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THE EFFECT OF EXPOSURE TO EXTREMELY LOW FREQUENCY MAGNETIC FIELDS ON TEMPE FERMENTATION

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Abstract :
This study explores the novel effect of Extremely Low Frequency (ELF) magnetic field radiation on the ripening process of raw fermented tempe, a traditional Indonesian food made from soybeans. ELF magnetic fields are environmental factors that can influence the growth of microorganism activity. The study uses a unique laboratory experimental method that employs a Current Transformer (CT) device to produce an ELF magnetic field with an intensity of 500miu, which is a relatively high intensity compared to the natural background level of ELF magnetic field. The study examines 20 raw tempe samples, each weighing 100g, divided into two groups: a control group and an experimental group. The experimental group is exposed to the ELF magnetic field for 24 hours, while the control group is not. The study measures the changes in the microbial population, pH, moisture content, and sensory quality of the tempe samples after the exposure. The study aims to prove the effect of ELF magnetic field radiation on food security and to provide insights for the development of new food preservation techniques.

Keywords: Extremely Low Frequency, Electromagnetic, Microorganisms, Tempe

INTRODUCTION

The ELF magnetic field is an alternative technology that helps preserve food without reducing food quality. The ELF magnetic field comes from electromagnetic waves which are a combination of electric and magnetic fields that oscillate without any intermediary. Extremely Low Frequency force field in the electromagnetic wave spectrum, frequency below 300 Hz (Santini et al., 2005; Justo et al., 2006; Tirono, 2022; Rahayu et al., 2023). An electromagnetic field is a mixture or combination of a magnetic field and an electric field. The main sources of electromagnetic areas are generators, power generators, factories, doctor's equipment and many more. The very small magnetic field energy causes the resulting temperature changes to non-thermal impacts, which cannot cause temperature changes when connected through the system (Perez et al., 2007; Zhang et al., 2014; Bektiarso et al., 2020; Iswardani et al., 2023).

When electricity flows through transmission, distribution networks, or is used in various equipment, it produces magnetic fields and electric fields around those lines and equipment. This field can then spread to the surrounding environment and cause electromagnetic pollution. The level of impact of this pollution is still a subject, especially at low frequencies which are referred to as Extremely Low Frequencies (Gao, Zhang, & Feng, 2011; Zhang et al., 2016; Rahman & Sudarti, 2021; Sudarti et al., 2022; Tirono, 2022;). Along with this modern era, technology is developing rapidly, and this makes human exposure to electric and magnetic fields inevitable.

Advances in various technological tools have also become a source of exposure to magnetic fields. Electromagnetic waves come from two types of sources: natural and artificial. For example, natural sources of electromagnetic waves include gamma rays, X-rays, ultraviolet light, visible light, infrared light, radio waves, and microwaves. On the other hand, man-made electromagnetic sources come from cable systems and electrical equipment (Alvarez et al., 2006; Uzdenslry, 2009; Zhou et al., 2009; Magfirah, Prihandono, & Sudarti, 2022; Iswardani et al, 2023).

Exposure to Extremely Low Frequency electromagnetic waves can inhibit the decline in pH values, thereby slowing the growth of bacteria on a material or product. In this context, electromagnetic waves have great potential to increase food security and meet daily needs. By considering the intensity and duration of exposure to ELF electromagnetic waves in this process, this can be a useful reference in efforts to increase the durability of a food product (de Andrade et al., 2021; Li et al., 2021; Munawaroh, 2022; Sudarti et al., 2023).

Tempe is a fermented food made from soybeans or other types of beans using the molds Rhizopus oligosporus and Rhizopus oryzae. During fermentation, soybeans or other types of beans undergo a transformation into a product that has a unique taste, delicious texture and distinctive aroma. The presence of these microorganisms also provides digestive benefits, making tempe a healthy food choice that has a high vegetable protein content. The nutritional characteristic of tempe is taste. Therefore, tempe contains various nutrients that the body needs, such as fat, carbohydrates and minerals (Sudarti et al., 2018; Apriani et al., 2021; Nurhaerani et al., 2022; Guzmán-Armenteros et al., 2023).

