FREQUENCY DEPENDENCE OF PROMOTION DEGREE IN LACTIC FERMENTATION PROMOTION USING SOUND AND ULTRASOUND

Kunihiko Katayama, Nobuyoshi Masuzawa

Department of Electronics and Communication Engineering,
Musashi Institute of Technology
1-28-1 Tamazutsumi, Setagaya-ku
Tokyo 158-8557, Japan
masuzawa@ipc.musashi-tech.ac.jp

Abstract

Food processing with lactic acid bacteria has been made in various ways. Yogurt and kefir are representative and are paid to attention recently because they are good for health. By adding lactic acid bacteria to milk, yogurt and kefir are produced by lactic acid fermentation. We have studied promotion effect of ultrasonic irradiation in the fermentation process. In the previous studies, it was proven that ultrasonic irradiation was extremely effective to promote fermentation of yogurt and kefir and that degree of increase of promotion with ultrasonic frequency is slight.

In this study, considering the change of degree of increase of promotion with frequency is larger in audio frequency range, we expanded the measurement range from ultrasonic frequency to audio frequency of 5 kHz. Since we could not find appropriate vibrating system in audio frequency range on the market, we made and used vibrating systems with ultrasonic transducer to both ends of which metal pieces adhered in order to decrease resonant frequency.

From the measurement result of wide frequency range, it was found that degree of increase of promotion was changed abruptly in the audio frequency range as expected and that the change was exponential.

Eds.: J. Eberhardsteiner, H.A. Mang, H. Waubke

INTRODUCTION

In recent years, various kinds of food processing using lactic acid bacteria are carried out. Yogurt and kefir are paid to attention recently because they are good for health. Yogurt and kefir are produced through lactic acid fermentation by adding lactic acid bacteria to milk [1][2][3]. We have studied on the promotion of fermentation by irradiating ultrasound in the fermentation process. In the previous studies, the following facts were proven [4][5][6].
(1) Ultrasonic irradiation is extremely effective to promote fermentation.
(2) Degree of increase of promotion with ultrasonic frequency is slight.
In this study, considering the change of degree of increase of promotion with frequency is larger in audio frequency range, we expanded the measurement range from ultrasonic frequency to audio frequency.

LACTIC FERMENTATION

By adding lactic acid bacteria to milk, yogurt and kefir are produced by lactic acid fermentation. The lactic acid bacteria resolve the glucose of milk in an anaerobic condition and generate lactic acid. pH falls down by generated lactic acid, and protein solidifies.

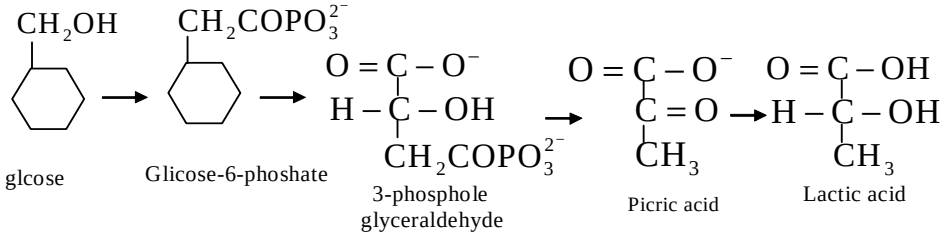

Figure 1. Generation of lactic acid

METHOD

A schematic of the experimental equipment is shown in Fig. 2. Water is filled into a water tank. Water temperature in the tank is kept at 30℃ by temperature regulator. Sound absorber material was placed inside of the tank to avoid the effects of standing waves. In this study, the highly activated kefir fungus from Nakagaki Co. is used. 1g of kefir fungi are put and stirred when water in a water tank and 500 ml of milk in a polyethylene bag became the same temperature. Defining this moment as the beginning of fermentation, fermentation time is measured. The degree of progress is judged by a change of acidity with lactic acid generation. For 12 hours, acidity is measured every 30 min by pH meter. Completely solidified time is

