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An analysis of soy milk physical resistance exposed to extremely low frequency (ELF) magnetic fields of 300 µT and 500 µT intensities

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ABSTRACT

Several studies have reported that exposure to ELF magnetic fields can increase cell death and inhibit bacterial proliferation. This study aimed to analyze the resistance of soy milk exposed to ELF magnetic fields with 300 µT and 500 µT intensities. The researchers employed a completely randomized design. The soy milk samples were exposed to ELF magnetic fields intensities of 300 µT and 500 µT for 60, 90, and 120 minutes. The variables studied were physical resistance (aroma, color, texture, and clot formation), pH, and density. The physical condition data were analyzed descriptively, while the pH and density data were analyzed using Mann Whitney and Kruskal Wallis statistics. The results showed that the aroma, texture, and clot formation on the surface of the samples exposed to the 500 µT intensity were better than the control group until ten hours after exposure. However, the color was not different from the control group. Therefore, exposure to ELF magnetic fields intensity of 500 µT potentially increased the soy milk resistance. The research results can be used as the basis for developing food security technology with ELF electromagnetic wave radiation.

INTRODUCTION

Milk is a beneficial beverage product for public consumption. Consuming two glasses of soy milk can meet 30% of the daily protein requirement. The nutritional benefits of soy milk are almost similar to cow milk (Suarjana et al., 2019). Sohouli et al (2021) state that soy milk has a beneficial effect on blood pressure. However, soy milk has a limited shelf life at room temperature and can be contaminated by bacteria. Those factors can damage the quality of milk, so attention is needed to make soy milk. Bacteria that contaminate milk are grouped into pathogenic bacteria and spoilage bacteria. Pathogenic bacteria include *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella sp.*, while the spoilage bacteria include *Micrococcus sp.*, *Pseudomonas sp.*, and *Bacillus sp* (Suwito, 2010).

One indicator of the soy milk quality based on SNI 01-3830-1995 is pH, which is 6.5 – 7.0. pH is an indicator to determine the level of damage to soy milk. Good quality soy milk according to SNI 01-3830-1995 should have 1) maximum total plate count of microbial contamination of 2 x 102 colonies/ml, 2) maximum coliform bacteria of 20 APM/ml, 3) *Escherichia coli* of less than 3 APM/ml, 4) no *Salmonella* and *Vibrio sp*, 5) *Staphylococcus aureus* of 0 colonies /ml and the maximum mold of 50 colonies/ml. Muharromah et al (2018) claim that the pH decrease of fresh cow milk is influenced by bacteria that convert lactose into lactic acid. If there are more bacteria, the lactic acid in the milk will increase, and the H^+ ions released during the formation of lactic acid will increase and cause cow's milk to become sour.

Electromagnetic waves consist of electric and magnetic fields that can radiate without any propagation medium. One of the electromagnetic waves is the Extremely Low Frequency (ELF) electromagnetic wave. ELF radiation or extremely low frequency consists of frequencies lower than 0.3 kHz, wavelength lower than 1000 km, and energy per photon lower than 1.24 peV (Anies, 2005). ELF-EMF can be used for surface treatment where unwanted bacteria grow. This approach could be a solution for hospitals and food processing plants to fight pathogens (Bayir et al., 2015).

The shelf life of a product affects the characteristics of the product. It needs to be considered to comply with product standards before consumption. Due to many factors, soy milk products have a relatively low shelf life at room temperature. Preservation methods by utilizing electromagnetic fields do not require a medium of propagation. ELF-EMF affects the freezing process and physicochemical properties of water in the frequency band of the 100-250Hz (Zhan et al., 2019). Besides, exposure to 50 Hz ELF magnetic fields and aluminium did not cause primer damage to DNA (Villarini et al., 2017). The nature of magnetic fields in food is non-invasive, so this technology becomes very attractive in improving food quality and processing, which can be viewed from microbiological and Physico-chemical aspects Fields(Miñano et al., 2020). The magnetic fields inhibit growth and cell reproduction. Low-frequency magnetic fields impact cells and tissues, while the high-intensity low-frequency magnetic fields destroy microbial cell membranes and microbial organelles (Liu et al., 2017).

Based on previous research, the ELF magnetic fields positively impact the food sector. According to Anggraeni & Prihandarini (2013) research, preserved soy milk at 25°C for twelve hours causes microbes to grow to exceed the maximum SNI standard. However, those stored at 5°C and 10°C do not show any microbial growth at organic or inorganic soy milk. Another related research was conducted by Sudarti (2016), who showed that the intensity of 646.7 μT for 30 minutes could reduce the population of *Salmonella typhimurium* in fresh Gado-Gado (vegetable salad). Research by (Sari et al., 2018) found that the intensity of exposure of 500 μT and 700 μT for 30 and 60 minutes inhibited the pH decrease of chicken meat. Furthermore, Ariyani et al (2019) showed that exposure to an ELF magnetic field intensity of 1000 μT affected the pH of edamame, where the pH in the experimental group tended to be higher than the pH in the control group.

Based on the description of the previous research results, the researchers aimed to study further the ELF magnetic fields to extend the physical resistance of soy milk. This research examined the effect of Extremely Low Frequency (ELF) magnetic fields exposure of 300 μT and 500 μT within 60, 90, and 120 minutes on physical resistance (aroma, color, texture, and clot formation), pH, and density of soy milk.

