ORIGINAL

Indonesian Tempeh from Soybeans Can Be Included in Japanese Main Dishes and Can Increase Fiber Intake

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ABSTRACT ***Background and purpose.*** Currently, major health problems, not only in Japan, include lifestyle-related diseases such as diabetes, dyslipidemia and myocardial infarction. Insufficient fiber intake is one of the main factors for these conditions. Although the Japanese Recommendation Dietary Intakes for fiber are 20g/d for men and 18g/d for women, according to a recent nation-wide nutrition survey intakes were about 15g and 14g, respectively. An increase in dietary fiber intake is usually expected from increased consumption of vegetables and grains but not from main dishes such as meat, fish, eggs, dairy products, or soybean protein products, because these contain little fiber. In this study, we focused on the use of tempeh (dietary fiber 10.2g/100g), Indonesian fermented soybeans, as a main dish. *Purpose*. An increase in dietary fiber intake through main dishes using tempeh. ***Method***. The subjects were female students, faculty and staff, security guards, and cleaners (totaling 60 people) at a university. Ten Japanese-style main dishes were prepared using the usual principal ingredients, such as eggs and meats, and ten dishes that replaced those ingredients with tempeh. The ten dishes were: rolled thick omelet, teriyaki, Chinese-style fried chicken, keema curry, piccata, hamburger steak, croquette, tofu in meat-and-chili sauce, sweet-and-sour pork, and stuffed pouches of deep-fried tofu. We offered each control dish (normal ingredients) and its parallel tempeh-based dish on the same plate for lunch. Overall taste, aroma, mouth feel and basic taste were evaluated by scores from 1 to 4 (4 very good; 3 good; 2 poor; 1 very poor). ***Results***. The average evaluations of the 10 control dishes and tempeh dishes were 3.7 and 3.5 points for overall taste, 3.7 and 3.4 points for aroma, 3.4 and 3.1 points for mouth feel and 3.7 and 3.4 points for basic taste, respectively. Evaluations of tempeh dishes were close to those of the control dishes. Especially for keema curry, hamburger steak, and stuffed pouches of deep-fried tofu, the tempeh dishes received high evaluations. In these three dishes, we used finely chopped tempeh, which suggests that the optimal use of tempeh was in a finely chopped form. The amount of dietary fiber increased by about 2g with tempeh dishes. ***Conclusion***. We found that tempeh can be used as a part of Japanese main dishes to increase dietary fiber by about 2g from each meal.
Keywords: Tempeh, fiber, main dish, Japanese.

INTRODUCTION

Lifestyle-related diseases, such as diabetes, dyslipidemia, and myocardial infarction, have been increasing, not only in Japan but also globally (1). One of the important dietary factors for this is insufficient fiber intake (2-3). However, it is usually difficult to meet sufficient amounts of fiber. According to the Dietary Reference Intakes (DRI) for Japanese (2015), the recommendation is 20g/d for men and 18g/d for women (4), while the actual intake of fiber reported by a recent Nationwide Dietary Survey was 14.5g/d for men and 13.9g/d for women in 2016 (5). This means that actual daily fiber intake is about 5g short. It is difficult to satisfy the recommended intake of dietary fiber from vegetables and staple foods. We need to look for new fiber sources. In this study, we examined ways to increase fiber intake from main dishes. For this purpose, we chose tempeh, which is rich in dietary fiber and can be used as a main dish. Fiber concentrations of tempeh are high. Fiber in 200kcal tempeh and in natto is 10.1g and 6.7g, respectively (6). Tempeh has been a traditional fermented soybean food in Indonesia for more than 500 years. It can easily be obtained at a low price (about 50 Yen (half a US dollar) per one serving size of 400g) and used in cooking in a great variety of ways.

