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Original Paper

Analysis of Exposure to an Extremely Low Frequency (ELF) 700 μT and 1000 μT Magnetic Fields in Tuna Meat (Euthynnus Affinis C)

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Abstrak: The resistance of tuna meat in a room temperature classed quietly short as it takes approximately 6 hours has encountered a process of decay. Consequently, the technology is needed to increase its durability. This study aims to analyze the exposure to Extremely Low Frequency (ELF) 700 μT and 1000 μT magnetic fields in tuna meat (Euthynnus Affinis C). The sample was 3300 grams of fresh tuna meat, which had been stored in the refrigerator for 4 hours as it was divided into 66 plastic wrappers (50grams), then grouped into three groups. They were the control group (K), the ELF magnetic fields intensity 700 μT (E_{700}) group, and the ELF magnetic fields ELF intensity 1000 μT (E_{1000}) group with variations in an exposure time of 15 minutes, 30 minutes, and 45 minutes. Measurement of pH and assessment of physical condition was carried out on the 5th, 10th, and 15th hours after being exposed to the ELF magnetic fields. The results highlighted the pH value in all groups exposed to the ELF magnetic fields was significantly lower ($p < 0.05$) than the control group. Meanwhile, the physical condition of tuna exposed to the ELF magnetic fields appeared to be better than the control until the 15th hour of storage. Conclusion: Exposure to an ELF magnetic field with an intensity of 1000 μT for 15 minutes has the potential to increase the physical resistance of tuna until the 15th hour after being exposed to an ELF magnetic field.

Keywords: Tuna meat; ELF magnetic fields; Physical resistance

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INTRODUCTION

Tuna is acknowledged as the ten most consumed-fish species in the world (Jääskeläinen et al., 2019). The nutritional content of fresh tuna includes 69.4% water, 24.6% protein, 0.54% fat, 1.32% ash, 4.14% carbohydrates, and <0.50 IU of vitamin A (Anwar et al., 2020). The high content of protein, fat, and water defines a decent medium for the proliferation of pathogenic bacteria to speed up the decay process quickly. Getu et al., (2015) assorted an issue that the quality and freshness of fish are able to decrease as it leads to the process of decay due to the fundamental activity of bacteria and chemicals contained in the fish body.

Enterobacter aerogenes have a persistent role in accelerating the decayed of fresh fish. In further, substantial efforts to foster fish resistance are the freezing method (supercooling technology), the chemicals addition, e.g., formalin, and traditional drying methods (Kang et al., 2020) (Sanyal et al., 2017) (Patel & Haldar, 2019). This condition indicates less effective and safe because it will be activating chemical changes and potentially becoming toxic. The underlying mechanism of the fish resistance

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process is killing out the pathogenic bacteria or inhibiting their proliferation. Therefore, throughout this study, science and technology are needed to kill pathogenic bacteria or inhibit their proliferation for increasing fish resistance and safety. ELF electromagnetic resonance waves potentially damage the growth of salmonella thypimurium bacteria (Fadel et al., 2014). Exposure to an Extremely Low Frequency (ELF) magnetic field at an intensity of 646.7 μT for 30 minutes was able to suppress the population of salmonella thypimurium bacteria up to 56% in gado-gado seasoning and 17% in vegetables (Sudarti, 2016).

The effect of ELF magnetic field intensity of 0.4 mT 0.5 Hz suppressed the microtubules – cytoskeleton (Wu et al., 2018). Exposure to a magnetic field intensity of 250 mT for 6 hours showed a significant decrease in colony-forming growth followed by an increase between 6 hours and 9 hours (Kthiri et al., 2019). Exposure to the ELF magnetic field intensity of 880 μT for 2x30 minutes could suppress the total bacterial population in milkfish up to 62% (Sudarti et al., 2020). The effect caused by the ELF magnetic field can inactivate bacteria to increase the safety of food products (Alenyorege et al., 2019). Therefore, it informed that the ELF magnetic field has antimicrobial and antibiotic properties to treat Staphylococcus aureus infections (Juncker et al., 2021).

Based on the previous studies mentioned, they have illustrated that exposure to the ELF magnetic field potentially can inhibit the proliferation of bacteria, as it hopefully can increase the physical resistance of the tuna meat. Furthermore, the ELF magnetic field can penetrate almost all materials, directly interact with the cell membrane, and affect the cell membrane potential. In highlight, this study aims to examine the potential for exposure to ELF magnetic fields with an intensity of 700 μT and 1000 μT in inhibiting the proliferation of Enterobacter aerogenes and its effect on the resistance of tuna meat (Euthynnus affinis C.).

This experimental study used a completely randomized design (CRD). Specifically, the independent variable was exposure to the ELF magnetic field with an intensity of 700 μT and 1000 μT and variations in an exposure time of 15 minutes, 30 minutes, and 45 minutes. Besides, the dependent variables included pH and the physical condition of tuna meat. The source of exposure to the ELF magnetic field came from the Current Transformer Machine at the Advanced Physics Laboratory, Faculty of Teacher Training and Education, Jember University.