METHODS

As a treatment, exposure to Extremely Low Frequency (ELF) magnetic fields was produced by a Current Transformer (CT) machine equipped with an EMF tester of the Lutron EMF-827 type. This research was conducted at the Physics Laboratory of the Faculty of Teacher Training and Education, University of Jember. The researchers employed the Completely Randomized Design (CRD). The research samples were 70 bottles of soy milk with 50 ml each. The samples were divided into seven groups of ten bottles in each group. They were one control group (K), three groups exposed to the ELF magnetic fields intensity of 300 μT with variations in an exposure time of 60 minutes ($E_{300.60}$), 90 minutes ($E_{300.90}$), and 120 minutes ($E_{300,120}$). Furthermore, three groups were exposed to the ELF magnetic fields with an intensity of 500 μT with variations in an exposure time of 60 minutes ($E_{500.60}$), 90 minutes ($E_{500.90}$), and 120 minutes ($E_{500.120}$). The research design is presented in Figure 1.

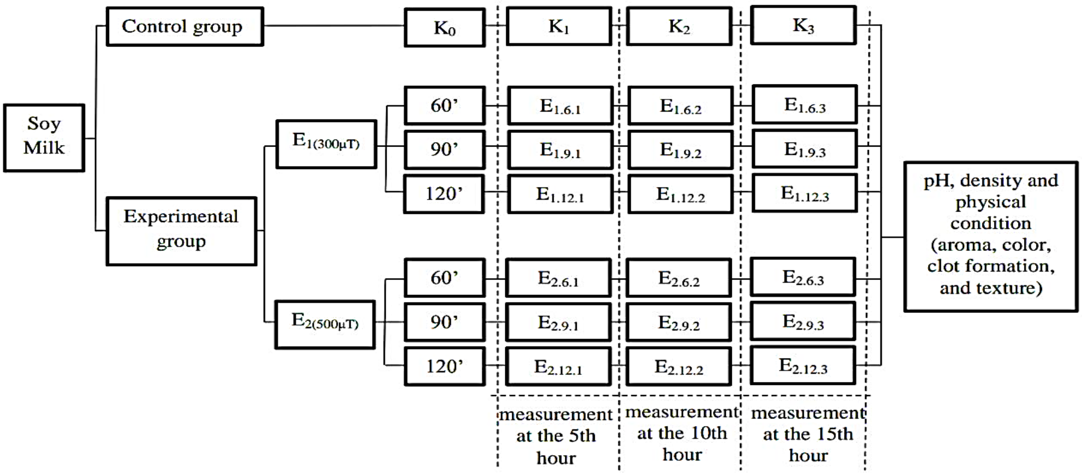

Figure 1. Research Design

The first stage of this research was preparation. Here, the researchers prepared tools and soy milk samples and checked and calibrated the equipment. The samples were divided into control and experimental groups, where K_0 was the sample of soy milk before exposure. The second stage was the treatment. The researchers exposed the samples with the ELF magnetic fields in an exposure chamber generated by the Current Transformer. The researchers set the current and voltage to produce an ELF magnetic field with an intensity of around 300 μT and 500 μT and reduced the intensity of the electric field to 30 – 50 V/m. The duration variation of magnetic field exposure was 60 minutes, 90 minutes, and 120 minutes. The third stage was measuring physical conditions (aroma, texture, clot, and color), density, and pH. The measurements were carried out at the 5^{th} hour, 10^{th} hour, and 15^{th} hour after the exposure. The control group was the soy milk sample group without exposure to the ELF magnetic fields. In contrast, the experimental group was the soy milk sample group exposed to the ELF magnetic fields.

The scoring criteria for the physical condition of soy milk include the aroma (5 = fresh and distinctive aroma, 3 = less fresh aroma, and 1 = sour aroma), color (5 = pure white, 3 = cloudy white, and 1 = cloudy and yellowish), clot (5 = no clot layer, 3 = thin clot layer, and 1 = thick clot layer), and texture (5 = runny texture, 3 = slightly thickened texture, and 1 = thick and cracked texture). The data would be statistically analyzed using the one-way ANOVA test if the data were normally distributed and the Mann-Whitney and Kruskal Wallis test if the data were not normally distributed. The researchers were assisted by SPSS 25 software. Furthermore, the research procedure chart is presented in Figure 2.

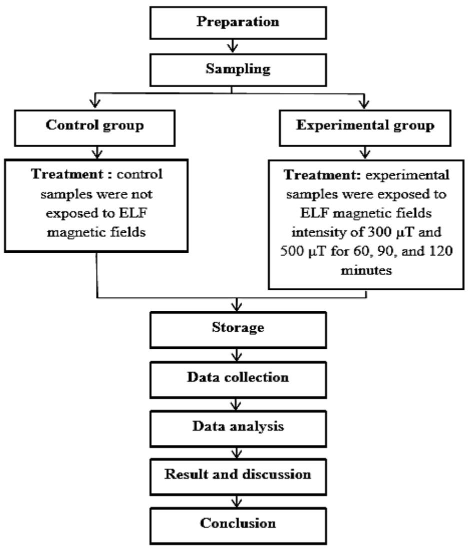

Figure 2. Research Procedure Chart

RESULTS AND DISCUSSION

The observations on the physical conditions and the measurements of density and pH on soy milk samples were carried out before exposure (0th hour) and after exposure (5th hour, 10th hour, and 15th hour). The researchers measured the density using a pycnometer and the pH using a pH meter that had previously been calibrated using a buffer solution. Figures 3 to 6 display the average physical condition data (aroma, color, clot formation, and texture).

