ISSN 2087-3336 (Print) | 2721-4729 (Online)

TEKNOSAINS: Jurnal Sains, Teknologi dan Informatika
Vol. 12, No. 2, 2025, page. 235-245
http://jurnal.sttmcileungsi.ac.id/index.php/tekno
https://doi.org/10.37373/tekno.v12i2

A completely randomized experimental design with 3 factors on tempe resistance

Afifah Dilla Indrawati Haryono, Atika Nurani Ambarwati*

[*] Institut Teknologi Statistika dan Bisnis Muhammadiyah Semarang, Jawa Tengah – Indonesia, 50185

* Corresponding Author: atika.nurani@itesa.ac.id

Submitted: 25/02/2025 Revised: 01/05/2025 Accepted: 13/05/2025

ABSTRACT

Tempe produced in Indonesia generally uses soybeans fermented with microorganisms as the main raw material. This fermented food is liked by many people from various levels of society because of its taste and protein and carbohydrate content. However, tempe can only last for 1-2 days. The average per capita consumption of tempe per week in 2023 increased by 0.143 kg from the previous year. The Central Statistics Agency revealed that the supply of around 335 thousand tons of local soybeans from 2.7 million tons of national soybean needs. The need for soybeans for tempe reaches 70% of the total national need, further strengthening the fact that the amount of local soybeans is decreasing, so that the country must import to meet the supply of soybean needs. In the city of Semarang, tempe is made from imported soybeans. Course, other types of local beans are substitutes. The demand for tempe production continues to increase, but some producers have not been able to maintain the quality and durability of tempe. The 3-factor design helps to determine the treatment factors that affect the durability of tempe. Based on the experiment, the durability of tempe was influenced by factors of beans, inoculum, fermentation, bean-inoculum interaction, beans-fermentation, and beans-inoculum-fermentation. Cowpea tempe with yeast inoculum fermented for 24 hours had the best durability.

Keywords: Experimental design; variation: tempe

1. INTRODUCTION

Tempe originated from Java Island over 300 years ago or the 16th century. The origin of the word tempe is thought to be Old Javanese, "tumpi" refers to the white color of food made from sago flour [1]. In addition to the protein content in soybeans, which is equivalent to animal products, tempe is rich in important minerals, high in fiber, and low in fat, which is produced during the fermentation process [2]. Therefore, tempe has become a very popular dish not only in Indonesia but also abroad, especially among vegetarians. Tempe was even included in the list of Intangible Cultural Heritage of Indonesia in 2017 [3]. Indonesia, as a major tempe producer, has approximately 160,000 tempe craftsmen from the Indonesian Tempe and Tofu Cooperative Association in 2022 [4]. This amount is expected to balance the amount of tempe consumption every day. The average per capita consumption of tempe per week in 2023 increased by 0.143 kg from the previous year, which was 0.140 kg [5].

The main raw material for tempe, which is generally soybeans, is an important indicator in the production process to meet the needs of the tempe consumer demand. The need for soybeans for tempe each year is 70% of the national soybean requirement. However, the Ministry of Trade (2023) revealed that only around 335 thousand tons of local soybeans from 2.7 million tons of national soybean requirements [6]. The scarcity that occurred was caused by the increase in the price of local soybeans necessary to import from America and other countries. A study on tempe craftsmen in Semarang City indicated that many used imported soybeans with high expansion power as raw materials [7]. There is research that produces tempe from various types of beans, even local ones, with better quality. Meanwhile, from observations on the market, the quality of tempe from some market

traders is often uncertain, causing tempe to have difficulty lasting long. In general, the shelf life of tempe is only 1-2 days at room temperature, but the lower the storage temperature, the longer the tempe will last [8]. Good quality tempe has a distinctive sour smell, taste, and a white color that is even on the surface. Tempe producers say that the instability of tempe quality is due to the price of raw materials, especially soybeans, often going up and down [9]. The instability of raw material prices does not affect the selling price, producers are forced to reduce raw materials, production volumes, and product sizes. As a result, the quality of tempe decreases and varies, especially in terms of durability. The demand for tempe production continues to increase, but some producers have not been able to maintain the quality and durability of tempe.