The materials used in this present study were as follows: tuna meat, ice cubes, aquades, buffer, 70% alcohol, plastic wrap, tissue, sticker labels, *spiritus* (denatured alcohol), and EMB Agar media (Eosin Methylene Blue Agar). Besides, the tools used in this research were as follows: Current Transformer Machine, EMF Tester, pH meter, mortar pestle, test tube, glass beaker, LAF (Laminar Air Flow), stirring rod, dropper pipette, Vortex Portable Mixer, styrofoam box, and knife.

Figure 1. Current Transformer

Figure 2. EMF *Tester*-827

METHOD

This research was an experimental laboratory with a completely randomized design (CRD). The researchers utilized magnetic field exposure treatment of Extremely Low Frequency (ELF) intensity of 700 µT and 700 µT with variations in an exposure time of 15 minutes, 30 minutes, and 45 minutes. In addition, the research sample was 66 pieces of fresh tuna meat (@ 50 grams) wrapped in plastic wrap then divided into 7groups, such as one control group (K), without being exposed to the ELF magnetic field. However, the 1st group had exposed to an ELF magnetic field with an intensity of 700 µT, respectively with an exposure duration of 15 minutes (E-$_{700\ \mu T,\ 15'}$), 30 minutes (E-$_{700\ \mu T,\ 30'}$), and 45 minutes (E-$_{700\ \mu T,\ 45'}$). Next, the 2nd group had exposed to an ELF magnetic field with an intensity of 1000 µT, respectively with an exposure duration of 15 minutes (E-1000 µT, 15'), 30 minutes (E-$_{1000\ \mu T,\ 30'}$), and 45 minutes (E-$_{1000\ \mu T,\ 45'}$), as it in line with the research design in the following Figure 2 (see Figure 3).

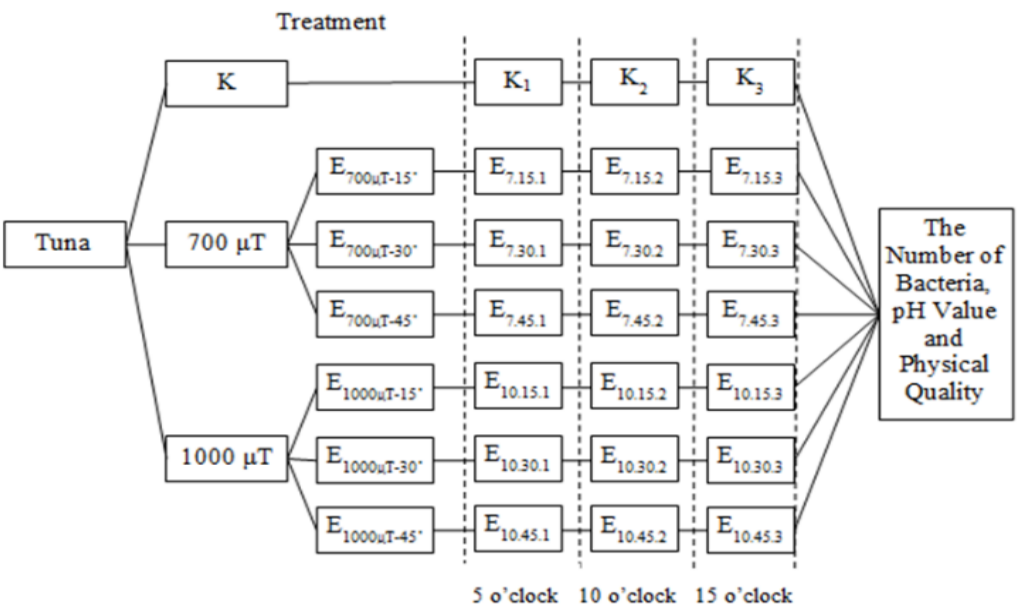

Figure 2. Research design

Fresh tuna meat samples were obtained from fishermen and had stored for 4 hours in the refrigerator before being exposed to the ELF magnetic field. Exposure to the ELF magnetic field was done by following the proper research design, then stored at room temperature. Measurement of pH and physical condition assessment at 0 hours (shortly before being exposed to the ELF magnetic field), 5 hours, 10 hours, and 15 hours after being exposed to the ELF magnetic field. The fundamental indicators of the physical condition of tuna meat had inferred through the color, smell, and texture in which it referred to the fish specifications according to the Indonesian National Standard (SNI) 01-2346-2006, with indicators described in the following Table 1.