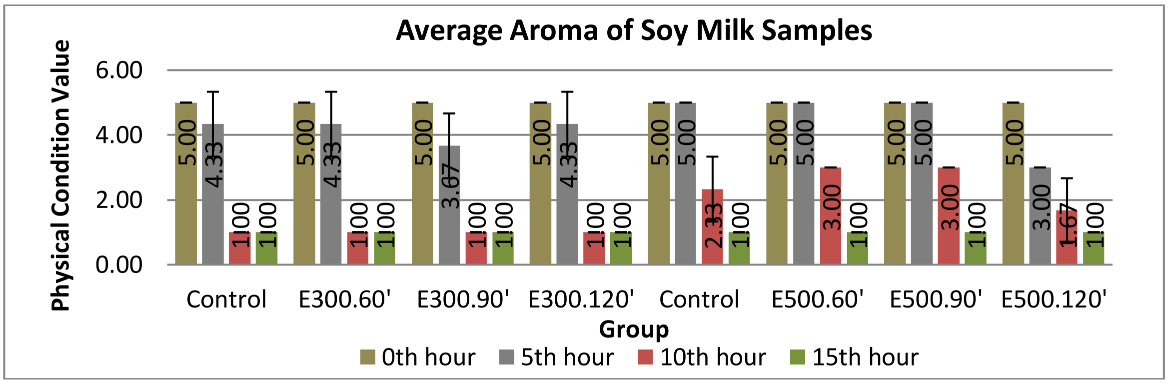

Figure 3. Average Aroma of Soy Milk Samples

Figure 3 shows that soy milk had a fresh and distinctive aroma in the 300 μT exposure intensity group, namely $E_{300.60'}$ and $E_{300.120'}$ (5th hour), while the intensity of 500 μT was $E_{500.60'}$ and $E_{500.90'}$ (5th hour). At the 10th hour, the $E_{500.60'}$ and $E_{500.90'}$ groups smelled less fresh. At the 15th hour, all sample groups had sour smells. Soy milk is in good condition has a distinctive and fresh aroma. Still, soy milk has a bad smell due to the oxidation reaction of unsaturated fats by the lipoxygenase enzyme activity (Kusnandar, 2019). Soy milk contains volatile ethyl-phenyl-ketone compounds that cause off-flavour or deviations in taste and aroma (Esvandiari et al., 2010).

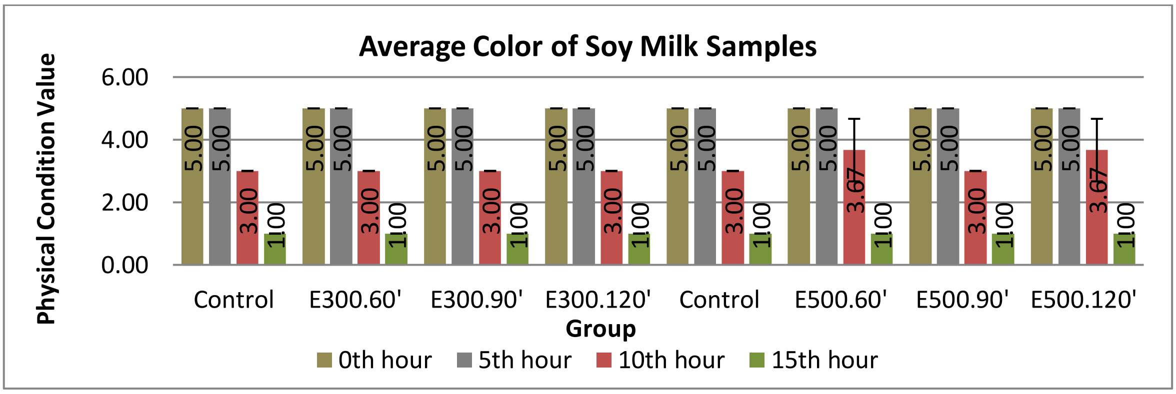

Figure 4. Average Color of Soy Milk Samples

Figure 4 displays that the control and experimental groups had pure white colors (5th hour). At the 10th hour, all sample groups were murky white. At the 15th hour, all sample groups were murky and yellowish. Thus, there was no difference between the color of soy milk in the control and experimental group at every hour of measurement. However, the color changed from pure white into murky white and murky and yellowish. Regarding the color change, Arini (2017) states that the color of milk after expiration is cloudy white. Diastari & Agustina (2013) state that sometimes milk is slightly yellowish due to carotene, which is the main yellow pigment of milk fat.

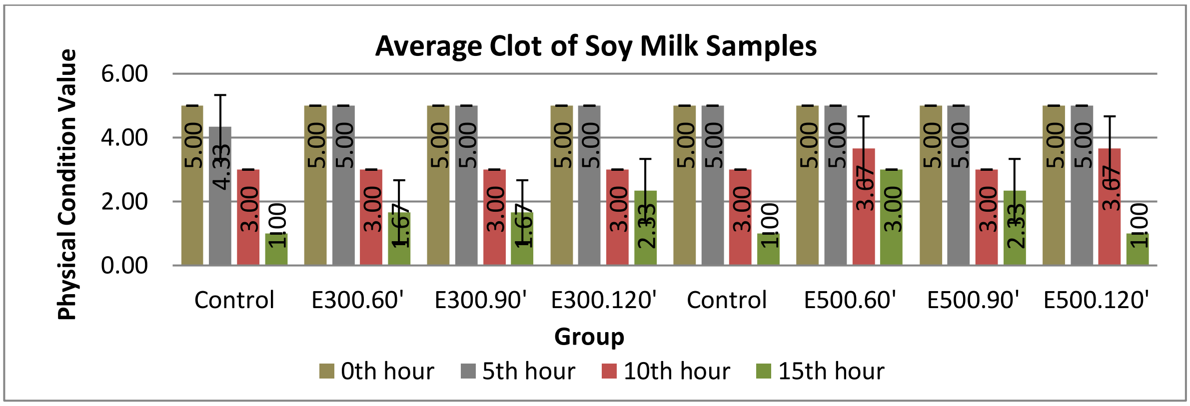

Figure 5. Average Clot of Soy Milk Samples

Figure 5 shows that there was no clot layer in the control group and the experimental group (5th hour). At the 10th hour, there was a thin layer of the clot in all sample groups. Then, at the 15th hour, there was a thick layer of the clot. However, in the $E_{500.60'}$ group, there was a thin layer of the clot. The control group had more clots compared to the experimental group. Thus, the longer soy milk is stored, the more clot produced due to the proliferation of bacteria. According to Aritonang (2017), spoilage bacteria can attack casein and break it down, causing milk to clot and smell bad.

