk on chemical content, organoleptic tests, total microbes, and PH, as considerations in processing and preserving cow milk. In this study, cow milk was used locally produced in Jember Regency, Indonesia. This research plays an important role in determining the potential for exposure to ELF waves for processing pasteurized milk in terms of reducing total microbes, changes in pH, shelf life and chemical content in pasteurized milk.

2. MATERIALS AND METHODS

Samples of 10 liters of fresh cow milk in this study were taken from local dairy farmers whose milking method uses a milking machine to make it more hygienic. Milk samples were taken in the morning during the cow milking process, fresh milk samples were then taken directly to the livestock processing laboratory, and samples were carried using special fresh milk containers to avoid air contamination. Before using fresh milk as a sample, an alcohol test was first carried out, if the result was negative, it could be used as a sample in this study. Furthermore, 3 liters of fresh milk were put in sample bottles for treatment and analysis of fresh milk, each sample bottle contained 50 ml, some samples of fresh milk were exposed to ELF waves. Then the remaining 7 liters are pasteurized, then some of the pasteurized milk is exposed to ELF waves. Pasteurization of milk was carried out using the high temperature short time (HTST) method, heating at 72 °C for 15 seconds, using a Pasteurizer FT 75 armfield.

This research used a completely randomized design, the treatment used two variables. The first variable is the type of milk, which includes fresh cow milk, pasteurized cow milk, fresh cow milk exposed to the 834.8 µT ELF wave, and pasteurized cow milk exposed to the 834.8 µT ELF wave. The second variable is storage time, which includes storage time of 2; 6; and 21 h. Storage was carried out at room temperature. Each treatment was replicated three times.

Exposure to ELF waves on the treatment material is carried out using an electromagnetic field source ELF wave generator. Before the sample is placed in the magnetic field area, adjustments and measurements of wave intensity are made at various positions in the magnetic wave area, in order to obtain uniformity of wave intensity, measurement of ELF waves is carried out with an electromagnetic field tester. In this study, the average intensity of the ELF waves in the wave area was 834.8 T, the exposure of the waves to the treatment sample was carried out for 90 minutes. The process of exposing ELF waves to the sample is presented in Figure 1.

Data analysis in this research included pH analysis, chemical content analysis, analysis of the total number of microbes, and sensory test analysis. The parameters observed in this study were pH, chemical content, total microbes, and sensory analysis.

2.1. pH Analysis

The pH measurement was carried out with a digital pH meter using an electrode dipped in a milk sample. 50 ml of milk sample was put into a beaker, then the pH was measured.

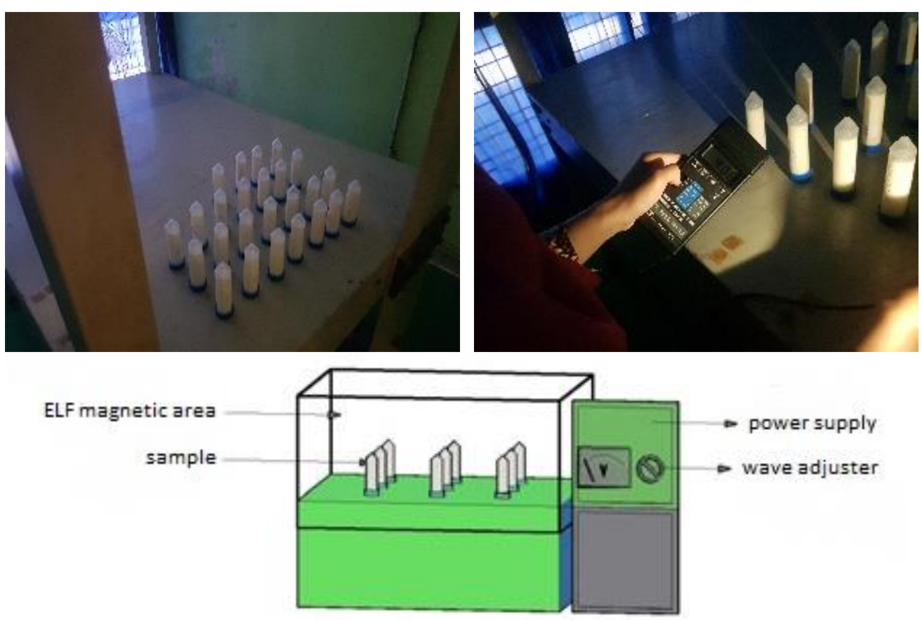

Figure 1. Installation chart of exposure of ELF waves to research samples

2.2. Chemical Content Analysis

Measurement of chemical content was carried out to determine the chemical content due to the influence of treatment materials and storage time. Measurements were carried out using the Lactostar (c) 2008 Funke Gerber, chemical content which includes; fat, solid non-fat, protein, and lactose.

