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The Effect of ELF Electromagnetic Radiation on Microorganism Development in The Sticky Rice Tape Production Process

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Abstract
The purpose of this research is to assess the effect of electromagnetic radiation, specifically Extremely Low Frequency (ELF) radiation, on the growth and activity of microorganisms involved in the fermentation of sticky rice for making *tape ketan*. The research method involves applying ELF radiation treatment to 10 samples of *tape ketan* fermented by yeast microorganisms and comparing them with 10 other samples that were not exposed to ELF radiation. Microbial growth is measured using parameters such as pH, alcohol content, sensory evaluation through taste, and observations of changes in appearance, odor, and flavor, as well as comparisons of their density. The results indicate changes in the fermentation rate, the number of microorganisms, and the overall quality of *tape ketan* affected by ELF radiation. Some types of microorganisms exhibit slower growth compared to those in *tape ketan* that were not exposed to ELF radiation.

Keywords: *density, microorganisms, effect of ELF radiation, pH, electromagnetic radiation*.

Pengaruh Radiasi Elektromagnetik ELF Terhadap Perkembangan Mikroorganisme dalam Proses Pembuatan Tape Ketan

Abstrak
Tujuan penelitian ini adalah untuk menilai pengaruh radiasi elektromagnetik atau *Extremely Low Frequency (*ELF) terhadap pertumbuhan dan aktivitas mikroorganisme yang terlibat dalam fermentasi beras ketan untuk pembuatan tape ketan. Metode penelitian yang digunakan melibatkan pemberian perlakuan radiasi ELF pada 10 sampel tape ketan yang difermentasi oleh mikroorganisme ragi, kemudian dibandingkan dengan 10 sampel tape ketan lainnya yang tidak terpapar radiasi ELF. Pengukuran pertumbuhan mikroba dilakukan dengan menggunakan parameter seperti pH, kadar alkohol, evaluasi sensori melalui uji rasa, serta pengamatan terhadap perubahan tampilan, aroma, dan cita rasa, serta perbandingan kerapatan mikroba. Hasil penelitian menunjukkan adanya perubahan pada laju fermentasi, jumlah mikroorganisme, dan kualitas tape ketan yang dipengaruhi oleh radiasi ELF. Beberapa jenis mikroorganisme mengalami pertumbuhan yang lebih lambat dibandingkan dengan tape yang tidak diberi perlakuan radiasi ELF.

Kata Kunci: *densitas, mikroorganisme, pengaruh radiasi ELF, pH, radiasi elektromagnetik.*

Introduction

Nowadays, electromagnetic radiation has become an inseparable part of everyday life. In addition to being produced by technological devices, exposure to magnetic fields is often present around us without our realization. Electromagnetic radiation in the frequency range of 30–300 Hz is known as Extremely Low Frequency (ELF). ELF radiation is a type of non-ionizing radiation because it does not have the ability to ionize the material it passes through. Given the potential negative effects of ELF radiation on the environment and human health, research on exposure to this radiation is crucial (Cintya et al., 2024).

Electromagnetic waves are a natural phenomenon that serves as the foundation for many modern technologies. These waves are defined as waves that can propagate without requiring a medium. ELF plays a significant role in various fields, including wireless communications, environmental monitoring, and geophysical studies. Additionally, ongoing research aims to explore and develop its potential so that its unique characteristics can be optimally utilized (Ariyani et al., 2024). Electromagnetic waves consist of electric and magnetic field components (Rasiman et al., 2024). These waves propagate through space at the speed of light and cover a wide spectrum, including ultraviolet rays, radio waves, gamma rays, visible light, X-rays, and infrared rays (Seniari N. M., 2020). The phenomenon of electromagnetic waves is essential in various aspects of modern life, including communication, medical technology, industry, and scientific research. Electromagnetic waves can influence biological systems, particularly in health, agriculture, and biotechnology (Iswardani et al., 2023).

The electromagnetic wave spectrum is categorized based on wavelength and frequency, including gamma rays and X-rays (short wavelength, high frequency), microwaves, ultraviolet rays, infrared radiation, visible light, and radio waves (long wavelength, low frequency) (Jumingin et al., 2022). Low-frequency electromagnetic waves (ELF), typically in the range of 0–300 Hz, have gained significant attention in biological and medical research (Khumairoh, 2023). Various studies have demonstrated that ELF exposure can affect biological processes at both the cellular level and the organism as a whole. These effects may include changes in enzyme activity, cell division, metabolic rate, and even impacts on the nervous system and microbial growth. Therefore, a deeper understanding of ELF's effects on biological systems is essential for applications in industrial process control, medical technology, agriculture, and biotechnology.