In the study of the development of tempe mold with variations in substrate and incubation time, it turned out that the type of substrate did not have a significant effect on the total mold in tempe inoculation. The best tempe inoculation material used a mixture of rice flour with an incubation period of 96 hours [10]. The results of Sapitri's research show that the quality of tempe with tunggal yeast is as good as that of substrate yeast with concentrations of 0.5%, 1%, and 1.5% [11]. The quality of tempe made from sword beans wrapped in banana leaves looks solid, has a distinctive tempe aroma, and is evenly white [12]. Research on the quality of tempe with variations in fermentation time resulted in the best quality tempe being fermented for 48 hours rather than 36 hours, or 72 hours [13]. The organoleptic test experiment of soybean (Glycine max) and red bean (Phaseolus vulgaris) tempe concluded that from 100% soybean, 100% red bean, and 80% red soybean 20%, on average, untrained analysts liked red bean tempe from the sensory test [14].

The experiment will focus on measuring the resistance of tempe with raw materials of soybeans, cowpeas, and sword beans after considering the quality of previous research. Another consideration is that cowpeas and sword beans are local beans cultivated in Indonesia, so they are expected to be an alternative to the scarcity and instability of soybeans. The inoculation material is also varied by adding wheat flour to determine the effect on each bean variation. Variations in fermentation time will also be studied for their effect on measuring the resistance of tempe. The use of teak leaves is useful for maintaining temperature circulation during the fermentation process due to the presence of natural spores on the surface of the leaves [15]. The factorial completely randomized design (CRD) method will be applied in the study because there are two different treatment factors/variations in the manufacturing process to produce quality tempe. Factorial CRD is an experimental method to simultaneously test several factors in research. It is expected that a valuable result from the research will be used in the development and innovation in the production of high-quality tempe in the future. The objectives of the study include testing the effect of bean variations, inoculation materials, and fermentation time, as well as the possibility of interaction between variation factors on the durability of tempe, and knowing the differences in each variation factor that has an effect.

2. METHOD

Data source

The study began by collecting data from a tempe-making experiment in December 2024, when the temperature in Semarang City ranged from 21˚C to 33˚C. The methods for making tempe are divided into 7 types, the study used method IV. The resulting tempe will be observed for its physical changes, especially changes in odor produced after the incubation/fermentation period at room temperature during the rainy season.

Table 1. How to make tempe

Tahap	Metode						
	1	2	3	4	5	6	7
1	Bean seeds	Bean seeds	Bean seeds	Bean seeds	Bean seeds	Bean seeds	Bean seeds
2	Peeling	Boiling	Immersion	Boiling	Boiling	Immersion	Immersion
3	Washing	Immersion	Peeling	Immersion	Cooling	Boiling	Boiling
4	Boiling	Peeling	Washing	Peeling	Peeling	Washing	Cooling
5	Drain	Washing	Boiling	Washing	Washing	Boiling	Peeling
6	Cooling	Drainage	Drainage	Boiling	Immersion	Cooling	Washing
7	Inoculation	Inoculation	Cooling	Drainage	Boiling	Peeling	Immersion
8	Packaging	Packaging	Inoculation	Cooling	Drainage	Washing	Boiling

Tahap	Metode						
	1	2	3	4	5	6	7
9	Incubation	Incubation	Packaging	Inoculation	Cooling	Drainage	Drainage
10	Tempe	Tempe	Incubation	Packaging	Inokulasi	Inokulasi	Cooling
11	-	-	Tempe	Incubation	Packaging	Packaging	Inoculation
12	-	-	-	Tempe	Incubation	Inkubasi	Packaging
13	-	-	-	-	Tempe	Tempe	Incubation
14	-	-	-	-	-	-	Tempe

Table 1 contains various methods for making tempe, which were introduced by Saono in 1986. The technique used must be adjusted to the conditions and weather at the time of producing tempe [17]. In this study, the fourth method of manufacturing technique was used. On average, producers in Semarang City most often use the fourth method, especially during the rainy season.

Research variables

The experiment was conducted with 3-factor variables consisting of bean variations, inoculation material variations, and fermentation duration variations to measure the dependent variable.

a. Bean factor

Regarding the raw materials themselves, it turns out that a lot of research has been carried out that along with the development of food technology, tempe can be produced using various types of beans other than soybeans that are cultivated in Indonesia, such as koro benguk, koro pedang, lamtoro, green beans, peanuts, red beans, and cowpeas.