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METHODS

Development of tempeh dishe: The subjects were female students, faculty and staff, security guards, and

cleaners at universities where the researchers work. We explained the purpose of this research and those who agreed to participate signed the informed consent form (50 people in total). Prior to the main study, we conducted a pilot study to find the best cooking methods for 10 types of tempeh dishes. These dishes were familiar to Japanese and did not require special cooking skills. For some dishes, the ingredients were completely replaced with tempeh, while in others they were partially replaced. Details of the cooking methods for the 10 dishes are shown below.

Rolled thick omelet: We explored how much tempeh could be added to the egg solution. The tempeh was not finely chopped, but it was ground and mixed with raw beaten eggs. The trial tests started with 30% of the total solution but this resulted in a hard and dry texture. Trial production and tasting were repeated, gradually decreasing the proportion of tempeh. As a result, we found that an 80% egg and 20% tempeh mixture was the most delicious (Fig 1-1).

Teriyaki: Chicken was replaced with tempeh. When tempeh was coated with potato starch and fried, the texture became soft. This would be good for people with chewing difficulties. When tempeh was covered with wheat flour and fried, it was chewy and more delicious. In this study, wheat flour was used. A flavorful sweet sauce went well with the tempeh, so we fried the tempeh and simmered it with the sauce; this was the best tasting version and the one used in the study (Fig 1-2).

Fig 1-1. Rolled thick omelet lunch
right: with tempeh
left: only eggs (control)

Fig 1-2. Teriyaki lunch
right : tempeh
left : chicken (control)

Fig 1-3. Chinese-style fried chicken lunch
right : tempeh
left : chicken (control)

Fig 1-4. Keema curry lunch
right : with tempeh
left : ground beef and pork (control)

Fig 1-5. Piccata lunch
right : tempeh
left : chicken (control)

Fig 1-6. Hamburger steak lunch
right : with tempeh
left : ground beef and pork (control)

Fig 1-7. Croquette lunch
right : tempeh
left : ground beef and pork (control)

Fig 1-8. Tofu in meat-and-chili sauce lunch
right : with tempe
left : ground pork (control)

Fig 1-9. Sweet-and-sour pork lunch
right : tempeh
left : pork (control)

Fig 1-10. Stuffed pouches of deep-fried tofu lunch
right : with tempeh
left : ground chicken (control)

Fig 1. Ten lunches given to subjects

Chinese-style fried chicken: Chicken was replaced with tempeh. When tempeh was coated with potato starch and fried, it was smooth and easy to eat. The tempeh was delicious with reduced acid, especially when seasoned with soy sauce before cooking. This taste was best and was the version used in this study (Fig 1-3).

Keema curry: Mixed ground meat and tempeh in various proportions and found that 30% meat and 70% tempeh was most delicious (Fig 1-4).

Piccata: Chicken was replaced 100% with tempeh and seasoned with soy sauce. When egg and grated cheese were added, the taste was markedly improved (Fig 1-5).

Hamburger steak: Started with 70% ground meat and 30% tempeh. This tasted good, but it was difficult to form the hamburger patty. We tried to find the best combination for taste and shaping the burger and decided on 50% chopped meat and 50% tempeh (Fig 1-6).

Croquette: Used 100% tempeh without meat. The taste was good and cooking was not difficult. With soy sauce and sugar, the taste became much better (Fig 1-7).

Tofu in meat-and-chili sauce: At first we used 100% tempeh without meat. The taste was too bland without any fat. Therefore we increased the meat and found finally that 70% tempeh and 30% meat was best (Fig 1-8).

Sweet-and-sour pork: Pork was completely replaced with tempeh and the taste was as good as the original pork. However, the tempeh was easily broken up when we cooked it with vegetables; therefore, we cooked the tempeh and vegetables separately (Fig1-9).

Stuffed pouches of deep-fried tofu: At first we used 100% tempeh but this was too soft. We tried to find the best combination and found 50% ground meat and 50% tempeh was most delicious (Fig 1-10).