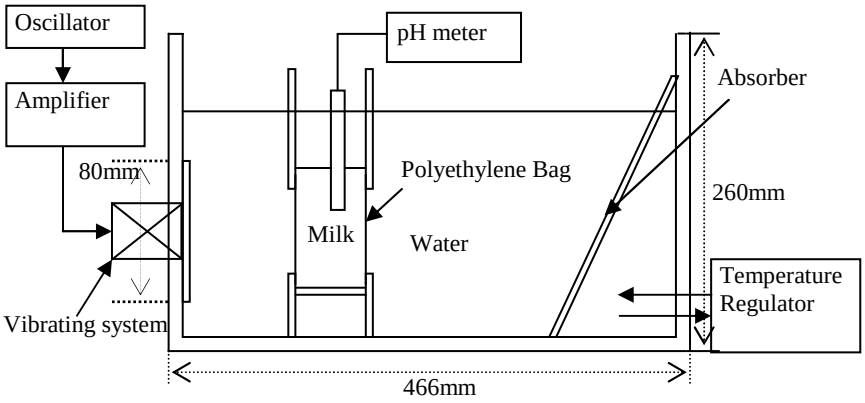

Figure 2. Schematic of experimental setup

defined as the time when pH becomes 4.5 in this experiment. Ultrasonic frequencies are changed by installing vibration systems of different frequencies.

Vibrating systems

(1) Ultrasonic frequency range

We made the vibrating systems in this frequency range as follows. Plain disk ceramic transducer was bonded to circular stainless steel plate of 80 mm diameter. We provided this kind of vibrating systems of 28 kHz, 150 kHz and 250 kHz

(2) Audio frequency range (Under 20 kHz) [7]

Since we could not find appropriate vibrating system in audio frequency range on the market, we made the vibrating systems in this frequency range as follows. As shown in figure 3, we made and used vibrating systems with ultrasonic ferrite transducer of 20 kHz to both ends of which metal pieces adhered in order to decrease resonant frequency. By changing the length of the bonded metal pieces, the resonant frequencies fall from 20 kHz to 5 kHz, 7 kHz and 16 kHz. Respective transducers were bonded to circular stainless steel plates of 80 mm diameter.

Figure 4 to figure 7 show vibrating systems used in this study. Figure 4 is a picture of 20 kHz vibrating system. As shown, the vibrating system consists of 20 kHz ferrite transducer and circular stainless steel plate. Figure 5 is resonant characteristics of 20 kHz vibrating system of Fig.4. Figure 6 is a picture of audio frequency vibrating system. As shown, to both ends of 20 kHz ferrite transducer, metal pieces to decrease resonant frequency are adhered. Figure 7 is resonant characteristics of the vibrating system of Fig. 6. Resonant frequency is 7 kHz.