Food processing often produces high-quality ingredients, but these ingredients can be highly perishable. One alternative technology to address this issue is ELF radiation, which aids in food preservation without compromising quality. ELF exposure can damage the cell structures of pathogenic bacteria, leading to their destruction. While low-intensity electromagnetic radiation has minimal effects on cells, high-intensity radiation has a greater potential to influence cell development. The application of ELF magnetic field technology in preserving *tape ketan* can inhibit the growth of spoilage-causing microorganisms, thereby extending shelf life and ensuring safety for consumption (Munawaroh, 2022).

Low-frequency electromagnetic waves (ELF) have been applied in various technological fields, such as communication systems, remote sensing, and medical devices. However, the effects of ELF radiation on living organisms, particularly microorganisms involved in fermentation, remain a subject of ongoing research. Previous studies have shown that extremely low-frequency magnetic fields can influence microbial growth, metabolism, and the quality of biotechnological products, such as those in food and beverage fermentation (Nuriyah et al., 2022). As electromagnetic processing technology advances, it is crucial to understand how ELF waves impact biological and biotechnological processes. Such insights can pave the way for new industrial applications involving microorganisms while enhancing efficiency and product quality. The suitability of food products for consumption can often be determined by evaluating their shelf life (Utami & Zakiya El Firdausi, 2024). Previously, ELF radiation have been implemented by Tiwulandari et al. (2024) to enhance the durability (shelf life) of meat.

Tape, a traditional fermented food, is made by fermenting sticky rice to create *tape ketan*, a delicacy known for its distinctive taste. Fermentation is a crucial biochemical process in *tape ketan* production, involving microorganisms such as *Saccharomyces cerevisiae* (yeast) and various lactic acid bacteria. During fermentation, these microorganisms convert starch (carbohydrates) into glucose, imparting a characteristic taste and aroma to *tape ketan* (Firdausi, 2023). The success of this process depends on several factors, including humidity, temperature, fermentation duration, and environmental conditions that support microbial growth (Kanino, 2019). The fermentation of *tape ketan* consists of four stages. In the first stage, starch molecules (amylum) in sticky rice are broken down into simple sugars through enzymatic hydrolysis. In the second stage, these sugars undergo fermentation, producing alcohol. In the third stage, alcohol is oxidized into organic acids by *Acetobacter* bacteria. Finally, in the fourth stage, some organic acids react with alcohol, forming ester compounds that contribute to the characteristic aroma of *tape ketan* (Rahmawati et al., 2023). The shelf life of *tape ketan* is largely influenced by acid-forming bacteria, which directly impact the product's pH (acidity level). Bacterial activity in the fermentation process produces acetic acid (CH_3COOH), which can lower pH. ELF magnetic field technology can help prevent excessive pH reduction by transferring energy to bacterial ions, ultimately leading to bacterial cell death. Research by Ferlita et al. (2024) has also shown that ELF magnetic fields can enhance food quality and extend shelf life. Magnetic fields influence microbial growth and reproduction through electromagnetic oscillations.

The quality of *tape ketan* is not only determined by taste but also by its sugar, alcohol, and acidity content. By reducing acid-producing microorganisms, pH decline can be inhibited. Electromagnetic waves play a vital role in controlling microbial growth in the food industry, particularly through pH regulation. pH, which indicates acidity or alkalinity, affects microbial activity. Most bacteria grow optimally in a neutral pH range (4.6–7.0). Therefore, pH control is a key strategy for managing microbial populations that contribute to food spoilage. Electromagnetic wave technology enables pH monitoring and regulation to maintain food quality and longevity (Shabitna et al., 2023).