Sensory Evaluation

We evaluated the 10 traditional Japanese dishes made with the usual ingredients such as egg, meat, etc. and the same dishes with the main ingredient partially or fully replaced with tempeh. The control and tempeh dishes were placed on the same plate. We did not inform subjects which was the tempeh dish and which was the control dish.

The subjects were female students, faculty and staff, security guards, and cleaners at universities where the researchers work. We explained the purpose of this research and those who agreed to participate signed the informed consent form (50 people in total). Overall taste, aroma, mouth feel and basic taste were evaluated by scores from 1 to 4 (4 very good; 3 good; 2 poor; 1 very poor). Statistical analyses were conducted by paired Student *t*-test and Turkey using excel.

RESULTS

Table 1 shows the number of subjects and average age by gender. Total number of subjects was 60 (13 males and 47 females). The average age was about 39y (58y for males and 33y for females). Table 2 shows the comparison of scores of overall taste, aroma, mouth feel and basic taste between tempeh and control foods in 10 different menus. Among 10 dishes, 6 dishes were evaluated higher for the control than for the tempeh ($p<0.05$), however, the difference was not large. On average for the 10 dishes, the scores for tempeh and control were respectively 3.5 and 3.7 for overall taste, 3.4 and 3.7 for aroma, 3.1 and 3.4 for mouth feel and 3.4 and 3.7 for basic taste.

Fig 2 shows the comparison of 3 tempeh cooking methods (chopped, cut in blocks and ground). The order was consistent regardless of the 4 evaluation items, with chopped highest, block second, and ground third. Table 3 shows comparison of evaluations for the best 4 tempeh dishes by age. Age differences were not observe Fig 3 shows fiber in one serving of lunch. Average dietary fiber included in the control and tempeh dishes was 4.2 g and 6.3 g for lunch. Teriyaki lunch increased 3.4g. By using tempeh dish as the main dish, it is possible to increase the dietary fiber intake by 2.1g.

Table 1. Number of subject and average age by gender

	Number	Age (year) Mean±SD
Male	13	58 ± 10
Female	47	33 ± 18
Total	60	39 ± 19

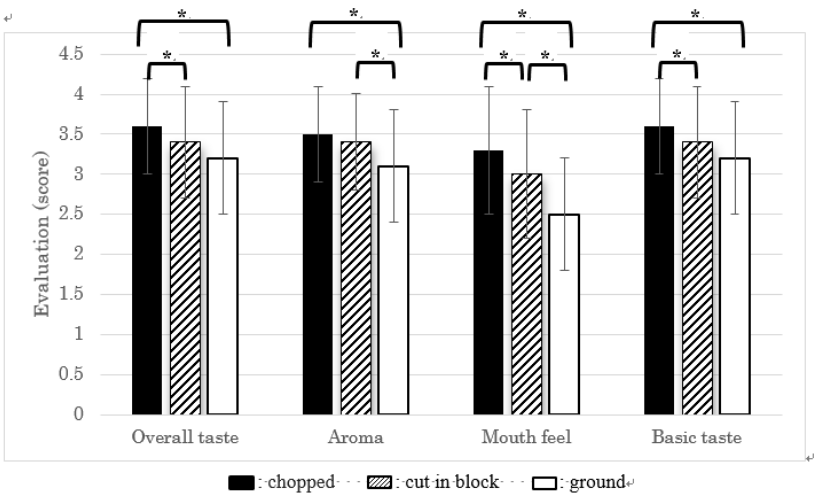
Table 2. Comparison of scores of overall taste, aroma, mouth feel and basic taste between tempeh and control foods in 10 different menus