Table 2. Bean variation factors

Types of Bean	Types of Beans	Usage Proportion
Soya bean Legumes with low production levels. Soybeans for quality tempe raw materials have a characteristic texture with an overall yellow color but slightly brownish and round [18].	*Glycine max* (L.) Merr	1 kg
Cowpea The Center for Post-Harvest Agricultural Research and Development in 2006 stated that cowpeas are useful as a raw material for making tempe without having to be mixed with soybeans, so that local cowpeas have the potential to be a raw material for tempe [19].	*Vigna unguiculanta* L.	1 kg
Koro Sword The protein content is quite high at 30.36%, so it is considered capable of replacing soybeans in meeting the nutritional standards of tempe. Unfortunately, the hygroscopic nature of protein concentrate causes a short shelf life and is easily damaged [20].	*Canavalia ensiformis*	1 kg

Table 2 explains about the beans that can be used as the main raw material for tempe. The most frequently used soybeans will be compared in their durability with the cowpeas and sword bean, which have been used several times in experiments in making tempe.

b. Inoculation factors

The best substrate for the growth of tempe mold is rice, which contains high water and carbohydrates as a source of nutrition. The very high-water content of rice causes damage to the yeast more quickly, so in making yeast, it must be mixed with other substrates with low water content. Sale argues that in addition to rice, some substrate media that can be used to obtain spores include wheat, rice, corn, or tubers [21]. Using too much inoculum will cause imperfect fermentation, but using too little will cause the growth of destructive bacteria [17]. Using too much inoculum will cause imperfect fermentation, but using too little will cause the growth of destructive bacteria.

c. Fermentation factors

Affected by temperature, time, relative humidity (RH), and the availability of oxygen needed for yeast to grow. The key to tempe quality is, of course, how well the inoculum spreads evenly and then

forms mycelium on the raw material during the fermentation process. The longer the fermentation takes place, the faster the decay phase, which reduces the quality of tempe [22]. Phases in the fermentation process [23] at this stage, namely the rapid growth period of around 0-30 hours, the formation of mycelium on the surface of the seeds will be seen to be increasingly dense, the transition period of around 30-50 hours is the most optimal time to be marketed or consumed, and the decay period of around 50-90 hours where the growth of microorganisms stops but protein degradation continues to form ammonia. Therefore, tempe fermentation will be tested for 24 hours and 36 hours.

d. Dependent variable

Steps to determine the durability of tempe can be known by conducting a sensory test. The purpose of sensory testing is to ensure more in-depth the quality of tempe, including the texture, color, and aroma of tempe. The Indonesian National Standard stipulates that the quality of tempe in Indonesia must be characterized by a clean white that is evenly distributed on its surface, has a homogeneous and compact structure, does not fall off easily, and the taste, shape, and aroma of tempe are free from ammonia odor [13]. If the tempe does not have these characteristics, then the tempe is said to have rotted.

Research method

a. Factorial completely randomized design

Experimental design has three basic principles so that an experiment can be said to be valid [24]. Three basic principles in designing experiments include: repetition, randomization, and environmental control. Repetition will be done 2 times with 3 factors, so the experimental design is 3 × 2 × 2 × 2 (total sample 24). Table *3* explains the experimental design in the factorial completely randomized design method. Each factor goes through repetition, randomization, and combination, which is denoted by Y as resistance with a unit of time in hours.

Table 3. Experimental design

Bean	Inoculum	Fermentation 24 Hours	Fermentation 36 Hours	Total
Koro Sword	Yeast	Y_{111}	Y_{112}	Y_{11k}
	Yeast+Flour	Y_{121}	Y_{122}	Y_{12k}
Cowpea	Yeast	Y_{211}	Y_{212}	Y_{21k}
	Yeast+Flour	Y_{221}	Y_{222}	Y_{22k}
Soya bean	Yeast	Y_{311}	Y_{312}	Y_{31k}
	Yeast+Flour	Y_{321}	Y_{322}	Y_{32k}
Total		Y_{ij1}	Y_{ij2}	Y_{ijk}
Average		$\overline{Y_{ijk}}$		

In the factorial design guidebook, the procedures written include normality and homogeneity tests, variance analysis, and advanced/mean difference tests.

Normality

Find out the truth of the distribution of research sample data from a population that is evenly distributed. The normalization test uses the Lilliefors method. The hypothesis is used.
H_0: The sample comes from a normally distributed population
H_A: The sample does not come from a normally distributed population
If the sig value. > 5%, H_0 failed to reject the intention of the sample from a normally distributed population.

Homogeneity

Find out the truth of the research sample comes from a population that has the same variance. The homogeneity test uses the Bartlett method with the Chi-Square test statistic. The hypothesis is used.
H_0: ${s_1}^2 = {s_2}^2$, Samples come from populations with the same variance
H_A: ${s_1}^2 \neq {s_2}^2$, Samples do not come from populations with the same variance

If the sig value. > 0,05 or $\chi^2_{Count} < \chi^2_{(k-1)}$, then H_0 failed to reject with the intention of sampling from populations with the same variance.