One of the advantages of ELF magnetic fields is their non-ionizing nature, low energy level, and ability to penetrate most materials. In contrast, electric fields lack penetration capability. As a result, ELF magnetic fields have become a focal point of research, including studies conducted by students, aiming to develop solutions for various challenges in the food industry (Sudarti et al., 2021). ELF fields, with frequencies below 300 μT, belong to the non-ionizing radiation spectrum. Non-ionizing radiation, including infrared radiation and microwaves, lacks sufficient energy to ionize atoms or molecules. These electromagnetic waves arise from oscillating electric and magnetic fields perpendicular to their direction of propagation. Unlike electric fields, which are easily obstructed by barriers, magnetic fields can penetrate most materials, including solid objects. Moreover, electric fields require a medium to conduct current, while ELF magnetic fields cannot be blocked and are generated wherever electric currents flow (Yulandari et al., 2024). According to Iswardani et al. (2023), both magnetic and electric fields form wherever electrical currents exist.

This research aims to investigate the impact of low-frequency electromagnetic waves on various biological systems and to identify the mechanisms underlying biological responses to ELF radiation. Through this study, valuable contributions can be made toward developing more environmentally friendly and efficient technologies while deepening our understanding of electromagnetic wave applications across different industries and scientific research domains.

Method

Research Types, Equipment, and Materials

The research conducted was an experimental study in a laboratory setting using a control and experimental group method, where the reactions of both groups were compared. The experimental group (E1-10) was exposed to magnetic radiation, while the control group (K1-10) received no treatment. A total of 20 packs of early fermentation sticky rice (two days before cooking) were used, divided into two trays, with each tray containing 50 grams of sticky rice. The study involved sticky rice that had been inoculated with yeast and subsequently treated with an ELF magnetic field at 300 μT for an exposure time of 20 minutes. Data collection included measurements of pH and density, as well as an examination of the physical condition of the samples. The equipment and materials used in this experiment included plastic trays, an ELF Magnetic Field Generator, spoons, early fermented sticky rice, 20 large zip lock bags, label paper, permanent markers, and one EMF meter.

Measurement Method

The measurement method involved examining the physical condition of *tape ketan* (sticky rice tape), which included aroma, texture, and taste. Taste assessment was conducted using a scale of 1–3, where 1 indicated "less," 2 indicated "moderate," and 3 indicated "strong."

The second step was measuring the density. This was done by taking a portion of each sample, weighing it using a digital scale, and recording the results. A measuring cup was filled with approximately 30 ml of water, and this initial volume was recorded as V_0. The weighed sample was then placed into the measuring cup, and the new volume was recorded as V_1. The density of the sample was calculated using the formula:

$$\rho = \frac{m}{\Delta V} \quad (1)$$

where $\Delta V = V_1 - V_0$. The observation results for ΔV were then recorded in the observation table. The pH measurement was conducted by mixing the sample with 100 ml of water and stirring until evenly distributed. A pH meter was then dipped into the solution to obtain the reading.

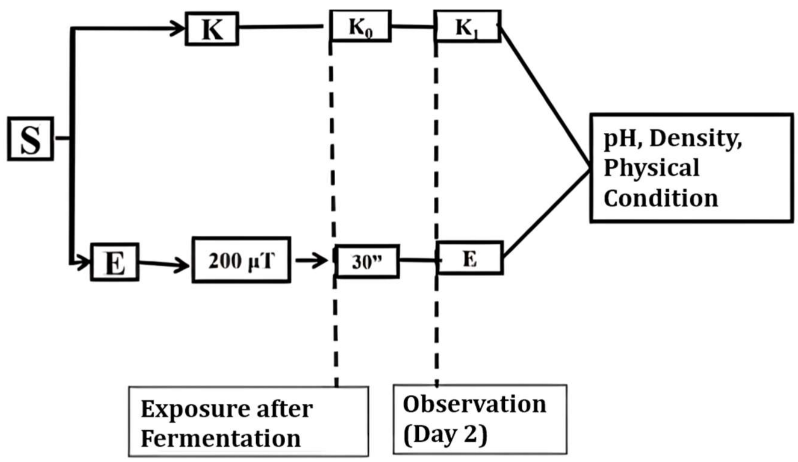

Figure 1. Experimental group and control group design

Results and Discussion

In this study, *tape ketan* (sticky rice tape) was used with two methods: the experimental group was exposed to ELF radiation, while the control group was not. The density of *tape ketan* is shown in Table 1. Initially, the sticky rice tape had a mass of 50 grams. After fermentation, its mass decreased, as indicated in the data. The initial volume of the sticky rice tape was measured at 100 ml. After treatment, the volume increased. The change in volume (ΔV) was determined by subtracting the initial volume from the final volume.