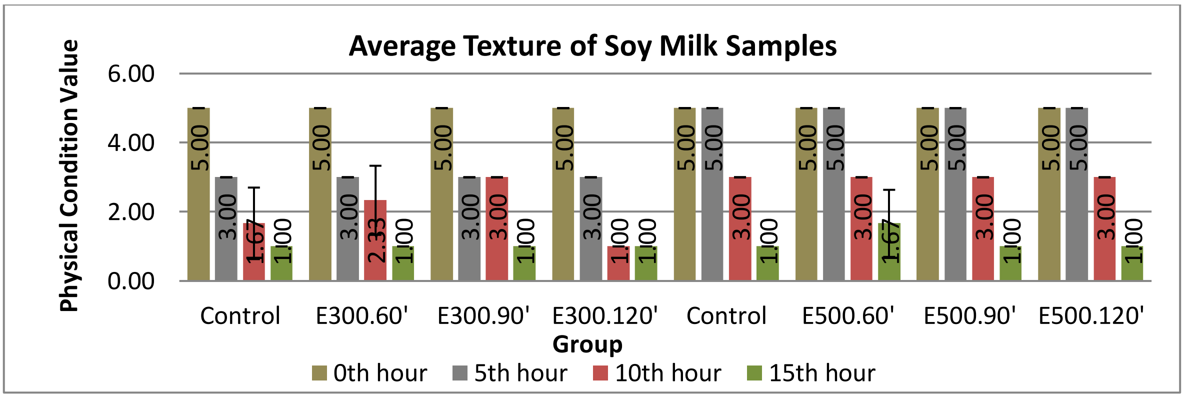

Figure 6. Average Texture of Soy Milk Samples

Figure 6 displays that the soy milk had a runny texture in the $E_{500.60'}$, $E_{500.90'}$, and $E_{500.120'}$ groups (5th hour). At the 10th hour, the sample group had a slightly thickened texture, but the control group and $E_{300.120'}$ had a thick and cracked texture. At the 15th hour, all sample groups were thick and cracked. Thus, the longer the soy milk is stored, the more dense and cracked the soy milk will be. The soy juice will separate from the water. Texture changes occurred due to substances in soy milk. Soybeans contain carbohydrates in the form of starch so that if it is mixed with water, it can make starch granules absorb water which can make soy milk curdle (Picauly et al., 2015). The longer the milk is stored, the more acidic it will be. It causes the casein to clot and the milk to thicken and break (Aritonang, 2017).

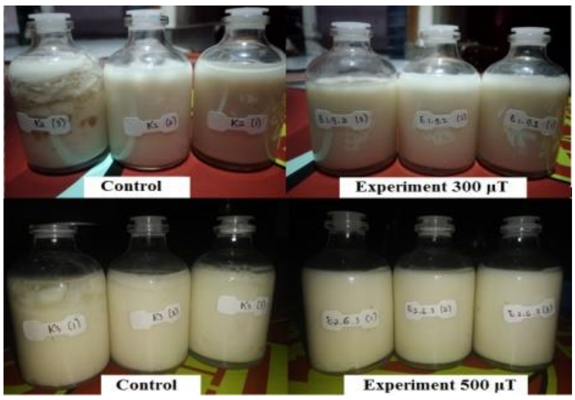

Figure 7. Soy Milk Physical Condition

The soy milk density measurement was measured at the 0th hour, 5th hour, 10th hour, and 15th hour after exposure using a pycnometer. Figure 8 (intensity of 300 μT) and Figure 9 (intensity of 500 μT) show the average density of soy milk for the control and experimental groups.

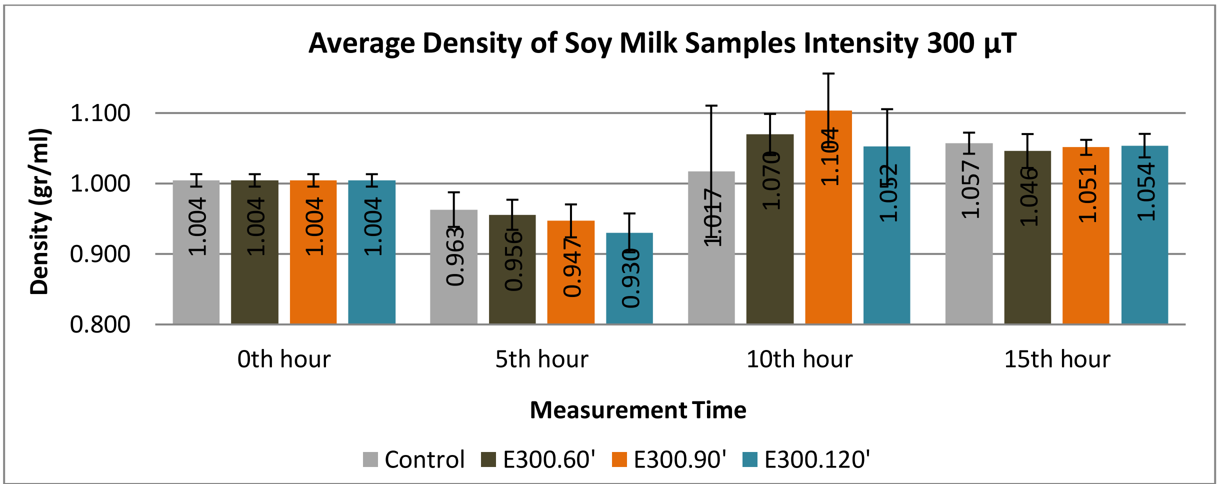

Figure 8. Average Density of Soy Milk Samples in the Control and Experimental Groups with an Intensity of 300 μT