Analysis of Variance

- Correction factor calculation

$$FK = \frac{\sum Y^2}{r \times ab} \quad (1)$$

Where:
$\sum Y$ = Total amount of observation data
r = Many repetitions
a = Total of treatments on the bean factor
b = Total of treatments on the inoculation factor

- Calculation of the total sum of squares

$$JKP = \sum Y_{..k^2} - FK \quad (2)$$

Where:
$\sum Y_{..k}$ = the number of each observation in each repetition
FK = Correction factor

- Calculation of the sum of squares of treatment

$$JKP = \frac{\sum Y_{...2}}{r \times p} - FK \quad (3)$$

Where:
$\sum Y_{...}$ = the amount of each variation in the observed data

- Calculation of the sum of squares of interactions (example: interaction between beans and inoculation)

$$JKI(AB) = \frac{\sum Y_{ijk^2}}{r} - FK - JKP(A) - JKP(B) \quad (4)$$

Where:
$\sum Y_{ij.}$ = the number of each bean factor and inoculation in the observation data

- Calculation of the sum of squares of the interaction of 3 factors

$$JKI(ABC) = \frac{\sum Y_{ijk^2}}{r} - FK - JKP(A) - JKP(B) - JKP(C) \quad (5)$$

Where:
$\sum Y_{ijk}$ = the number of each row and column in the observation data

- Calculation of the sum of squares of errors

$$JKG = JKT - JKP(A) - JKP(B) - JKP(C) - JKI(AB) - JKI(BC) - JKI(AC) - JKI(ABC) \quad (6)$$

Where:
JKT = Total sum of squares

The calculation results are continued using Table 4, namely the table of sources of diversity/variance, which helps the analysis process with the F test. The F test can also be done more practically with SPSS.

Table 4. Analysis of variance

Source of Diversity	db	JK	KT	Fcount	F_{tabel}
A	(a-1)	JKP(A)	KTA	KTA/KTG	$F_{\alpha(db\ A;\ db\ G)}$
B	(b-1)	JKP(B)	KTB	KTB/KTG	$F_{\alpha(db\ B;\ db\ G)}$
C	(c-1)	JKP(C)	KTC	KTB/KTG	$F_{\alpha(db\ C;\ db\ G)}$
AB	(a-1)(b-1)	JKI(AB)	KT(AB)	KT(AB)/KTG	$F_{\alpha(db\ AB;\ db\ G)}$

Source of Diversity	db	JK	KT	Fcount	F_{tabel}
BC	(b-1)(c-1)	JKI(BC)	KT(BC)	KT(BC)/KTG	$F_{\alpha(db\ BC;\ db\ G)}$
AC	(a-1)(c-1)	JKI(AC)	KT(AC)	KT(AC)/KTG	$F_{\alpha(db\ AC;\ db\ G)}$
ABC	(a-1)(b-1)(c-1)	JKI(ABC)	KT(ABC)	KT(ABC)/KTG	$F_{\alpha(db\ ABC;\ db\ G)}$
Error	ab(r-1)	JKG	KTG		
Total	abr-1	JKT			

The hypothesis tested is:

$\boldsymbol{H_0 : \mu_1 = \mu_2}$ There was no real influence of variations in treatment factors

$\boldsymbol{H_1 : \mu_1 \neq \mu_2}$ There is a real influence of variations in treatment factors

A. Further test/mean difference

The Coefficient of Variance (CC) is a coefficient that measures the degree of precision or accuracy, and reliability of the results of an experiment [24].

$$KK = \frac{\sqrt{KTG}}{Y_{ijk}} \times 100\% \quad (7)$$

Where:

Y_{ijk} = average observation data

When the KK value produced is high, it means that the degree of accuracy, and reliability is high, and the validity of the conclusion of an experiment is high. In Table 5, the criteria for further test methods that need to be carried out are written based on the value of the coefficient of diversity produced.

Table 5. Further test criteria

Data/KK	Small	Medium	Large
Homogen	< 5%	5% – 10%	> 10%
Heterogen	< 10 %	10% – 20%	> 20%
	Duncan	BNT LSD	BNJ Tukey HSD

3. RESULTS AND DISCUSSION

The initial procedure was carried out with a normality test on the data before analyzing it by variance. Table 6 is the result of the normality test on SPSS on the distribution of the studied tempe resistance.

Table 6. Normality test (SPSS)

		Tempe Resistance
N		24
Normal Parameters [a,b]	Mean	93.2083
	Std. Deviation	58.94266
Most Extreme Differences	Absolute	.206
	Positive	.203
	Negative	-.206
Test Statistic		.206
Asymp. Sig. (2-tailed)		.010[c]
Monte Carlo Sig. (2-tailed)	Sig.	.231[d]
	99% Confidence Interval Lower Bound	.221
	Upper Bound	.242

The significance value of the Liliefors test results is 0.231, which is more than 0.05, so the data is assumed to be normally distributed for each treatment factor.