The research does not mention the previous studies that have investigated the effect of Extremely Low Frequency magnetic field radiation on food security, especially on raw fermented tempe food. The research also does not explain the mechanism of how the Extremely Low Frequency magnetic field influences the growth of microorganisms in the tempe. The research does not mention the previous studies that have investigated the effect of Extremely Low Frequency magnetic field radiation on food security, especially on raw fermented tempe food. The research also does not explain the mechanism of how the Extremely Low Frequency magnetic field influences the growth of microorganisms in the tempe. Therefore, this study aims to explore the new effects of Very Low Frequency (ELF) magnetic field radiation on the ripening process of fermented raw tempe, a traditional Indonesian food made from soybeans.

RESEARCH METHOD

This research uses a type of laboratory experimental research by comparing two groups, namely the control group and the experimental group. The design used in this research used an experimental design with a completely randomized design consisting of a control group and an experimental group. The ingredients used in this research include tempe obtained from the Bondowoso area. The tool used in this research is an Extremely Low Frequency magnetic field source in the form of a CT or (Current Transformer) which produces an Extremely Low Frequency magnetic field with an intensity of 500miu.

The pH meter is used as a tool to measure the pH value, the balance is used to weigh the tempe for each group, and the ziplock plastic is used to wrap the tempe. The procedure that was carried out in this research was first to prepare 2kg of leavened tempe, then divide the tempe into two groups, namely the experimental group and the control group. Each group consists of 10 pieces of raw tempe.

RESULTS AND DISCUSSION

Electromagnetic waves are waves that have energy and magnetic charges without requiring a propagation medium. Unlike waves in general which require a propagation medium, electromagnetic waves do not require a propagation medium (the same as radiation). Because they do not require a propagation medium, electromagnetic waves are often referred to as electromagnetic radiation. Electromagnetic waves are shaped like transverse waves in general, namely the direction of propagation is perpendicular to the direction of vibration.

Some important concepts in electromagnetic wave radiation include: Electromagnetic Waves: Electromagnetic radiation is a form of energy that propagates through space in the form of electromagnetic waves. Electromagnetic waves are waves that have energy and magnetic charges without requiring a propagation medium. Unlike waves in general which require a propagation medium, electromagnetic waves do not require a propagation medium (the same as radiation). Because they do

not require a propagation medium, electromagnetic waves are often referred to as electromagnetic radiation. Electromagnetic waves are shaped like transverse waves in general, namely the direction of propagation is perpendicular to the direction of vibration (Potenza et al., 2012; Chen et al., 2019; Sudarti et al., 2022; Komaria et al., 2023).

Some important concepts in electromagnetic wave radiation include: Electromagnetic Waves: Electromagnetic radiation is a form of energy that propagates through space in the form of electromagnetic waves (Berg, & Berg, 2006; Sudarti et al., 2022; Bektiarso et al., 2023; Guzmán-Armenteros et al., 2023). These electromagnetic waves consist of an electric field and a magnetic field that swing continuously perpendicular to each other, and both propagate at the speed of light in a vacuum. Electromagnetic Spectrum: Electromagnetic waves can be grouped into various categories based on their wavelength or frequency. The electromagnetic spectrum includes radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.

The results obtained in the ELF practicum of raw tempe fermentation were the pH of raw tempe in the control group and experimental group as well as the average pH, the density of raw tempe in the control group and experimental group as well as the average density, color of raw tempe in the control group and experimental group, raw rhyzopus tempe in the control group and experimental group, texture of raw tempe in the control group and experimental group, aroma of raw tempe in the control group and experimental group, and the taste produced in the control group and experimental group in raw tempe.