2.3. Total Microbial Analysis

The media for total bacterial analysis was PCA (plate count agar). Microbial observations were carried out to determine the development of the number of microbes due to the influence of treatment materials and storage time.

2.4. Sensory Analysis

Sensory analysis includes taste, color, aroma, and viscosity. Sensory analysis was carried out to determine the difference between the test and the control in the treatment of pasteurized milk and pasteurized milk exposed to the ELF wave. Rating scores from 1 to 7 with criteria; 1 = the same, 2 = a little different, 3 = a bit different, 4 = moderate, 5 = moderately large, 6 = large, 7 = very large. Sensory test was performed by a trained to equalize perception and experienced person to carry out sensory tests.

3. RESULTS AND DISCUSSION

3.1. Alcohol test

The research data showed that the cow milk used as the sample in this study was fresh and unbroken, this was evidenced by the alcohol test which showed negative results so that no clumping occurred during pasteurization heating. The chemical used is 70% alcohol. The milk sample was added to 70% alcohol in a test tube with a ratio of 1:1, then homogenized. Then, if a positive reaction occurs in the form of clumping or sticking of milk grains to the tube wall, this indicates an imbalance in calcium-phosphate. The alcohol test is positive because the acidity of the milk increases and it appears damaged or mixed with milk from the udder affected by mastitis.

3.2. pH value

Measurement of pH on the treatment samples showed that the pH of fresh milk after milking was 6.54, the fresh milk used still met the requirements according to the Indonesia Standard of SNI 01-3951-1995. The pH value of fresh milk and pasteurized milk exposed to ELF waves is more stable because the total number of microbes is reduced. The results of ANOVA on pH measurements after 2 hours, 6 hours, 21 hours on the type of milk treatment; fresh milk, fresh milk exposed to the ELF wave, pasteurized milk, pasteurized milk exposed to the ELF wave showed significant difference (p<0.05), as well as the effect of storage time was also significant (p<0.05). The highest pH value at 21 hours storage was found in pasteurized milk exposed to ELF waves with a pH value of 6.13. The average pH value in each treatment combination can be seen in Table 1.

Table 1. Effect of exposure to ELF 834.8 μT on the average pH of local cow fresh milk and pasteurized milk

Treatment	Storage time			Significance	
	0 hours	6 hours	21 hours	TM	ST
Fresh milk	6.54	6.07	5.09	ns	**
Fresh milk with ELF	6.48	6.11	5.13	ns	**
Pasteurized Milk	6.51	6.51	5.54	ns	**
Pasteurized Milk with ELF	6.57	6.57	6.13	ns	**

ELF = extremely low frequency, TM = type of milk, ST = storage time, ns = not significant (p>0.05), **= highly significant (p<0.01)

3.3. Chemical Content

Observation of chemical content was carried out to determine the effect of ELF waves on pasteurized milk and pasteurized milk exposed to ELF waves. The results of ANOVA analysis showed that the chemical content of fat, non-fat solids (SNF), protein, and lactose were not significantly different (P<0.05), both at 0 hours, 6 hours, and 21 hours of storage, so that exposure to ELF waves in pasteurized milk no effect on chemical content. The value of the chemical content can be seen in Table 2. Exposure to ELF waves does not cause chemical damage to milk because high temperatures are not used. Utilization of ELF magnetic fields in the food sector is increasing due to the ELF magnetic field is characterized as non-ionizing, non-thermal hindered (Garip *et al*., 2011).

Table 2. Average chemical content in local cow fresh milk and pasteurized milk the effect of exposure to extremely low frequency (ELF) waves 834.8 μT

Parameters	**Storage time/type of milk**						**Significance**		
	0 hours		6 hours		21 hours				
	PM	PME	PM	PME	PM	PME	TM	ST	INT
Fat (%)	2.75	2.77	2.85	2.80	2.09	2.58	ns	ns	ns
SNF (%)	7.74	7.77	7.72	7.78	6.48	7.34	ns	ns	ns
Protein (%)	3.63	3.64	3.62	3.64	3.13	3.67	ns	ns	ns
Lactose (%)	4.14	4.15	4.12	4.15	3.40	3.87	ns	ns	ns

PM = pasteurized milk, PME = pasteurized milk exposed to extremely low frequency waves, SNF = solid non fat, TM = type of milk, ST = storage time, INT = interaction between type of milk and storage time, ns = not significant (p>0.05).