Table 1. *Tape ketan* (sticky rice tape) experiment results in the control group, showing mass, volume, and density measurements before and after fermentation

Control Group				Experimental Group			
Sample	M	ΔV	ρ	Sample	M	ΔV	ρ
KI	49	45	1.08	E1	49	40	12.25
K2	48	30	1.60	E2	49	30	1.63
K3	48	35	1.06	E3	49	45	1.08
K4	49	30	1.63	E4	49	30	1.63
K5	48	25	1.92	E5	49	40	1.225
K6	48	40	1.20	E6	49	30	1.63
K7	49	35	1.40	E7	49	45	1.08
K8	49	45	1.08	E8	49	30	1.63
K9	49	45	1.08	E9	49	30	1.63
K10	47	30	1.56	E10	48	45	1.06
Average Density			1.361	Average Density			1.382

From the results, its clearly presented that he average density of the experimental sample was higher than that of the control group. Furthermore, observations of the texture of *tape ketan* (sticky rice tape) are presented in Table 2.

Table 2. Observation of *tape ketan* (sticky rice tape) texture, comparing the experimental group (with ELF exposure) and the control group (without ELF exposure)

Control Group				**Experimental Group**			
Sample	**Solid** (p1, p2, p3)	**Soft** (p1, p2, p3)	**Watery** (p1, p2, p3)	**Sample**	**Solid** (p1, p2, p3)	**Soft** (p1, p2, p3)	**Watery** (p1, p2, p3)
E1	1,1,1	3,3,3	1,1,1	K1	1,1,1	3,3,3	3,3,3
E2	2,2,2	2,2,2	1,1,1	K2	2,2,2	2,2,2	2,2,2
E3	3,3,3	1,1,1	1,1,1	K3	2,2,2	2,2,2	1,1,1
E4	3,3,3	1,1,1	2,2,2	K4	2,2,2	2,2,2	1,1,1
E5	3,3,3	1,1,1	3,3,3	K5	1,1,1	3,3,3	1,1,1
E6	3,3,3	1,1,1	1,1,1	K6	1,1,1	3,3,3	1,1,1
E7	3,3,3	1,1,1	2,2,2	K7	2,2,2	2,2,2	2,2,2
E8	3,3,3	1,1,1	1,1,1	K8	2,2,2	2,2,2	2,2,2
E9	3,3,3	1,1,1	2,2,2	K9	2,2,2	2,2,2	1,1,1
E10	2,2,2	2,2,2	1,1,1	K10	3,3,3	1,1,1	1,1,1

In Table 2, the effect of a 300 μT ELF magnetic field and electric current on texture resistance was observed after a period of three days without ELF exposure, with samples stored at room temperature. Groups K2, K3, K4, K6, K7, K8, and K9 produced a very dense texture (3). Groups K1 and K5 had a less dense texture (1), while group K10 was also very dense (3). Regarding softness, group K1 was very soft and watery, while groups K2, K3, K4, K6, K7, K8, and K9 produced a moderately soft texture (2). Group K10 had a less soft texture (1). In terms of water content, groups K2, K3, K7, and K8 had a moderately watery texture (2), while groups K4, K5, K6, K9, and K10 had a less watery texture (1) (Khumairoh, 2023).

For the experimental group exposed to the 300 μT ELF magnetic field and electric current, group E1 had a less dense texture (1), groups E2 and E10 had a moderately dense texture (2), and groups E3, E4, E5, E6, E7, E8, and E9 had a very dense texture (3). Regarding softness, group E1 was very soft (3), while groups E3, E4, E5, E6, E7, E8, and E9 had a less soft/mushy texture (1). Groups E2 and E10 had a moderately soft texture (2). In terms of water content, groups E1, E2, E3, E6, and E10 had a less watery texture (1), while group E5 was very watery (3). Based on these results, the ideal quality of *tape ketan* (sticky rice tape) has a moderately soft and dense texture, meaning it is neither too soft and watery, nor too dense (Khumairoh, 2023).