	n		Overall taste		Aroma		Mouth feel		Basic taste	
Rolled thick omelet	46 (M:10,F:36)	Tempeh	3.2±0.7	*	3.1±0.7	*	2.5±0.7	*	3.2±0.7	*
		Control	3.6±0.6		3.6±0.5		3.5±0.6		3.6±0.5	
Teriyaki	50 (M:10,F:40)	Tempeh	3.3±0.7	*	3.3±0.7	*	2.7±0.8	*	3.4±0.8	*
		Control	3.8±0.5		3.7±0.4		3.4±0.6		3.8±0.5	
Chinese-style fried chicken	51 (M:12,F:39)	Tempeh	3.4±0.7	*	3.6±0.5	ns	3.1±0.8	*	3.3±0.7	*
		Control	3.7±0.5		3.7±0.4		3.5±0.7		3.7±0.6	
Keema curry	50 (M:14,F:36)	Tempeh	3.8±0.4	ns	3.6±0.5	ns	3.3±0.8	ns	3.7±0.5	ns
		Control	3.7±0.5		3.5±0.7		3.3±0.7		3.6±0.6	
Piccata	45 (M:12,F:33)	Tempeh	3.5±0.5	ns	3.4±0.6	ns	3.0±0.8	ns	3.4±0.6	ns
		Control	3.7±0.5		3.5±0.6		3.3±0.7		3.5±0.5	
Hamburger steak	45 (M:14,F:31)	Tempeh	3.5±0.6	ns	3.5±0.6	ns	3.3±0.7	ns	3.5±0.6	ns
		Control	3.7±0.4		3.7±0.5		3.3±0.6		3.7±0.5	
Croquette	50 (M:12,F:38)	Tempeh	3.5±0.7	*	3.5±0.6	ns	3.3±0.8	ns	3.5±0.7	*
		Control	3.9±0.4		3.6±0.6		3.4±0.7		3.8±0.5	
Tofu in meat-and-chili sauce	60 (M:13,F:47)	Tempeh	3.5±0.7	*	3.3±0.8	*	3.1±0.8	*	3.3±0.6	*
		Control	3.7±0.5		3.8±0.5		3.4±0.6		3.8±0.5	
Sweet-and-sour pork	51 (M:12,F:39)	Tempeh	3.2±0.7	*	3.4±0.6	*	3.0±0.9	ns	3.3±0.7	*
		Control	3.6±0.6		3.7±0.5		3.3±0.8		3.7±0.5	
Stuffed pouches	50 (M:12,F:38)	Tempeh	3.8±0.4	ns	3.6±0.5	ns	3.5±0.7	ns	3.8±0.4	ns
		Control	3.8±0.4		3.8±0.5		3.3±0.8		3.8±0.4	
Average	50 (M:12,F:38)	Tempeh	3.5±0.7	*	3.4±0.6	*	3.1±0.8	*	3.4±0.7	*
		Control	3.7±0.5		3.7±0.5		3.4±0.7		3.7±0.5	

Values are mean ± SD.

** Significant difference by paired Student t-test between Tempeh and Control groups in each dish at p <0.05.*

M and F stand for male and female, respectively.