Table 1. Measurement of pH of raw tempe

Control Group		Experiment Group	
K1	5.54	E1	5.03
K2	5.03	E2	5.54
K3	5.13	E3	5.54
K4	5.44	E4	5.44
K5	5.44	E5	4.52
K6	4.32	E6	5.44
K7	5.13	E7	6.25
K8	5.54	E8	5.34
K9	4.93	E9	4.83
K10	5.04	E10	6.36
PH Mean	5.154	PH Mean	5.429

Based on observations made, the tempe pH in the control group 1-10 had an average value of 5.154, grouping the experimental group 1-10 with an average value of 5.429. This means that the pH of these two groups has a value <7, this means that the tempe at the beginning of the fermentation of the control and experimental groups was acidic.

Table 2. Measurement of the density of raw tempe

Control Group				Experiment Group			
Sample	m	Δv	ρ	Sample	m	Δv	ρ
K1	100	70	1.4	E1	100	30	3.3
K2	100	40	2.5	E2	100	40	2.5
K3	100	50	2.0	E3	100	20	5.0
K4	100	30	3.3	E4	100	30	3.3
K5	100	70	1.4	E5	100	30	3.3
K6	100	30	3.3	E6	100	40	2.5
K7	100	60	1.6	E7	100	30	3.3
K8	100	50	2.0	E8	100	20	5.0
K9	100	30	3.3	E9	100	40	2.5
K10	100	30	3.3	E10	100	40	2.5
Average density			2.41	Average density			3.32

Based on the data above, it can be seen that the tempe in control groups 1-10 has a mass of 100 grams each and an average density of 2.41 g/m3. Tempe in experimental groups 1-10 each had a mass of 100 grams and an average density of 3.32 g/m3. The calculation of the density obtained is obtained from calculations as table 3.

Table 3. The calculation of the density obtained is obtained from calculations

Control Group	Experiment Group
K1: ρ=m/Δv = 100/70= 1,4 gr/ml	E1: ρ=m/Δv = 100/30= 3,3 gr/ml
K2: ρ=m/Δv = 100/40= 2,5 gr/ml	E2: ρ=m/Δv = 100/40= 2,5 gr/ml
K3: ρ=m/Δv = 100/50= 2 gr/ml	E3: ρ=m/Δv = 100/20= 5 gr/ml
K4: ρ=m/Δv = 100/30= 3,3 gr/ml	E4: ρ=m/Δv = 100/30= 3,3 gr/ml
K5: ρ=m/Δv = 100/70= 1,4 gr/ml	E5: ρ=m/Δv = 100/30= 3,3 gr/ml
K6: ρ=m/Δv = 100/30= 3,3 gr/ml	E6: ρ=m/Δv = 100/40= 2,5 gr/ml
K7: ρ=m/Δv = 100/60= 1,6 gr/ml	E7: ρ=m/Δv = 100/30= 3,3 gr/ml
K8: ρ=m/Δv = 100/50= 2 gr/ml	E8: ρ=m/Δv = 100/20= 5 gr/ml
K9: ρ=m/Δv = 100/30= 3,3 gr/ml	E9: ρ=m/Δv = 100/40= 2,5 gr/ml
K10: ρ=m/Δv = 100/30= 3,3 gr/ml	E10: ρ=m/Δv = 100/40= 2,5 gr/ml

Table 4. Tempe Color Table

Sample	Normal			Brownish			Black		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
K1	-	-	-	✓	✓	✓	-	-	-
K2	-	-	-	✓	✓	✓	-	-	-
K3	-	-	-	✓	✓	✓	-	-	-
K4	-	-	-	✓	✓	✓	-	-	-
K5	-	-	✓	✓	✓	-	-	-	-
K6	-	-	✓	✓	✓	-	-	-	-
K7	-	-	✓	✓	✓	-	-	-	-
K8	-	-	✓	✓	✓	-	-	-	-
K9	-	-	-	✓	✓	✓	-	-	-
K10	-	-	-	✓	✓	✓	-	-	-
Sample	Normal			Brownish			Black		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
E1	-	-	-	✓	✓	✓	-	-	-
E2	-	-	-	✓	✓	✓	-	-	-
E3	-	-	-	✓	✓	✓	-	-	-
E4	-	-	-	✓	✓	✓	-	-	-
E5	-	-	-	✓	✓	✓	-	-	-
E6	-	-	-	✓	✓	✓	-	-	-
E7	-	-	-	✓	✓	✓	-	-	-
E8	-	-	-	✓	✓	✓	-	-	-
E9	-	-	-	✓	✓	✓	-	-	-
E10	-	-	-	✓	✓	✓	-	-	-

Based on the table of raw tempe observation results, the color of raw tempe in the control group was mostly brownish. Meanwhile, in the experimental group, all raw tempe was brownish in color.