Table 3. Taste results of sticky rice tape, comparing the experimental group (with ELF exposure) and the control group (without ELF exposure)

Control Group				**Experimental Group**			
Sample	**Good** (p1, p2, p3)	**Bitter** (p1, p2, p3)	**Sour** (p1, p2, p3)	**Sample**	**Good** (p1, p2, p3)	**Bitter** (p1, p2, p3)	**Sour** (p1, p2, p3)
E1	1,1,1	1,1,1	1,1,1	K1	2,2,2	1,1,1	1,1,1
E2	2,2,2	1,1,1	1,1,1	K2	3,3,3	1,1,1	1,1,1
E3	2,2,2	1,1,2	2,2,2	K3	2,1,2	1,1,1	1,1,1
E4	1,1,1	1,1,2	2,2,2	K4	3,2,3	1,1,1	1,1,1
E5	2,2,2	1,1,1	1,1,1	K5	3,3,3	1,1,1	1,1,1
E6	1,1,1	2,2,2	2,2,2	K6	2,2,2	1,1,1	1,1,1
E7	2,2,2	1,1,1	1,1,1	K7	2,2,2	1,1,1	1,1,1
E8	1,1,1	2,2,2	2,2,2	K8	2,2,2	2,2,1	1,1,1
E9	2,2,2	1,1,1	1,1,1	K9	2,2,2	1,1,2	2,2,2
E10	1,1,1	1,2,1	2,2,2	K10	1,1,1	1,1,1	1,1,1

The results of the study on the effect of a 300 μT extremely low frequency (ELF) magnetic field and electric current on sticky rice tape showed that after a period of 3 days without exposure to the ELF magnetic field at room temperature, groups K1, K3, K6, K7, K8, and K9 produced a fairly/moderately distinctive taste (2). This indicates fairly good quality, with a taste that is neither too bitter nor too sour (1). On the other hand, groups K2, K4, and K5 showed very good quality (3), with some samples having a slightly sour (1) and slightly bitter (1) taste. Group K10, however, showed very poor quality, with a fairly sour (2) and fairly bitter (2) taste. It is possible that factors such as an unoptimized fermentation process, sterility and cleanliness at each stage, and the duration of fermentation contributed to these results (Khumairoh, 2023).

The results of the ELF 300 µT magnetic field and electric current exposure on the experimental group's sticky rice tape showed that after a 3-day sedimentation period at room temperature and exposure to the ELF 300 µT field for 20 minutes, groups E1, E4, E6, E8, and E10 produced a less distinctive taste (1), tending to be slightly sour (1) or moderately sour (2). Meanwhile, groups E2, E3, E5, E7, and E9 produced a fairly distinctive taste (2), with very little sourness or bitterness (1). The flavors in the experimental group were influenced by several factors, such as yeast fermenting carbohydrates (glucose and fructose) into carbon dioxide and alcohol during the fermentation process, which contributed to bacterial growth and a slight brown color change in some samples. This discoloration is influenced by fungal and bacterial decay. Therefore, exposure to a 300 µT ELF magnetic field inhibited microbial growth and potentially damaged bacterial and fungal cell structures in sticky rice tape (Khumairoh, 2023).

Table 4. Observation of sticky rice tape aroma, comparing the experimental group (with ELF exposure) and the control group (without ELF exposure)

Control Group				Experimental Group			
Sample	**Normal** (p1, p2, p3)	**No Smell** (p1, p2, p3)	**Rotten** (p1, p2, p3)	**Sample**	**Normal** (p1, p2, p3)	**No Smell** (p1, p2, p3)	**Rotten** (p1, p2, p3)
E1	3,3,3	1,1,1	1,1,1	K1	2,2,2	1,1,1	1,1,1
E2	2,2,2	1,1,1	1,1,1	K2	1,2,1	1,1,1	1,1,1
E3	2,3,2	1,1,1	1,1,1	K3	1,1,1	1,1,1	1,1,1
E4	2,2,2	1,1,1	1,1,1	K4	2,2,1	1,1,1	1,1,1
E5	2,2,2	1,1,1	1,1,1	K5	2,2,1	1,1,1	1,1,1
E6	1,1,1	1,1,1	1,1,1	K6	2,2,2	1,1,1	1,1,1
E7	2,2,2	1,1,1	1,1,1	K7	2,2,2	1,1,1	1,1,1
E8	2,3,2	1,1,1	1,1,1	K8	2,2,2	1,1,1	1,1,1
E9	2,2,2	1,1,1	1,1,1	K9	2,2,2	1,1,1	1,1,1
E10	2,2,2	1,1,1	1,1,1	K10	1,1,2	1,1,1	1,1,1