The density value was obtained from the mass of the soy milk sample divided by the volume of the soy milk sample. Based on Figure 8, the control group had the highest density at 300 μT intensity five hours after the exposure. At the 10th hour measurement, the data showed an increase in density. Then, at the 15th hour after exposure, the density value of the control and experimental group $E_{300.120'}$ experienced a slight increase. Based on these data, there were differences between the control and experimental groups. The density value differences were due to the control and experimental groups' different characteristics. However, the density value differences at each measurement time were relatively small.

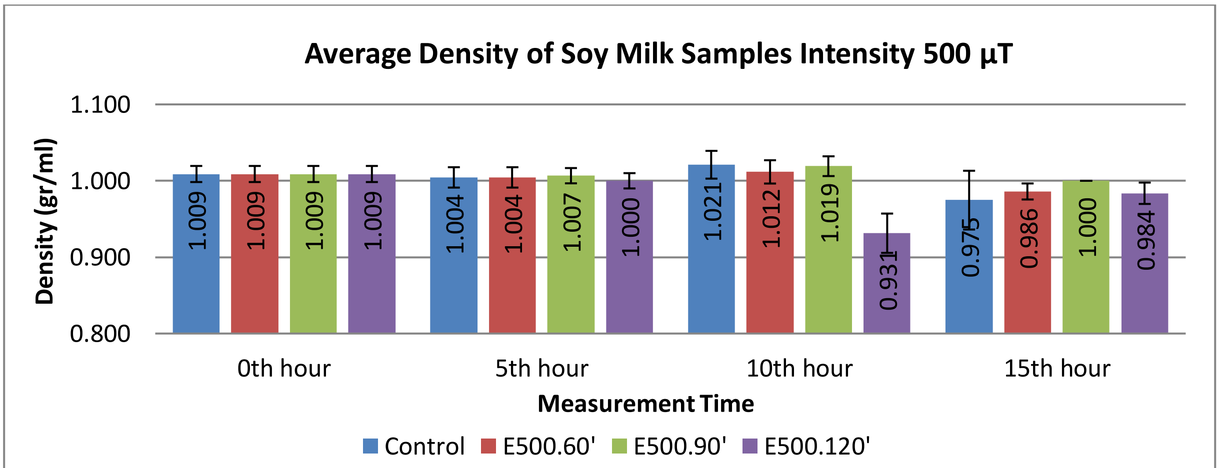

Figure 9. Average Density of Soy Milk Samples in the Control and Experimental Groups with an Intensity of 500 μT

Figure 9 shows that there was a significant difference between the control and experimental groups at the 10th and 15th-hour measurements after exposure. At the 5th hour measurement, there was a relatively small difference. Then, at the 10th hour and 15th-hour measurements, there was a change in the density value in the control group, $E_{500.60'}$ and $E_{500.90'}$ (10th hour), which experienced slightly increased density values. There were density value differences in each measurement time based on these data. Density changes affect the texture because if the texture is thick, the mass of soy milk increases so that the density is small. However, the density changes at each measurement were relatively small.

The pH measurement was carried out using a pH meter that had previously been calibrated using a buffer solution. Measurements were also carried out at 0th, 5th, 10th, and 15th hour after exposure. Figure 10 (intensity of 300 µT) and Figure 11 (intensity of 500 µT) show the average soy milk pH in the control and experimental groups.

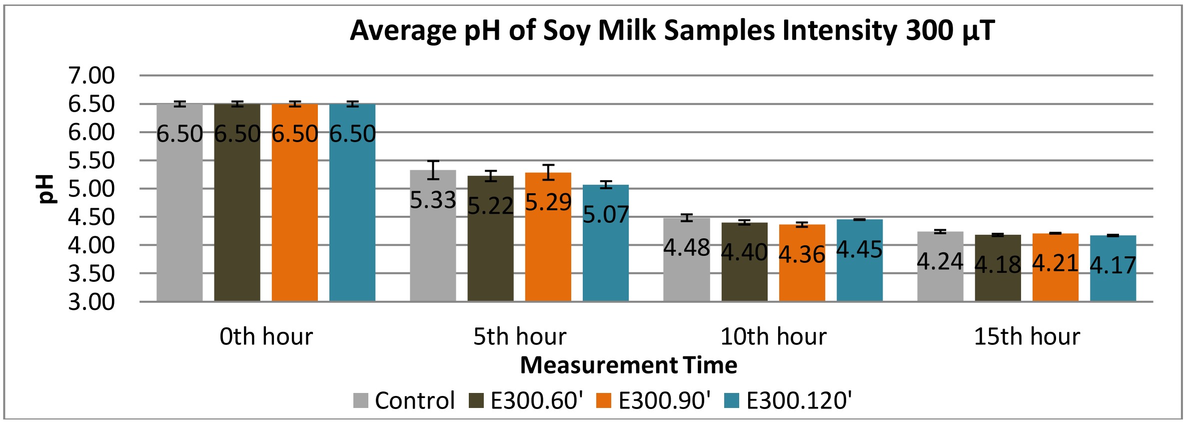

Figure 10. Average pH of Soy Milk Samples in the Control Grup and Experimental Group with an Intensity of 300 µT

Figure 10 shows a drastic decrease in the initial measurement towards the 5th-hour measurement after exposure. Then, at the 10th and 15th-hour measurements, there was a drastic pH value decrease. The highest pH values in the control group were 5.33 (5th hour), 4.48 (10th hour), and 4.24 (15th hour). Thus, the longer the soy milk is stored, the lower the pH value.