Table 1. Indicators of fish color, smell, and texture based on SNI 01-2346-2006 specifications

Color indicators	Smell indicators	Texture indicators	Score
The cutlet is very clear, type-specific	Very fresh smell, type-specific	Solid, compact, elastic	9
The cutlet is clear, type-specific	Fresh smell, type-specific	Slightly solid, compact, elastic	8
The cutlet is slightly clear, type specific	Neutral smell	Slightly solid, less compact, slightly elastic	7
The cutlet is starting to fade, and the brown color is a bit clear	Ammonia begins to smell, a little sour smell	Slightly soft, less elastic	5
The cutlet is dull, and has brown color	Strong ammonia smell, H_2S smell, vivid sour smell	Soft, visible finger marks when it pressed	3
The cutlet is very dull, and has brown color	vivid bad smell	Very soft, finger marks cannot disappear when it pressed	1

The data from the assessment were in the form of scoring and were analyzed statistically using One Way ANOVA.

RESULT AND DISCUSSION

This section discusses some changes in the pH of tuna meat and the physical condition of tuna meat which includes the texture, color, and smell of tuna meat as a result of exposure to the ELF magnetic field intensity of 700 μT and 1000 μT.

Ph Changes of Tuna Meat

Some changes in the pH of tuna meat were done by having exposure to the ELF magnetic field intensity of 700 μT and 1000 μT are presented in the following chart (see Figure 3).

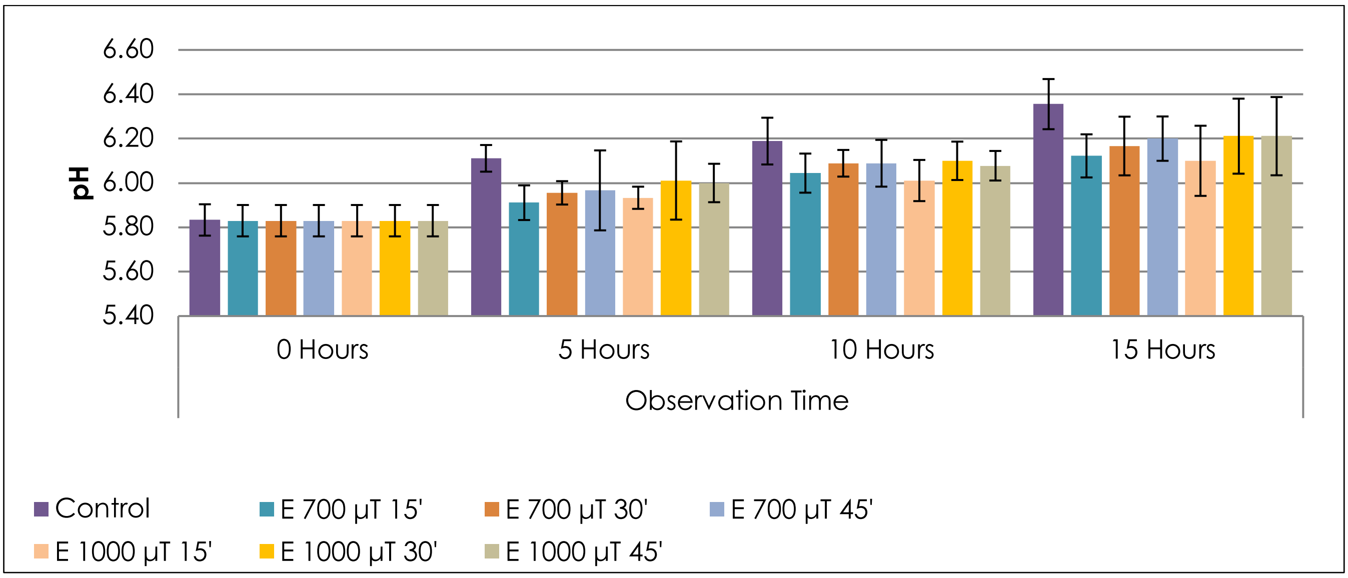

Figure 3. Chart of tuna meat pH at 5 hours, 10 hours, and 15 hours after being exposed to the ELF's magnetic field

The initial condition of the tuna meat samples in this present study was fresh as it had a pH value of 5.83. The control group naturally showed some pH changes in tuna meat since stored in a plastic wrap specifically at room temperature. The initial condition with a pH value of 5.83 increased a linear improvement at the 6th hour with a pH value of = 6.1111. It also happened at the 10th hour, with a pH value of 6.1889. And then, at the 15th hour, it came up with a pH value of 6.3556. It might happen due to the autolysis process. The fish meat turns protein degradation into essential basic volatile compounds, such as trimethylamine, ammonia, and other volatile compounds that cause changes in pH stabilization (Hidayati et al., 2019). The initial condition of the tuna meat samples in this present study was still fresh as it had a pH value of 5.83.

The pH value of tuna meat samples exposed to an ELF magnetic field with an intensity of 700 μT or 1000 μT seemed lower than the control group at the 5th hour, 10th hour, and 15th-hour measurements. It indicated that exposure to the ELF magnetic field intensity of 700 μT and 1000 μT could maintain the pH of tuna fish until the 15th hour of storage.