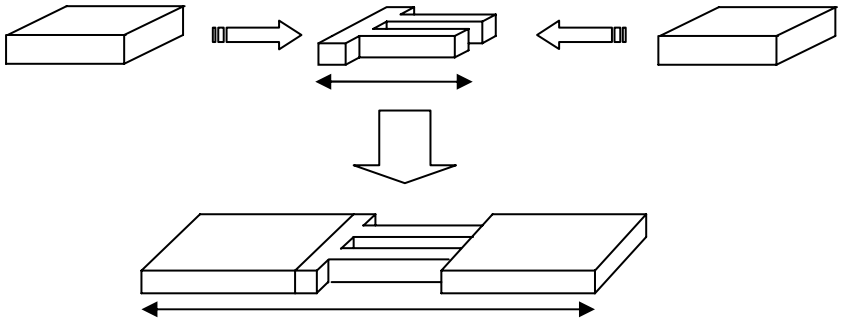

Figure 3. Schematic of vibrating system for audio frequency

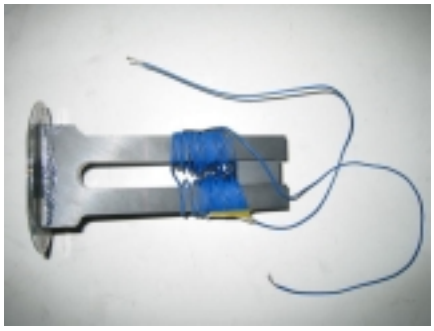

Figure 4. Picture of 20 kHz vibrating system

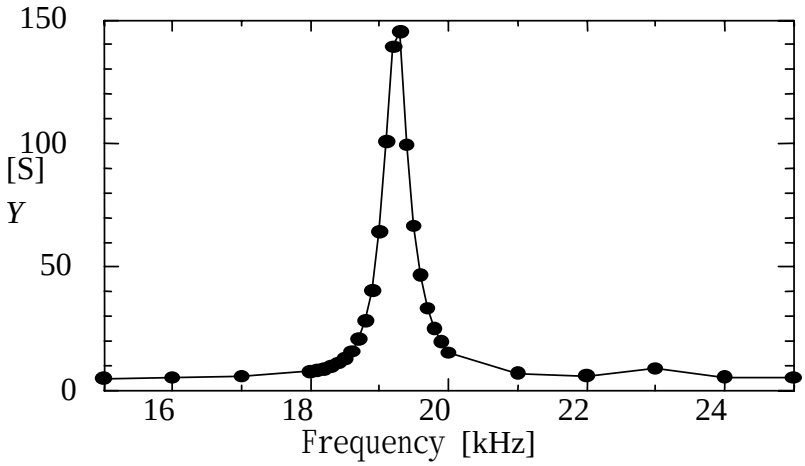

Figure 5. Resonant characteristics of 20 kHz vibrating system

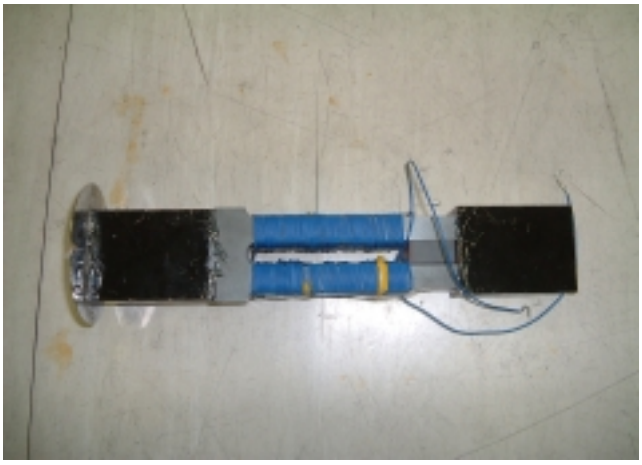

Figure 6. Picture of resonant frequency decreased vibrating system we made and used

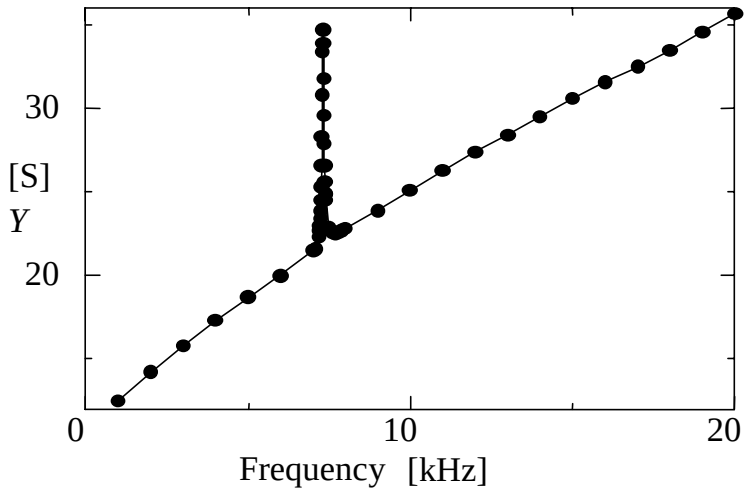

Figure 7. Resonant characteristics of frequency decreased vibrating system

RESULTS

Experimental results are shown in Fig. 8 and Fig. 9. In these cases, the sound pressure of irradiated ultrasound is constant at 10 kPa during whole experiments. For 12 hours, acidity is measured every 30 min by pH meter. Figure 8 shows relationship between pH and fermentation time. The differences of decrease of pH with frequency begin to appear around at passing 150 minutes from the measurement beginning. Promotion effect is larger in higher frequencies than in lower frequencies. Figure 9 shows the time of solidification versus frequency. The solidification time is the time at which the pH becomes 4.5. The equation of the curve fitted to the measured values is expressed as

$$t = -52 \ln f + 743 \ \text{[min]}, \qquad (1)$$

where the unit of frequency f is kHz.