Panelists conducted the experiment for aroma directly by inhaling one sample at a time. Panelist 1 to 3 gave a score of 2 (moderate) to samples K1, K6, K7, K8, and K9 for their distinctive aroma. Samples K2 and K4 received a score of 1 (less) from panelist 1 and 3, while panelist 2 gave them a score of 2 (moderate) for a distinctive aroma. Samples K3 and K10 received a score of 1 (less) from all three panelist. Sample K5 received a score of 2 (moderate) from panelist 1 and 2, while panelist 3 gave it a score of 1 (less) for a distinctive aroma. In the experimental section (E1–E10), the aroma test was conducted using three panelists. For the “normal” aroma category, the panelist noted that the aroma was not too pungent, resulting in an average score of 2. In the “no smell” aroma category, the panelists gave a score of 1 across all samples, as all sticky rice tape in this section had a detectable aroma. In the “rotten” aroma category, the panelists also assigned a score of 1 to all samples, as none of the sticky rice tape in this experimental section exhibited a rotten smell.

From the Table 8, the control group had a higher pH compared to the experimental group. For example, sample K5 had a pH of 6.8, while the experimental group had a pH of 6.5. Additionally, other samples in the control group also showed an increase in pH. Ideally, the increase in pH should have occurred in the experimental group exposed to 300 µT electromagnetic field (ELF) radiation and electric current, as these factors can influence the growth of microorganisms depending on storage duration. pH values tend to increase when not exposed to ELF. Conversely, when exposed to ELF, the pH values decrease. ELF exposure and storage time play a role in inhibiting the growth of fungi and bacteria, which affects the decay process. The 300 µT ELF magnetic field can damage the cell structure of bacteria and fungi responsible for the deterioration of sticky rice tape.

Table 8. The result of pH measurement experiment

Control Group		Experimental Group	
K1	6,6	E1	6
K2	6,6	E2	6,4
K3	6,6	E3	6,3
K4	6,6	E4	6,3
K5	6,8	E5	6,5
K6	6,3	E6	6,2
K7	6,6	E7	6
K8	6,2	E8	6,2
K9	6,4	E9	6,5
K10	6,6	E10	6,4
Average pH	6,53	Average pH	6,28

The experimental group showed a higher pH than the control group when exposed to a 1000 μT ELF magnetic field, indicating that pH values in the control group were lower than in the experimental group (Ramadhani et al., 2024). However, in this study, pH measurements showed that the control group had a higher pH than the experimental group. This discrepancy is likely due to measurement errors, such as the use of uncalibrated tools, leading to inaccurate data. Errors in sample collection and incorrect reading of the pH meter scale could also have contributed to the inconsistencies. The pH levels in the control group influenced taste, texture, and aroma indicators. The experimental group had a sourer taste, while the control group had a sweeter taste. The texture of the control group was softer and waterier, whereas the experimental group had a denser texture with minimal water content. Additionally, the aroma of the control group was stronger compared to the experimental group.

Based on the data obtained, exposure to a 300 μT ELF magnetic field and electric current affected pH and water content, although the impact was not significant. This could be due to external factors such as temperature, air humidity, the materials used in treatment, and other environmental conditions. These factors influence pH and water content during the fermentation process, which is also controlled by enzymatic and microbiological activity (Apriani et al., 2021).

Conclusion and Suggestions

The results of the experiment showed a significant difference in the physical properties of sticky rice tape exposed to a 300 μT electromagnetic field and electric current compared to sticky rice tape that was not exposed. Exposure to electromagnetic fields and electric currents inhibited bacterial activity, improved fermentation quality, and slowed down the decay process. Physically, the aroma of sticky rice tape exposed to electromagnetic fields was stronger and more distinctive than that of sticky rice tape that was not exposed. The texture of exposed sticky rice tape was denser, whereas unexposed sticky rice tape tended to be softer and waterier. However, there was no significant difference in taste, although the experimental group had a slightly sourer flavor.

Exposure to a 300 μT electromagnetic field and electric current has been shown to be effective in maintaining the physical quality of sticky rice tape. This is due to the inhibitory effects of electromagnetic fields and electric currents on microbial growth, which helps extend the shelf life and preserve the physical quality of sticky rice tape. For future research, variations in ELF intensity and exposure duration should be conducted to gain a deeper understanding of their effects on sticky rice tape fermentation.

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