The results of the One Way ANOVA clearly showed that the average pH value between 7 groups of tuna meat samples at 0 hours (shortly before being exposed to the ELF magnetic field) was not significantly different with $p = 1.00$ (> 0.05). However, there was a significant difference in pH between the 7 sample groups at the 5th hour storage with $p = 0.009$ ($p < 0.05$), at the 10th hour storage with $p = 0.005$ ($p < 0.05$), and last, at the 10th hour storage -15 with $p = 0.008$ ($p < 0.05$).

Further analysis with the least significant difference (LSD) revealed and proved that the average pH of tuna fish in 6 sample groups exposed to the ELF magnetic field intensity of 700 μT and 1000 μT was significantly lower than the control group ($p < 0.05$). However, the average pH value of tuna meat samples, whether exposed to an ELF magnetic field intensity of 700 μT or 1000 μT, did not differ significantly ($p > 0.05$) at the 5th hour, 10th hour, and 15th-hour measurements.

The pH value is one indicator that can determine the level of freshness of fish which the initial pH of fresh tuna being around 5.74 (Jinadasa et al., 2015). The longer the storage of fish pH, the closer to alkaline pH. Generally, the acceptable fish pH is around 6.8, while the values above 7.0 are categorized as decayed (Jinadasa et al., 2015). Then, it highlighted that pH value defines one of the factors which affects bacterial growth and enzyme activity (Hidayati et al., 2019).

In accordance with Oncul et al., (2016) report, exposure to an ELF magnetic field intensity of 1 mT, 50 Hz for 2 hours can affect physicochemical processes both in gram-positive and gram-negative bacteria. It might happen since one of the factors that cause changes in pH tuna meat is that the ability of the ELF magnetic field can affect the Hydrogen in the solvent, as it can also damage the balance of the liquid interface causing the pH changes.

Physical Resistance Tuna Meat

Furthermore, the physical condition of tuna meat was observed with some indicators of color, smell, and texture of tuna after being exposed to the ELF magnetic field and stored for 5 hours, 10 hours, and 15 hours. Next, it compared with the initial conditions (hour 0) referring to SNI 01-2346-2006 specifications.

a) *Results of the tuna meat color observation*

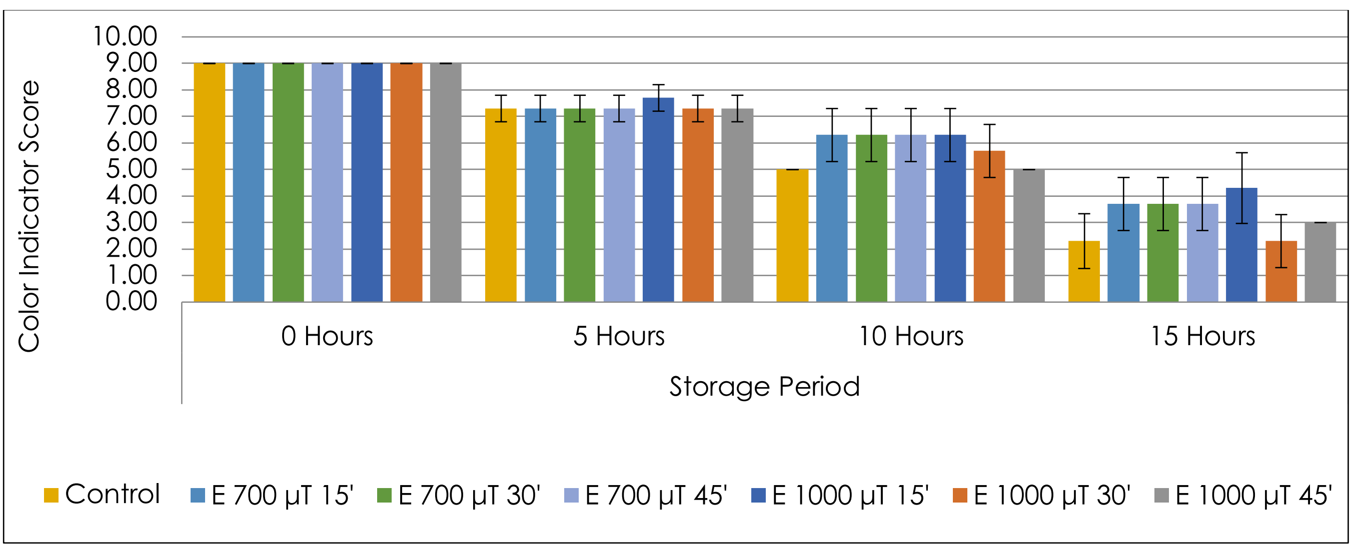

Figure 7. Changes of the tuna meat color during the storage of 5 hours, 10 hours, and 15 hours

Naturally, changes in tuna meat color during the storage of 5 hours, 10 hours, and 15 hours had reflected by the control group. According to the Indonesian National Standard (SNI 01-2346-2006), that value in the organoleptic assessment of fresh fish had merely indicated the substantial specifications for representing fresh red tuna, bright red flesh, and no milking along to the spine.