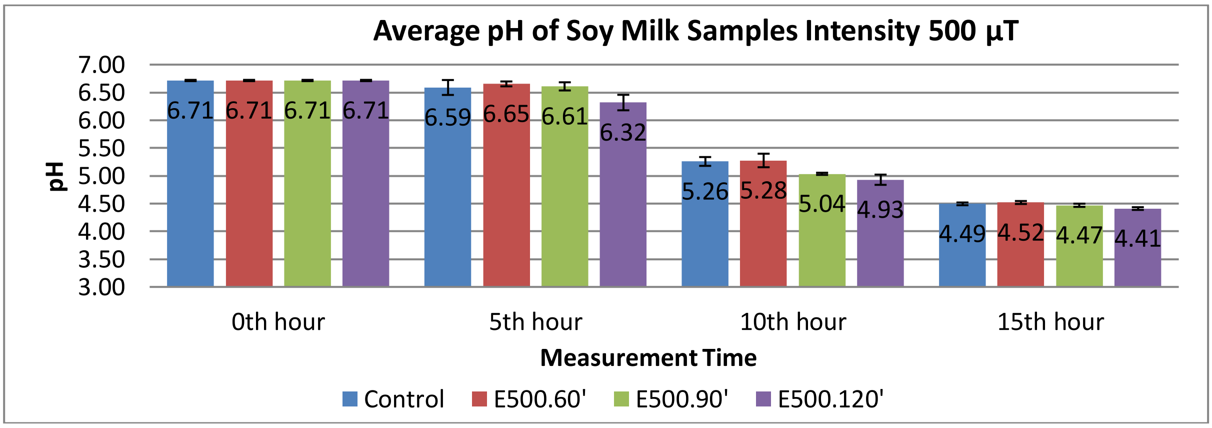

Figure 11. Average pH of Soy Milk Samples in the Control Grup and Experimental Group with an Intensity of 500 µT

Figure 11 shows that the decrease in the pH value was relatively small at the initial measurement towards the 5th-hour measurement. Then, at the 10th-hour measurement, there was a drastic decrease in the pH value. Furthermore, at the 15th-hour measurement, there was a drastic decrease in the pH value. Based on the figure, the highest pH value in the $E_{500.60'}$ group at each measurement time was 6.65, 5.28, and 4.52, respectively. Based on these data, there was a decrease in the pH value at each measurement time. However, the decrease in pH value at an intensity of 500 μT tends to be better than at an intensity of 300 μT; thus, the decrease was not too drastic.

The analysis of density and pH data of soy milk was performed using SPSS 25. In the normality test using the Kolmogorov-Smirnov test, if the significance value is less than 0.05, the data is not normally distributed. If the data is normally distributed, it is continued with the one-way ANOVA test and LSD test. If the data is not normally distributed, it is continued with the Mann Whitney and Kruskal Wallis test.

The analysis showed that the Sig. density value was lower than 0.05. Therefore, the data were not normally distributed. Furthermore, the pH data analysis of soy milk showed that the Sig. value was higher than 0.05. Therefore, the data were normally distributed.

In the analysis of the one-way ANOVA test, the pH value of the experimental group with an intensity of 300 μT obtained a significance value of less than 0.05 ($0.000 < 0.05$) at the 5th hour, the 10th hour, and the 15th hour. If the significance value is higher than 0.05, then H_0 is accepted. On the other hand, if the significance value is less than 0.05, then H_0 is rejected (Arifin, 2017). Thus, H_a was accepted so that there was a significant difference between the pH of the control group and the experimental group.

In the LSD test, it was found that the $E_{300.120'}$ group (5th hour); $E_{300.60'}$ and $E_{300.90'}$ (10th hour); $E_{300.60'}$, $E_{300.90'}$, and $E_{300.120'}$ (15th hour) had a significance value of less than 0.05. Therefore, H_0 was rejected, and H_a was accepted. In conclusion, there was a significant difference between the pH of the control group and the experimental group.

The Mann-Whitney test is an alternative test on data if the data do not meet the independent sample t-test. Furthermore, the Kruskal Wallis test is an alternative for data analysis tests that do not meet the requirements for normality and homogeneity (Setyawan, 2017). The density and pH data with an intensity of 500 μT were not normally distributed. In the Mann Whitney test, the density of the Sig. (2-tailed) value was lower than 0.05 in the $E_{300.90'}$, $E_{500.60'}$, $E_{500.90'}$, and $E_{500.120'}$ groups (10th hour). The pH at the intensity of 500 μT of the $E_{500.120'}$ group (5th hour), $E_{500.90'}$, $E_{500.120'}$ (10th hour), and $E_{500.120'}$ (15th hour) had Asymp values. Sig (2-tailed) of lower than 0.05. If the Asymp value. Sig (2-tailed) is lower than 0.05 in the Mann Whitney test, then H_0 is rejected, and H_a is accepted. On the other hand, in the Kruskal Wallis test, if the Asymp value of Sig (2-tailed) is higher than 0.05, then H_0 is accepted, and H_a is rejected (Santoso, 2016). In the density analysis using the Kruskal Wallis test, the obtained Asymp value. Sig (2-tailed) was higher than 0.05 at the 500 μT intensity group (10th hour) and the pH intensity of 500 μT at the 5th, 10th, and 15th hours. The results indicated that H_0 was rejected and H_a was accepted, meaning there was a density value difference between the control and experimental groups.