Table 5. Rhyzopus Table

Sample	Area (mm)			Thickness
	P (mm)	L (mm)	Wide (mm)	
K1	135	59	7.965	23
K2	125	60	7.500	20
K3	125	60	7.500	20
K4	130	70	9.100	10
K5	120	65	7.800	15
K6	120	65	7.800	10
K7	110	60	6.600	15
K8	120	60	7.200	10
K9	125	57	7.125	10
K10	120	60	7.200	15
Sample	Area (mm)			Thickness
	P (mm)	L (mm)	P (mm)	
E1	100	60	6.000	20
E2	100	60	6.000	20
E3	95	60	5.700	20
E4	100	55	5.500	30
E5	100	55	5.500	20
E6	100	60	6.000	20
E7	100	60	6.000	20
E8	100	55	5.500	15
E9	100	55	5.500	20
E10	100	55	5.500	15

Based on the table of rhyzopus observation results, the length of the control group ranged from 110mm-135mm, the width ranged from 57mm-70mm, the area ranged from 6000mm-9100mm, and the thickness ranged from 10-23mm. Meanwhile, in the experimental group, the length was mostly 100mm, the width ranged from 55mm-60mm, the area ranged from 5500mm-6000mm, and the thickness ranged from 15-30mm.

Table 6. Aroma Table

Sample	Normal/Typical			No fragrance			Rotten		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
K1	-	-	-	-	-	-	✓	✓	✓
K2	-	✓	-	-	-	-	✓	-	✓
K3	✓	✓	-	-	-	-	-	-	✓
K4	✓	✓	-	-	-	-	-	-	-
K5	✓	-	-	-	-	-	-	✓	✓
K6	✓	✓	-	-	-	-	-	-	✓
K7	✓	✓	-	-	-	-	-	-	✓
K8	✓	✓	-	-	-	-	-	-	✓
K9	✓	✓	-	-	-	-	-	-	✓
K10	-	-	-	-	-	-	✓	✓	✓
Sample	Normal/Typical			No fragrance			Rotten		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
E1	✓	✓	✓	-	-	-	-	-	-
E2	✓	✓	-	-	-	-	-	-	✓
E3	✓	✓	✓	-	-	-	-	-	-
E4	✓	✓	-	-	-	-	-	-	✓

Sample	Normal/Typical			No fragrance			Rotten		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
E5	✓	✓	✓	-	-	-	-	-	-
E6	✓	✓	✓	-	-	-	-	-	-
E7	✓	-	✓	-	-	-	-	✓	-
E8	✓	✓	✓	-	-	-	-	-	-
E9	✓	✓	-	-	-	-	-	-	✓
E10	✓	✓	-	-	-	-	-	-	✓

Based on the table of results observing the aroma of tempe in the control group, there was tempe that had a distinctive aroma but there was also some that had a foul smell. Meanwhile, in the experimental group, most of the tempe had a distinctive aroma.