Table 3. Average total number of microbes (CFU/mL) in local cow fresh milk and pasteurized milk the effect of exposure to extremely low frequency (ELF) waves 834.8 μT

Treatment	**Storage time**			**Significance**		
	0 hours	6 hours	21 hours	TM	ST	INT
Fresh milk	11,000	83,700	112,000	**	**	**
Fresh milk with ELF	4,880	13,900	36,000	**	**	**
Pasteurized Milk	446	1,570	6,410	**	**	**
Pasteurized Milk with ELF	58	1,240	3,080	**	**	**

ELF = extremely low frequency, TM = type of milk, ST = storage time, INT = interaction between type of milk and storage time, ** = highly significant (p<0.01)

3.4. Total Number of Microbes

Observations on the number of microbes were carried out in all treatments, the research data showed that the total number of microbes in fresh milk exposed to ELF waves was still greater than the total number of microbes in pasteurized milk. The smallest total number of microbes occurs in pasteurized cow milk exposed to ELF waves, this is a consideration in milk sterilization methods that maintain its nutritional content. Data on the total number of microbes in the milk type treatment can be seen in Table 3.

Based on the results of ANOVA analysis, the total number of microbes in the different types of milk treatment (p<0.05), as well as the total number of microbes in the long storage treatment were also significantly different (p<0.05), so that exposure to ELF waves had an effect on the total number of microbes. The mathematical equation for the results of the regression analysis for the total number of microbes in pasteurized milk exposed to ELF waves is expressed as $Y = 149.08X + 18.229$ ($R^2 = 0.9615$), where Y is the total number of microbes (CFU/ml), while X is the storage time (hours). The longer milk is stored, the number of microbes also increases. Based on the description of previous research, field exposure ELF magnets on foodstuffs have great benefits in inhibiting microbial growth, thus preserving the material food in an environmentally friendly way (Saleh *et al*, 2022).

Arini (2017) elucidated that through bacterial colony counting, it was determined that after 24 h of observation, the milk with the lowest bacterial count was pasteurized milk, followed by packaged milk, and then non-pasteurized milk (raw milk). Conversely, after 48 h of observation, the milk with the fewest bacteria was packaged milk, followed by pasteurized milk. Both pasteurized and packaged milk demonstrated the ability to either reduce bacterial count or eliminate bacteria present in the milk. The research findings indicated an average total bacterial count of 3.15 x 10^6 CFU/ml and a milk pH of 5.6.

3.5. Sensory Test

In the sensory test measurements were compared between pasteurized and pasteurized milk exposed to ELF waves, as well as the effect of storage time. Table 4 shows that differences in flavor, color, scent, thickness began to occur after 10 h of storage. Sensory changes in pasteurized milk exposed to ELF waves were still smaller than pasteurized milk without exposure to ELF waves. Analysis of sensory test data is presented in Table 4. Storing fresh cow milk in the refrigerator is done to delay changes in the quality of the milk protein levels. In general, changes in temperature result in a delay in all changes due to biochemical reactions (decarboxylation, deamination and Strickland reactions) caused by microorganisms. (Putri, 2016). The effect of room temperature storage at a storage time of 3 h has shown an increase in the number of bacteria, namely 3.5x106 cfu/ml and an increase at temperatures of 4.5 h and 6 h. (Hendrawati and Utomo, 2017).

Table 4. Quantitative data of sensory test

Storage time	Sensory parameters	Pasteurized Milk	Pasteurized Milk with ELF
0 (R)	Flavor	1	1
	Color	1	1
	Scent	1	1
	Thickness	1	1
6 hours	Flavor	1	1
	Color	1	1
	Scent	1	1
	Thickness	1	1
10 hours	Flavor	1.9	1.5
	Color	1.8	1.8
	Scent	2.4	1.7
	Thickness	3	2.3
21 hours	Flavor	4.2	4.2
	Color	4	4
	Scent	3.9	3.9
	Thickness	5.3	4.8
24 hours	Flavor	5.1	4.4
	Color	4.5	4.1
	Scent	4.7	4.3
	Thickness	6	5.1

Mean of rating scores : 1 = same as control, 2 = a little different, 3 = a bit different, 4 = moderate, 5 = moderately large, 6 = large, 7 = very large.

4. CONCLUSIONS

The effect of exposure to ELF waves of 834.8 µT for 90 minutes on cow milk is pasteurization method that it can maintain the pH value, reduce the total number of microbes but does not damage the chemical content, the organoleptic side is better. Based on observations of storage time, exposure to ELF waves has the potential to be developed in pasteurization, storage of cow milk, and retain its nutritional content.

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