** Significant difference by Turkey at p <0.05.*

Fig 2. Comparison of 3 cooking methods in tempeh score

Table 3. Comparison of evaluation for best 4 tempeh dishes by age

		20～30's		40～50's		60～70's	
		Control	Tempeh	Control	Tempeh	Control	Tempeh
Keema curry	Overall taste	3.9±0.3	3.9±0.3	3.6±0.5	3.7±0.5	3.3±0.8	3.6±0.5
	Aroma	3.5±0.7	3.7±0.5	3.4±0.7	3.2±0.4	3.5±0.8	3.5±0.5
	Mouth feel	3.4±0.7	3.3±0.9	3.1±0.8	3.0±0.7	3.1±0.7	3.6±0.5
	Basic taste	3.7±0.5	3.8±0.4	3.3±0.7	3.6±0.5	3.3±0.8	3.5±0.5
Stuffed pouches of deep-fried tofu	Overall taste	3.9±0.3	4.0±0.0	3.8±0.4	3.7±0.5	3.7±0.5	3.6±0.5
	Aroma	3.9±0.4	3.7±0.5	3.7±0.5	3.6±0.5	3.6±0.7	3.7±0.5
	Mouth feel	3.1±0.9	3.5±0.7	3.7±0.5	3.6±0.7	3.4±0.7	3.3±0.8
	Basic taste	3.9±0.3	4.0±0.2	3.7±0.5	3.8±0.5	3.7±0.5	3.6±0.5
Piccata	Overall taste	4.0±0.0	3.8±0.4*	3.4±0.5	3.2±0.7	3.3±0.5	3.3±0.5
	Aroma	3.8±0.5	3.6±0.6	3.4±0.5	3.2±0.7	3.1±0.7	3.3±0.6
	Mouth feel	3.5±0.7	3.2±0.9	3.1±0.8	2.7±0.7	3.1±0.8	2.9±0.8
	Basic taste	3.8±0.4	3.5±0.5	3.2±0.4	3.1±0.8	3.3±0.5	3.4±0.5
Hamburger steak	Overall taste	3.9±0.3	3.7±0.6	3.8±0.4	3.2±0.7	3.4±0.5	3.5±0.5
	Aroma	3.9±0.3	3.7±0.5	3.3±0.7	3.1±0.8	3.5±0.5	3.5±0.5
	Mouth feel	3.5±0.7	3.5±0.7	3.1±0.8	3.1±0.8	3.2±0.4	3.3±0.7
	Basic taste	4.0±0.0	3.7±0.6*	3.4±0.5	3.0±0.5	3.4±0.8	3.4±0.6

Values are mean ± SD

** Significant difference by paired Student t-test between Tempeh and Control groups in each dish at p <0.05*

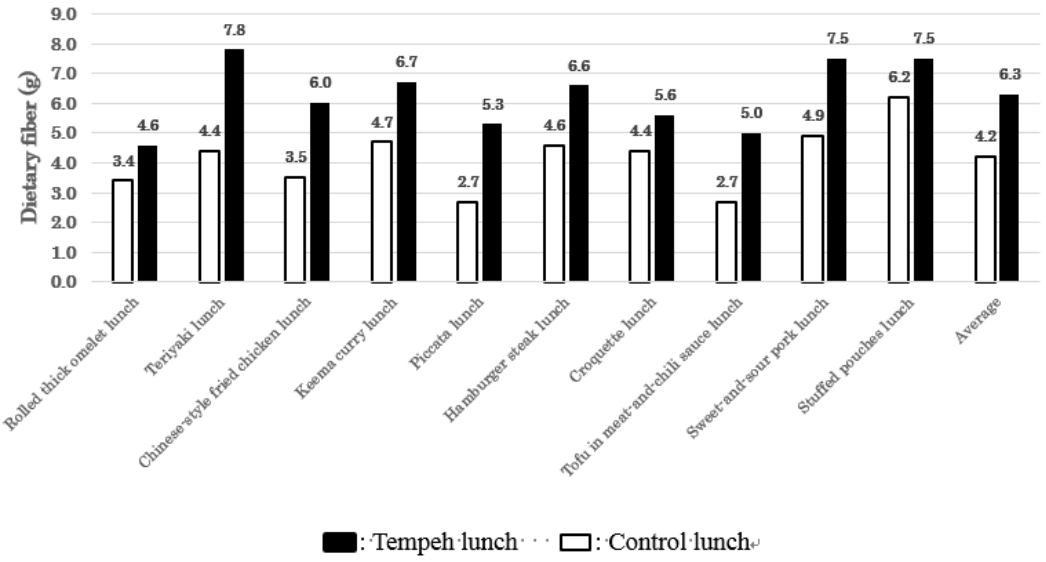


Fig 3. Dietary fiber in one serving lunches

DISCUSSION

With this study we found that tempeh can be used as a part of Japanese main dishes and can increase dietary fiber by about 2g from each meal.