The longer the milk is left alone, the more bacteria will grow. Stale milk is at a pH below 6.5 due to many bacteria. Therefore, the longer the milk is left, the more bacteria will increase and lower the pH (Anggraeni & Winardi, 2015). The pH decrease is caused by an increase of lactic acid due to the metabolism. Lactic acid bacteria can reduce the pH of the medium (Charalampopoulos et al., 2002). The proliferation of bacteria affects the density of milk. As the number of bacterial colonies increases, the density also increases. The density is caused by the condensed fat and the increased acidity of the milk so that the milk coagulates, which results in an increased density (Roza & Aritonang, 2006). This statement is in line with Suhendra et al (2020) research, which states that increased levels of fat and lactose in milk increase the milk density value.

The ELF magnetic fields can radiate without the need for a propagation medium. They affect the ion's activity and the polarization of the dipoles in the cell (Pazur & Rassadina, 2009). The energy from the magnetic fields can be transferred to the ions of the acid-forming bacterial cells. It makes the flow rate of ions, such as Ca^{2+}, that pass through the cell membrane increase and damage the cell's proteins. Damage to cell proteins disrupts cell metabolism processes, causing cell death (Sadidah et al., 2015). The research by (Sudarti et al., 2020) states that the ELF magnetic fields can overcome and inhibit the invasion process. Therefore, exposure to the ELF magnetic fields can inhibit the proliferation of bacteria.

CONCLUSION AND SUGGESTION

Conclusion

The analysis showed that the exposure of the ELF magnetic fields with the intensities of 300 µT and 500 µT on soy milk's physical resistance did not significantly differ from the control group. The physical condition of soy milk exposed to the ELF magnetic fields with an intensity of 300 µT did not differ from the control group. However, the aroma, texture, and clot in soy milk exposed to an ELF magnetic fields intensity of 500 µT were better than the control group, although the color of soy milk was not different from the control group. This result proves that exposure to the ELF magnetic fields intensity of 500 µT potentially increases soy milk's physical resistance, which includes aroma, clot, and texture up to 10 hours after exposure. The results of this study are useful as a basis for developing food security technology with ELF electromagnetic wave radiation.

Suggestion

Exposure to the 500 µT intensity of the ELF magnetic fields did not show real results because of the low intensity. Therefore, it is necessary to research by increasing the intensity of the ELF magnetic field by more than 500 µT or increasing the exposure time to more than 120 minutes to increase the durability of soy milk.

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REFERENCES

Anggraeni, F. D., & Prihandarini, R. (2013). Pengaruh jenis komoditi kedelai (organik dan anorganik) dan suhu penyimpanan terhadap umur simpan susu kedelai. *Agrika: Jurnal Ilmu-Ilmu Pertanian, 7*(2), 98-108.

Anggraeni, N. D., & Winardi, S. (2015). Pendeteksi susu basi dengan sensor pH dan Sensor Suhu Berbasis Mikrokontroler. *E-Jurnal Spirit Pro Patria*, *1*(1), 47–53. https://doi.org/https://doi.org/10.29138/spirit%20pro%20patria.v1i1.50

Anies. (2005). *Seri Kesehatan Umum: Electrical Sensitivity*. Elex Media Komputindo. https://books.google.co.id/books?id=Q-M8DwAAQBAJ

Arifin, J. (2017). *SPSS 24 untuk Penelitian dan Skripsi*. Elex Media Komputindo. https://books.google.co.id/books?id=hDBIDwAAQBAJ

Arini, L. D. D. (2017). Faktor-faktor penyebab dan karakteristik makanan kadaluarsa yang berdampak buruk pada kesehatan masyarakat. *Jurnal Ilmiah Teknologi Dan Industri Pangan UNISRI*, *2*(1), 15–24. https://doi.org/http://dx.doi.org/10.33061/jitipari.v2i1.1531

Aritonang, S. N. (2017). *Susu dan Teknologi*. LPTIK Universitas Andalas.

Ariyani, E., Sudarti, & Prastowo, S. H. B. (2019). Pengaruh paparan extremely low frequency magnetic field terhadap ph edamame. *Jurnal Pembelajaran Fisika*, *8*(3), 132–136. https://doi.org/https://doi.org/10.19184/jpf.v8i3.15215

Bayir, E., Bilgi, E., Sendemir-Ürkmez, A., & Hameş-Kocabaş, E. E. (2015). The effects of different intensities, frequencies and exposure times of extremely low-frequency electromagnetic fields on the growth of Staphylococcus aureus and Escherichia coli O157:H7. *Electromagnetic Biology and Medicine*, *34*(1), 14–18. https://doi.org/10.3109/15368378.2013.853671

Charalampopoulos, D., Wang, R., Pandiella, S. S., & Webb, C. (2002). Application of cereals and cereal components in functional foods: A review. *International Journal of Food Microbiology*, *79*, 131–141. https://doi.org/http://dx.doi.org/10.1016/S0168-1605(02)00187-3

Diastari, I. G. A. F., & Agustina, K. K. (2013). Uji organoleptik dan tingkat keasaman susu sapi kemasan yang dijual di pasar tradisional kota Denpasar. *Indonesia Medicus Veterinus*, *2*(4), 453–460.