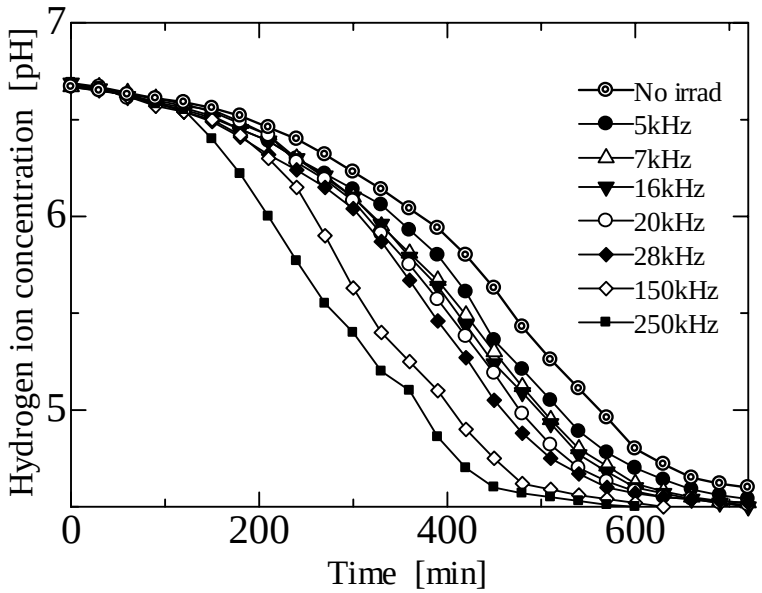

Figure 8. Relationship between pH and fermentation time

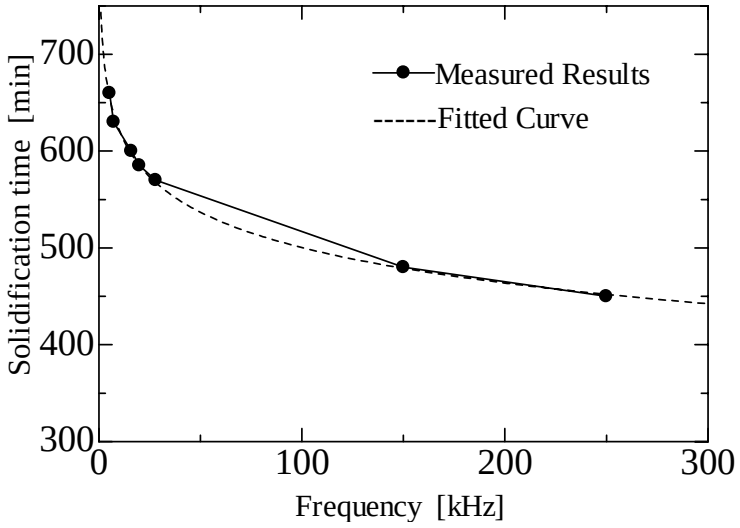

Figure 9. Relationship between solidification time and frequency

CONCLUSIONS

For the purpose of elucidating the frequency dependence of promotion in lactic acid fermentation, we made and used vibrating systems to expand the measurement range from ultrasonic frequency to audio frequency. It was found that promotion of fermentation was seen in both frequency ranges, and that degree of increase of promotion was changed abruptly in the audio frequency range as expected. Also, it was found that shortening of solidification time with frequency was exponential.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. E. Ohdaira, Messrs. Y. Hara and T. Okazaki for their cooperation and assistance on this study.

REFERENCES

[1] Nyusankin-kenkyu shudankai, *Nyusankin-no Kagaku-to Gijutsu* (Science and Technology of Lactic Bacteria) (Gakkai-shuppan-senta, Tokyo, 1986) [in Japanese].

[2] Y. Uchimura and S. Okada, *Nyusankin Jikken Manuaru* (Experiment Manual on Lactic Bacteria) (Asakura-shoten, Tokyo, 1922) [in Japanese]
[3] N. Masuzawa and E. Ohdaira, "Effect of Ultrasonic Irradiation on Phenol Compounds in Wine", Japanese Journal of Applied Physics, **39** 2978 (2000)
[4] N. Masuzawa and E. Ohdaira, "Attempts to Shorten the Time of Lactic Fermentation by Ultrasonic Irradiation", Japanese Journal of Applied Physics, **41** 3277 (2002).
[5] N. Masuzawa, A. Kimura and E. Ohdaira, "Ultrasonic Monitoring of the Progress of Lactic Acid Fermentation", Japanese Journal of Applied Physics, **42** 2963 (2003)
[6] T. Shimada, E. Ohdaira and N. Masuzawa, "Effect of Ultrasonic Frequency on Lactic Acid Fermentation Promotion by Ultrasonic Irradiation", Japanese Journal of Applied Physics, **43** 2831 (2004).
[7] J. Saneyoshi, Y. Kikuchi and O. Nomoto, *Chouonpa Gijutsu Binran* (Handbook on Ultrasonics) (Nikkankougyou Shinbunsha, Tokyo, 1989) [in Japanese]