Figure 6 naturally showed changes in tuna meat color that were done by the control group as the longer the color got duller. Increasing the amount of time of the storage activity can cause the color of tuna meat to gradually decreases (Wang & Xie, 2020). The initial condition of fresh tuna meat had an average score of 9.0. Then, at the 5th hour, it returned to 7.3. At the 10th hour, it became 5.0. At the 15th hour, decreased to 2.3 as it meant that the cutlet was dull, had a brown color, or became decayed. The color of the tuna meat exposed to the ELF magnetic field with an intensity of 700 μT and 1000 μT at the 10th and 15th hours was still better rather than the control group. Besides, the results of the analysis on the 10th-hour observations showed that the color scores of tuna that exposed to an ELF magnetic field of 700 μT intensity for 15 minutes, 30 minutes, and 45 minutes, and those exposed to an ELF magnet of 1000 μT intensity for 15 minutes and 30 minutes was significantly higher than the control group ($p < 0.05$). The results of observations at the 15th hour represented the color score of tuna exposed to the ELF magnetic field intensity of 700 μT for 15 minutes, 30 minutes, and 45 minutes, and those exposed to the ELF magnetic field intensity of 1000 μT for 15 minutes significantly higher than the control group ($p <0.05$). These issues indicated that exposure to an ELF magnetic field with an intensity of 1000 μT for 15 minutes potentially maintained the color of tuna meat until the 10th hour of storage, with a color score > 6.0 or the color of the cutlet was slightly clear.

It appeared that the score of the tuna meat color at the 5th-hour observation did not differ from all groups involved. Hence, the difference began to appear at the 10th and 15th-hour of observation. In short, the color score of tuna meat samples exposed to an ELF magnetic field of 1000 μT intensity for 15 minutes was higher than the color scores of the other sample groups. Based on the specification of SNI 01-2346-2006, the results revealed the color resistance of tuna meat could last with a score of more than 7 to 5 hours. In other words, it took 9 hours from the time obtained from fishermen.

b) Results of the tuna meat smell observation

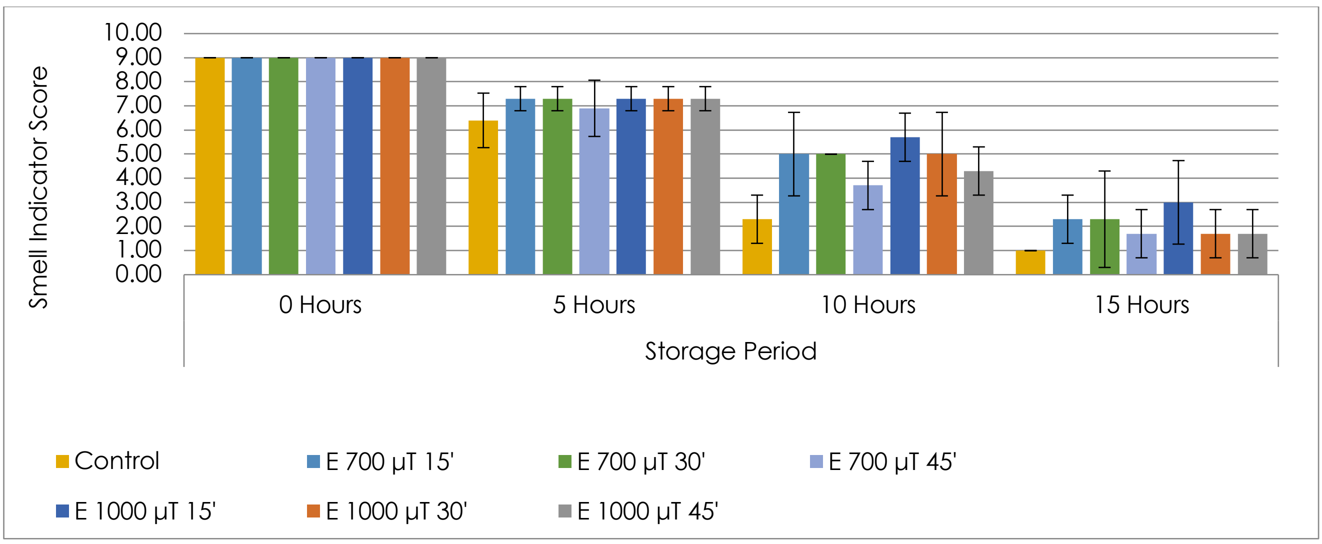

Figure 8. Changes of the tuna meat smell during the storage of 5 hours, 10 hours, and 15 hours