The increase of fiber was quite significant. Although the Japanese Dietary Recommended Intakes (DRI) for fiber in 2015 is 20g/d for men and 18g/d for women (4), according to a recent nation-wide nutrition survey in 2016, the intakes were about 15g and 14g, respectively (5). An increase in dietary fiber intake is usually expected from increased consumption of vegetables and grains but not from main dishes such as meat, fish, eggs, dairy products, or soybean protein products, because these contain little fiber. If we increase the amount from white rice, we have to eat 400g of white rice (uncooked). On the other hand, if we use brown rice, only 80g is sufficient; however, many people dislike its hardness and smell, so it is not easy to increase fiber by this method. The Japanese recommendation for vegetables is 350g/d but at present average intake is about 280g, which contains about 8g fiber; this intake has been decreasing for the last 10 years (5), indicating that in order to supply 2g fiber from common Japanese vegetables, we would need about 70g additional vegetables, which is difficult. When we have difficulties in supplying fiber, tempeh is really a good main dish.

In Japan there is a traditional fermented soybean food "natto", but it uses a different type of microorganism from that used in tempeh. The microorganism for natto is a bacterium, “Bacillus subtilis var. natto”, whereas for tempeh it is a mold,

"Rizopus oligosporus". This is a filamentous fungus that belongs to the genus Rizopus. In Indonesia, it is a common mold which naturally occurs on the underside of banana and hibiscus leaves. In Japan, tempeh is manufactured with bacteriologically pure cultured Rizopus oligosporus (called tempeh fungus). Tempeh has a high dietary fiber content because the fungus cells themselves are fibrous. The main component of the mycelia is thought to be "chitin" (7-8). Chitin is an insoluble dietary fiber distributed in fungi, animals and plants. Tempeh can be a high-dietary fiber-containing food because there are many dietary fibers in the constituents of the mycelia. Since tempeh, unlike natto, has little smell or stickiness, it can be adapted to various dishes. It is soft and easy to chew for persons with chewing difficulties. From these facts, we believe that if we can use tempeh as the prime ingredient in Japanese main dishes, we can increase dietary fiber intake to the level meet the RDA.

Although tempeh is a new food for Japanese and can be a significant fiber source, it will be accepted only if people like the taste. Ten Japanese-style main dishes were prepared using the usual principal ingredients, such as eggs and meats, and ten dishes that replaced those ingredients with tempeh. The ten dishes were: rolled thick omelet, teriyaki, chinese-style fried chicken, keema curry, piccata, hamburger steak, croquette, tofu in meat-and-chili sauce, sweet-and-sour pork, and stuffed pouches of deep-fried tofu. We thought that the ordinary food dishes would have higher evaluations than the tempeh dishes, but surprisingly the tempeh dishes had quite high evaluations, with 4 out of 10 dishes evaluated as high as the ordinary dishes. Among the best 4 tempeh dishes, finely chopped tempeh was used in 3 dishes. These were keema curry, hamburger steak, and stuffed pouches of deep-fried tofu (Table 2).

The reason why the taste of finely chopped tempeh dishes is rated highly is that the taste of the soybeans themselves was not noticed when the tempeh was mixed with sufficient amounts of other ingredients. If we eat tempeh itself, not finely chopped, we sense the smell and taste of the soybeans. In the case of croquettes, which are fried, tempeh is less greasy than meat and may be easier to eat.

Tempeh piccata was evaluated one of the best 4, but the tempeh was left as it was and not chopped. The reason for this may be the browning of the grated cheese added to the seasoned egg mixture. Browning grated cheese in the egg mixture in a frying pan produces a fragrant aroma, which may reduce the awareness of the soybean smell of tempeh.

The limitations of this study, if there are any, are the number of male and female subjects and also the difference in the age groups. In this study, we evaluated 10 types of tempeh dishes that were tested by about 50 people. This total number is similar to the published papers using panel test (9-15). Although the number of male and female subjects and also the age structure were different, the results in Table 3 show similar scores for 20-30's, 40-50's and 60-70's except for minor differences, indicating that the results obtained in this study were not affected by such factors.