Esvandiari, M., Sholihin, H., & Suryatna, A. (2010). Studi kinerja adsorpsi arang aktif-bentonit pada aroma susu kedelai. *Jurnal Sains dan Teknologi Kimia*, *1*(2), 135–149.

Kusnandar, F. (2019). *Kimia Pangan Komponen Makro*. Bumi Aksara. https://books.google.co.id/books?id=JlX5DwAAQBAJ

Liu, Z., Gao, X., Zhao, J., & Xiang, Y. (2017). The sterilization effect of solenoid magnetic field direction on heterotrophic bacteria in circulating cooling water. *Procedia Engineering*, *174*, 1296–1302. https://doi.org/10.1016/j.proeng.2017.01.274

Miñano, H. L. A., Silva, A. C. de S., Souto, S., & Costa, E. J. X. (2020). Magnetic fields in food processing perspectives, applications and action models. *Processes*, *8*(7), 1-11. https://doi.org/10.3390/pr8070814

Muharromah, N. N. A., Sudarti, & Subiki. (2018). Pengaruh paparan medan magnet extremely low frequency (elf) terhadap sifat organoleptik dan ph susu sapi segar. *Seminar Nasional Pendidikan Fisika 2018*, *3*(2), 13–18.

Pazur, A., & Rassadina, V. (2009). Transient effect of weak electromagnetic fields on calcium ion concentration in Arabidopsis thaliana. *BMC Plant Biology*, *9*(47), 1–9. https://doi.org/10.1186/1471-2229-9-47

Picauly, P., Talahatu, J., & Mailoa, M. (2015). Pengaruh Penambahan Air pada Pengolahan Susu Kedelai. *AGRITEKNO: Jurnal Teknologi Pertanian*, *4*(1), 8–13. https://doi.org/10.30598/jagritekno.2015.4.1.8

Roza, E., & Aritonang, S. (2006). Pengaruh lama penyimpanan setelah diperah terhadap ph, berat jenis dan jumlah koloni bakteri susu kerbau. *Jurnal Peternakan Indonesia (Indonesian Journal of Animal Science)*, *11*(1), 74-78. https://doi.org/10.25077/jpi.11.1.74-78.2006

Sadidah, K. R., Sudarti, & Gani, A. A. (2015). Pengaruh paparan medan magnet ELF (extremely low frequency) 300 µt dan 500 µt terhadap perubahan jumlah mikroba dan ph pada proses fermentasi tape ketan. *Jurnal Pendidikan Fisika*, *4*(1), 1–8.

Santoso, S. (2016). *Panduan Lengkap SPSS Versi 23*. Elex Media Komputindo. https://books.google.co.id/books?id=qCtIDwAAQBAJ

Sari, L. D., Prihandono, T., & Sudarti. (2018). Pengaruh paparan medan magnet ELF (extremely low frequency) 500 µt dan 700 µt terhadap derajat keasaman (ph) daging ayam. *Seminar Nasional Pendidikan Fisika 2018*, *3*(1), 195–199.

Setyawan, F. E. B. (2017). *Pengantar Metodologi Penelitian (Statistika Praktis)*. Zifatama Jawara. https://books.google.co.id/books?id=s5uWDwAAQBAJ

Sohouli, M. H., Lari, A., Fatahi, S., Shidfar, F., Găman, M. A., Sernizon Guimarães, N., Sindi, G. A., Mandili, R. A., Alzahrani, G. R., Abdulwahab, R. A., Almuflihi, A. M., Alsobyani, F. M., Albu Mahmud, A. M., Nazzal, O., Alshaibani, L., Elmokid, S., & Abu-Zaid, A. (2021). Impact of soy milk consumption on cardiometabolic risk factors: A systematic review and meta-analysis of randomized controlled trials. *Journal of Functional Foods*, *83*, 1-13. https://doi.org/10.1016/j.jff.2021.104499

Suarjana, I. M., Padmiari, I. A. E., & Sugiani, P. P. S. (2019). Sosialisasi pentingnya konsumsi susu kedelai sebagai minuman sehat, kaya protein, dan serat serta alami untuk anak sekolah dasar di kecamatan Ubud kabupaten Gianyar. *Jurnal Pengabmas Masyarakat Sehat*, *1*(3), 208–215. https://doi.org/https://doi.org/10.33992/ms.v1i3.934

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*, 1–6. https://doi.org/10.1088/1742-6596/1465/1/012005

Suhendra, D., Nugraha, W. T., Nugraheni, Y. L. R. E., & Hartati, L. (2020). Korelasi kadar lemak dan laktosa dengan berat jenis susu sapi friesian holstein di kecamatan Ngablak kabupaten Magelang. *Agrinimal Jurnal Ilmu Ternak Dan Tanaman*, *8*(2), 88–91. https://doi.org/https://doi.org/10.30598/ajitt.2020.8.2.88-91

Suwito, W. (2010). Bakteri yang sering mencemari susu: Deteksi, patogenesis, epidemiologi, dan cara pengendaliannya. *Jurnal Litbang Pertanian*, *29*(3), 96–100. https://doi.org/10.21082/jp3.v29n3.2010.p96-100

Villarini, M., Gambelunghe, A., Giustarini, D., Ambrosini, M. V., Fatigoni, C., Rossi, R., Dominici, L., Levorato, S., Muzi, G., Piobbico, D., & Mariucci, G. (2017). No evidence of DNA damage by co-exposure to extremely low frequency magnetic fields and aluminum on neuroblastoma cell lines. *Mutation Research - Genetic Toxicology and Environmental Mutagenesis*, *823*, 11–21. https://doi.org/10.1016/j.mrgentox.2017.09.001

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