The control group showed changes in the smell of tuna meat. It described as the longer the ammonia smell in the tuna meat, the more pungent it was. The initial condition of the fresh tuna meat in an average score of 9.0. Suddenly, at the 5th hour, it became 6.4. At the 10th hour, it became 2.3. Then, at the 15th hour, it became 1.0. It revealed that the condition of the tuna meat was getting decayed. In further, the condition of tuna exposed to an ELF magnetic field with an intensity of 700 μT and 1000 μT at the 5th-hour observation was still neutral as it showed 7.3 scores. It's better than the control group that achieved a score of 6.4. Continuing the observation processes at the 10th hour showed the smell of ammonia in tuna fish had started to smell with a score of <6. However, in the control group, the ammonia smell indicated the strongest with a score of 2.3. The results of observations at the 15th hour showed a very strong stench in the control group with an average score of 1, while the group exposed to the magnetic field had an average score of <1. The smell of tuna meat exposed to the intensity ELF magnetic field 700 µT and 1000 µT at the 10th and 15th-hour observations were still better than the control group. The results of the analysis on the observations at the 10th and 15th hours showed that the fixed smell score of tuna meat exposed to the ELF magnetic field intensity of 700 µT and 1000 µT for 15 minutes, 30 minutes, and 45 minutes significantly higher than the control group ($p< 0.05$).

It emphasized that the odor score of tuna exposed to an ELF magnetic field of µ1000 T intensity for 15 minutes was consistently higher than the other groups from the 5th hour, 10th hour, and 15th-hour observations. Therefore, it can be stated that exposure to an ELF magnetic field intensity of 1000 µT for 15 minutes potentially maintained the smell of tuna meat.

Based on the specification of SNI 01-2346-2006, the results of the assessment at the 5th hour showed that the odor score on the tuna meat samples exposed to the ELF magnetic field intensity of 700 µT and 1000 µT was still more than 7. In contrast, the odor score in the control sample was less than 6. This phenomenon indicated that exposure to the ELF magnetic field intensity of 700 µT and 1000 µT could maintain the freshness of tuna meat until the 9th hour of storage.

c) Results of the tuna meat texture observation

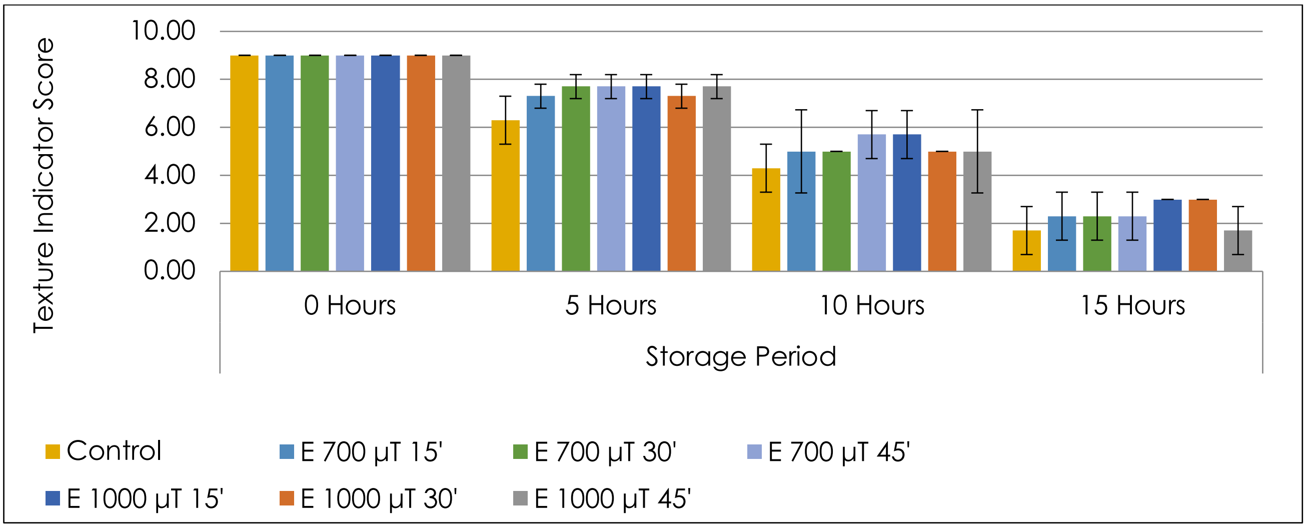

Figure 9. P Changes of the tuna meat texture during the storage of 5 hours, 10 hours, and 15 hours