In conclusion, tempeh dishes will be easily accepted by Japanese with proper cooking. High fiber and also soybean protein can be expected to control blood glucose and lipids significantly. Further studies are expected.

REFERENCES

1) Sugiura R, Sakamoto M, Murata M: Risk of life-style related diseases in young children. 2007. The Japanese Journal of Nutrition and Dietetics **65**: 67-73 (in Japanese).
2) Pereira MA, O'Reilly E, Augustsson K, Fraser GE, Goldbourt U, Heitmann BL, Hallmans G, Knekt P, Liu S, Pietinen P, Spiegelman D, Stevens J, Virtamo J, Willett WC, Ascherio A. 2004. Dietary fiber and risk of coronary heart disease. Archives of Internal Medicine **164**: 370-376.
3) Ludwig DS, Pereira MA, Kroenke CH, Hilner JE, Horn LV, Slattery ML, Jacobs DR, Jr. 1999. Dietary fiber, weight gain, and cardiovascular disease risk factors in young adults. JAMA **282**: 1539-1546.
4) Ministry of Health, Labour and Welfare of Japan: Dietary Reference Intakes for Japanese, 2015. 2015. Daiichi-shuppan Press, Tokyo (in Japanese).
5) Ministry of Health, Labour and Welfare of Japan. The outline report of the National Health and Nutrition Survey of Japan in 2016. https://www.mhlw.go.jp/file/04-Houdouhappyou-10904750-Kenkoukyoku-Gantaisakukenkouzoushinka/kekkagaiyou7.pdf (in Japanese), accessed: 15/11/2018.
6) Ministry of Education, Culture, Sports, Science and Technology of Japan: Standard Tables of Food Composition in Japan, 2015. 2016. Ishiyaku-shuppan Press, Tokyo (in Japanese).
7) Negishi Y: Nutritional and chemical studies on Tempe. 1993. Bulletin Kagawa Nutrition University **1**: 87-115(in Japanese).
8) Taguchi K, Kawabata M, Ohtsuki K, Tanaka Y. 1986. Changes in dietary fiber of Natto and Tempeh during fermentation. J Med Sci Biol **39**: 203-208.
9) Utari DM: The effect of Tempeh intervention on lipid profile, superoxide dismutase, Ox-LDL and malondialdehyde in postmenopausal women. 2011. Graduate School of Bogor Agricultural University.
10) Miyazawa S, Suzuki T, Matsuo M, Sakai E: Study on cooking and taste of Soy tempeh and Peanut tempeh. Bulletin Nagoya Bunri University 8: 29-32, 2008
11) Vital RJ, Bassinello PZ, Cruz QA, Carvaiho RN, Paiva JCM, Colombo AO: Production, quality, and acceptance of Tempeh and White bean tempeh burgers. 2018. Foods **7**:136.
12) Paredes-Lopez O, Harry GI, Gonzalez-Castaneda J: Sensory evaluation of Tempeh produced by fermentation of common beans. 1990. J Food Sci **55**: 123-126.
13) Ueta K, Watanabe I: Knowledge and food characteristics on Tempeh. 2009. Bulletin Shikoku University **31**: 15-19 (in Japanese).
14) Ishida M, Tezuka H, Hasegawa T, Cao L, Imada T, Imada T, Kimura E, Matsumoto H, Kawano R, Arai H. 2011. Sensory evaluation of a low-salt menu created with Umami, similar to savory, substance. J Med Sci Biol **64**: 305-311.
15) Fukai Y, Suzuki I, Nishi K, Ookuma K: Evaluation of snow room storage for low-temperature aging of locally fermented food. 2010. Journal of Cookery Science of Japan **43**: 246-259 (in Japanese).