Table 7. Texture Table

Sample	Normal/Typical			No fragrance			Rotten		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
K1	-	-	-	✓	✓	✓	-	-	-
K2	-	-	-	✓	✓	✓	-	-	-
K3	-	-	-	✓	✓	✓	-	-	-
K4	-	-	-	✓	✓	✓	-	-	-
K5	-	-	-	✓	✓	✓	-	-	-
K6	-	-	-	✓	✓	✓	-	-	-
K7	-	-	-	✓	✓	✓	-	-	-
K8	-	-	-	✓	✓	✓	-	-	-
K9	-	-	-	✓	✓	✓	-	-	-
K10	-	-	-	✓	✓	✓	-	-	-
Sample	Normal/Typical			No fragrance			Rotten		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
E1	-	-	-	✓	✓	✓	-	-	-
E2	-	-	-	✓	✓	✓	-	-	-
E3	✓	✓	✓	-	-	-	-	-	-
E4	-	-	-	✓	✓	✓	-	-	-
E5	-	-	-	✓	✓	✓	-	-	-
E6	-	-	-	✓	✓	✓	-	-	-
E7	✓	✓	✓	-	-	-	-	-	-
E8	✓	✓	✓	-	-	-	-	-	-
E9	✓	✓	✓	-	-	-	-	-	-
E10	-	-	-	✓	✓	✓	-	-	-

Based on the table of results observing the texture of tempe in the control group, all tempe had a soft texture. Meanwhile, in the experimental group, the texture of tempe was dense and some was soft. Based on the table of tempe taste observation results, the control group and the experimental group predominantly had a poor taste, indicated by the rating number 1 which means not good, number 2 which means quite good, and number 3 which means very good.

Table 8. Taste Table

Sample	Good/typical			Bitter			Sour		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
K1	1	1	1	-	-	-	-	-	-
K2	1	1	1	-	-	-	-	-	-
K3	1	1	1	-	-	-	-	-	-
K4	1	1	1	-	-	-	-	-	-
K5	1	1	1	-	-	-	-	-	-
K6	1	1	1	-	-	-	-	-	-
K7	1	1	1	-	-	-	-	-	-
K8	1	1	1	-	-	-	-	-	-
K9	1	1	1	-	-	-	-	-	-
K10	1	1	1	-	-	-	-	-	-
Sample	Normal/Typical			No fragrance			Rotten		
	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)	P(1)	P(2)	P(3)
E1	1	1	1	✓	✓	✓	-	-	-
E2	1	1	1	✓	✓	✓	-	-	-
E3	2	2	2	-	-	-	-	-	-
E4	1	1	1	✓	✓	✓	-	-	-
E5	1	1	1	✓	✓	✓	-	-	-
E6	1	1	1	✓	✓	✓	-	-	-
E7	2	2	2	-	-	-	-	-	-
E8	2	2	2	-	-	-	-	-	-
E9	1	1	1	-	-	-	-	-	-
E10	1	1	1	✓	✓	✓	-	-	-

The physical condition of the taste in the experimental group according to observer 1, Observer 2 and also observer 3 had the same taste observation, namely El had a taste that was less than the normal taste of tempe as well as E2, E4, E5, E6, E9, E10 while E3 , E7 and, E8 taste pretty much the same as normal tempe.

Description of the table observations in the form of number 1 Raw elf tempe products included in this category may have significant differences in taste compared to original tempe, number 2 Raw elf tempe products in this category may have some elements of tempe taste, but do not completely resemble the taste original tempe, and number 3 in the ELF product, raw tempe in this category has a taste that is almost identical to original tempe. Meanwhile, in the statement P(1) is the first observer, P(2) is the second observer, while P(3) is the third observer.

The research is novel because it uses a CT device or (Current Transformer) that produces an Extremely Low Frequency magnetic field with an intensity of 500miu, which is a relatively high intensity compared to the natural background level of Extremely Low Frequency magnetic field. The research also explores the effect of Extremely Low Frequency magnetic field radiation on a specific type of food, which is raw fermented tempe, which is a traditional Indonesian food made from soybeans. The research has some limitations, such as the small sample size of 20 raw tempe samples, the lack of control variables such as temperature, humidity, and light, and the short duration of exposure to the Extremely Low Frequency magnetic field, which is only 24 hours. The research also does not measure the changes in the chemical, physical, and sensory properties of the tempe after the exposure.

CONCLUSION

Based on the research results, it can be concluded that Extremely Low Frequency (ELF) magnetic field radiation can affect the samples tested. The results of the sample had a distinctive smell, even rotten, the color of the tempe also changed, the texture of the tempe became a little dense, and it had a non-distinctive taste.

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