Substantial changes in the texture of tuna meat had clearly shown by the control group. It described as the longer the texture of the tuna meat, the softer it was. The initial condition of the tuna meat was still fresh indicating an average score of 9.0. Hence, at the 5th hour, it became 6.3. At the 10th hour, it became 4.3. And, at the 15th hour, it became 1.7 as it represented the condition of the tuna meat was very soft. The texture of tuna meat exposed to an ELF magnetic field with an intensity of 700 µT and 1000 µT at the 5th-hour was in a slightly dense, less compact, slightly elastic condition with a score > 7.0. In short, the result was significantly higher than the control group. Next, the observations at the 10th hour showed that the texture score of tuna exposed to the ELF magnetic field intensity of 700 µT and 1000 µT in a slightly soft and less elastic condition with a score of 5.0. It was significantly higher ($p < 0.05$) than the control group. The condition of the control group tuna looked softer with a score of 4.3. Further, the results of observations at the 15th hour seemed to have softened with a score of 2.3 – 3.0. However, the condition of the tuna meat in the control group and the group exposed to the ELF magnetic field intensity of 1000 µT for 45 minutes was in very soft condition with a score of 1.7. This phenomenon showed that at the 15th hour, the texture score of tuna meat was exposed to an ELF magnetic field of 700 µT intensity for 15 minutes, 30 minutes, and 45 minutes, and exposed to an ELF magnetic field of 1000 µT intensity for 15 minutes, 30 minutes significantly higher ($p < 0.05$) than the control group.

Fish are generally regarded as easily damaged raw materials after being harvested and postmortem as the main result of the breakdown mechanism of pathogenic bacteria (Han et al., 2015). The decreasing mechanism of fish quality endogenously can be caused by the autolysis process. The fish meat does degradations protein into basic volatile compounds. They were trimethylamine, ammonia, and other volatile compounds that decreased the organoleptic assessment (Hidayati et al., 2019). The process of decaying meat is because of the pathogenic bacteria. It can be analyzed through the appearance of mucus on the surface, secreting lipase, and protease resulting in the formation of sulfide and trimethylamine (Rawat, 2015). Therefore, the emergence of microorganisms in fish meat affects smell changes due to protein degradation as it produces ammonia, H2S, indole, and histamine (Hidayati et al., 2019). It revealed that the texture score of tuna exposed to an ELF magnetic field of 1000 μT intensity for 15 minutes was consistently higher than the other groups from the 5th hour, 10th hour, and 15th-hour observations of measurements. Therefore, it can be highlighted that exposure to an ELF magnetic field intensity of 1000 μT for 15 minutes potentially maintained the texture of tuna meat.

Based on the specification of SNI 01-2346-2006, the results of the assessment at the 5th hour showed the texture score on the tuna meat samples exposed to the ELF magnetic field intensity of 700 μT and 1000 μT was still more than 7, while the smell score in the control sample was around 6. It showed that exposure to the ELF magnetic field with an intensity of 700 μT and 1000 μT could maintain the freshness of the tuna meat texture up to 9 hours of storage.

Exposure to 700 μT and 1000 μT ELF magnetic fields in tuna meat was proven could inhibit the increased processes in pH. It indicated some information that there was an obstacle in the autolysis process of fish meat. The protein degradation process into basic volatile compounds, such as trimethylamine, ammonia, and other volatile compounds, was also inhibited and would not result in the pH changes.

The quality, as well as the freshness of fish, can decrease as it might lead to the decay processes. It might happen due to the activity of bacteria and chemicals contained in the body of fish (Getu et al., 2015). This finding indicated that the decaying fish had a pH close to alkaline by bacterial activity; this phase is called the deterioration of fish quality. During this phase, the appearance of the fish also decreased. The organoleptic scores (meat color, texture, and smell) of tuna also decreased with the length of storage time (Hizbullah et al., 2019).

CONCLUSION

ELF magnetic field radiation intensity 1000 μT for 15 minutes potentially maintains the physical condition of tuna meat until the 5th hour after being exposed to the ELF magnetic field.

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REFERENCES

Alenyorege, E. A., Ma, H., & Ayim, I. (2019). Inactivation kinetics of inoculated Escherichia coli and Listeria innocua in fresh-cut Chinese cabbage using sweeping frequency ultrasound. Journal of Food Safety, 39(6), e12696. https://doi.org/10.1111/jfs.12696

Anwar, S. H., Hifdha, R. W., Hasan, H., Rohaya, S., & Martunis. (2020). Optimizing the sterilization process of canned yellowfin tuna through time and temperature combination. IOP Conference Series: Earth and Environmental Science, 425(1), 0–10. https://doi.org/10.1088/1755-1315/425/1/012031

Fadel, M. A., Mohamed, S. A., Abdelbacki, A. M., & El-Sharkawy, A. H. (2014). Inhibition of Salmonella typhi growth using extremely low frequency electromagnetic (ELF-EM) waves at resonance frequency. Journal of Applied Microbiology, 117(2), 358–365. https://doi.org/10.1111/jam.12527

Getu, A., Misganaw, K., & Bazezew, M. (2015). Post-harvesting and Major Related Problems of Fish Production. Fisheries and Aquaculture Journal, 06(04), 1–6. https://doi.org/10.4172/2150-3508.1000154

Han, F., Huang, X., Teye, E., & Gu, H. (2015). Quantitative Analysis of Fish Microbiological Quality Using Electronic Tongue Coupled with Nonlinear Pattern Recognition Algorithms. Journal of Food Safety, 35(3), 336–344. https://doi.org/10.1111/jfs.12180

Hidayati, N., Afrianto, E., Hasan, Z., & Liviawaty, E. (2019). The utilization of lactic acid bacteria from rusip to inhibit the formation of histamine on salted-boiled mackerel tuna-Euthynnus affinis (Cantor, 1849). An International Scientific Journal, 133, 85–97.

Hizbullah, H. H., Sari, N. K., Nurhayati, T., & Nurilmala, M. (2019). Quality changes of little tuna fillet (Euthynnus affinis) during chilling temperature storage. IOP Conference Series: Earth and Environmental Science, 404(1). https://doi.org/10.1088/1755-1315/404/1/012015

Jääskeläinen, E., Jakobsen, L. M. A., Hultman, J., Eggers, N., Bertram, H. C., & Björkroth, J. (2019). Metabolomics and bacterial diversity of packaged yellowfin tuna (Thunnus albacares) and salmon (Salmo salar) show fish species-specific spoilage development during chilled storage. International Journal of Food Microbiology, 293, 44–52. https://doi.org/10.1016/j.ijfoodmicro.2018.12.021

Jinadasa, B. K. K. K., Galhena, C. K., & Liyanage, N. P. P. (2015). Histamine formation and the freshness of yellowfin tuna (Thunnus albacares) stored at different temperatures. Cogent Food & Agriculture, 1(1), 1–10. https://doi.org/10.1080/23311932.2015.1028735

Juncker, R. B., Lazazzera, B. A., & Billi, F. (2021). The use of functionalized nanoparticles to treat Staphylococcus aureus based surgical-site infections: A systematic review . Journal of Applied Microbiology, 1–10. https://doi.org/10.1111/jam.15075

Kang, T., Shafel, T., Lee, D., Lee, C. J., Lee, S. H., & Jun, S. (2020). Quality retention of fresh tuna stored using supercooling technology. Foods, 9(10). https://doi.org/10.3390/foods9101356

Kthiri, A., Hidouri, S., Wiem, T., Jeridi, R., Sheehan, D., & Landouls, A. (2019). Biochemical and biomolecular effects induced by a static magnetic field in Saccharomyces cerevisiae: Evidence for oxidative stress. PLoS ONE, 14(1), 1–12. https://doi.org/10.1371/journal.pone.0209843

Oncul, S., Cuce, E. M., Aksu, B., & Inhan Garip, A. (2016). Effect of extremely low frequency electromagnetic fields on bacterial membrane. International Journal of Radiation Biology, 92(1), 42–49. https://doi.org/10.3109/09553002.2015.1101500

Patel, N. P., & Haldar, S. (2019). Evaluation of traditional fish preservation method of Masmin from skipjack tuna (Katsuwonus pelamis) in Lakshadweep, India, with respect to nutritional and environmental perspectives. Journal of Food Processing and Preservation, 43(10), e14124. https://doi.org/10.1111/jfpp.14124

Rawat, S. (2015). Food Spoilage: Microorganisms and their prevention. Pelagia Research Library Asian Journal of Plant Science and Research, 5(4), 47–56. Retrieved from www.pelagiaresearchlibrary.com

Sanyal, S., Sinha, K., Saha, S., & Banerjee, S. (2017). Formalin in fish trading: An inefficient practice for sustaining fish quality. Archives of Polish Fisheries, 25(1), 43–50. https://doi.org/10.1515/aopf-2017-0005

Sudarti. (2016). Utilization of Extremely Low Frequency (ELF) Magnetic Field is as Alternative Sterilization of Salmonella Typhimurium In Gado-Gado. Agriculture and Agricultural Science Procedia, 9, 317–322. https://doi.org/10.1016/j.aaspro.2016.02.140

Sudarti, Supriadi, B., Subiki, Harijanto, A., Nurhasanah, & Ridlo, Z. R. (2020). A potency of ELF magnetic field utilization to the process of milkfish preservation (chanos chanos). Journal of Physics: Conference Series, 1465(1). https://doi.org/10.1088/1742-6596/1465/1/012005

Wu, X., Du, J., Song, W., Cao, M., Chen, S., & Xia, R. (2018). Weak power frequency magnetic fields induce microtubule cytoskeleton reorganization depending on the epidermal growth factor receptor and the calcium related signaling. PLoS ONE, 13(10), 1–27. https://doi.org/10.1371/journal.pone.0205569

Zhan, X., Zhu, Z., & Sun, D. W. (2019). Effects of extremely low frequency electromagnetic field on the freezing processes of two liquid systems. LWT-Food Science and Technology, 103, 212–221. https://doi.org/10.1016/j.lwt.2018.12.079