Table 7. Results of analysis of variance (SPSS)

Source of Diversity	df	JK	KT	F_{hitung}	Sig.	Decision
Correct Model	11	79871,208	7261,019	2403,648	,000	Good Model
Intercept	1	208507,042	208507,042	69023,021	,000	Signifikan
A	2	79386,396	39693,198	13139,817	,000	H_0 rejected
B	1	51,042	51,042	16,897	,001	H_0 rejected
C	1	273,375	273,375	90,497	,000	H_0 rejected
AB	2	39,396	19,698	6,521	,012	H_0 rejected
BC	1	9,375	9,375	3,103	,104	H_0 accepted
AC	2	84,938	42,469	14,059	,001	H_0 rejected
ABC	2	26,688	13,344	4,417	,037	H_0 rejected
Error	12	36,250	3,021	***R Square***		1,000
Total	24	288414,500		***Adj. R Square***		0,999

Table 7 indicates that both variations in the type of beans, inoculum, and fermentation time effect the durability of tempe because they have a significance value below 0.05. Other factors that have an effect include the interaction between variations in the type of beans and inoculum, the interaction between the type of beans and fermentation time, and the interaction between the type of beans, inoculum, and fermentation time. Meanwhile, the interaction factor of inoculum variation and fermentation time does not affect the durability of tempe. The GLM model that was formed was good and fit with R Square 1 and Adj. R Square 0.999. This means that the factors in the analysis to explain the dependent variable in this case, the durability of tempe, by 99.9%.

Table 8. Homogeneity test (SPSS)

F	df1	df2	Sig.	KK
2,413	1	22	,135	1,86%

The significance value in the homogeneity test in Table 8 proves that the variance in each treatment factor is the same or not heterogeneous. The resulting coefficient of diversity is also worth 1.86% or below 5%. The average difference test will use the Duncan test method.

Table 9. Duncan test of bean factors

Bean	N	Subset		
		1	2	3
Cowpea (A2)	8	155,875		
Soya bean (A3)	8		107	
Koro Sword (A1)	8			17,125

Table 9 shows that the treatment (variation) of the bean factor produces tempe resistance, divided into 3 subsets. The influence given by each treatment of factor A is significantly different from each other. Cowpeas were tested to be able to survive the longest among the other 3 beans for an average of 156 hours. The resistance of soybeans is different from cowpeas and sword beans, which lasted for 107 hours. The lowest resistance is sword bean tempe, which only lasted for 17 hours.

Table 10. Duncan test of inoculum factors

Inoculum	n	Subset
Yeast (B1)	12	94,75
Yeast+wheat (B2)	12	91,92

Table 10 states that the effect of variation of factor B is not significantly different. However, yeast inoculum lasted 3 hours longer than yeast+flour inoculum.

Table 11. Duncan test fermentation factors

Fermentation	n	Subset	
		1	2
24 Hours (C1)	12	96,67	
36 Hours (C2)	12		90

Table 11 states that the effect of variation of factor C is significantly different. Tempe fermented for 24 hours lasts 7 hours longer than tempe fermented for 36 hours.

Table 12. Duncan test of AB factors

Interaction	n	Subset			
		1	2	3	4
A2B1	4	157			
A2B2	4	154,75			
A3B1	4		107,5		
A3B2	4		107		
A1B1	4			20,25	
A1B2	4				14

Table 12 shows that the effect of the interaction of AB factors is divided into 4 subsets. The first subset consists of cowpea tempe with yeast + wheat inoculum, which lasted 3.75 hours longer than cowpea tempe with yeast inoculum. The second subset contains soybean tempe with yeast inoculum, which lasted 0.5 hours longer than soybean tempe with yeast + wheat inoculum. The third subset contains sword bean tempe with yeast inoculum, and the fourth subset contains sword bean tempe with yeast + wheat inoculum.

Table 13. Duncan test of AC factors

Interaction	n	Subset				
		1	2	3	4	5
A2C1	4	147				
A2C2	4		139,5			
A3C1	4			113		
A3C2	4				101	
A1C1	4					18,75
A1C2	4					15,5

Table 13 shows that the effect of the AC factor interaction is divided into 5 subsets. Each subset indicates a significant difference from each group containing the AC interaction factor treatment. The first subset consists of 24-hour fermented cowpea tempe. The second subset contains 36-hour fermented cowpea tempe. The third subset contains 24-hour fermented soybean tempe. The fourth subset contains 36-hour fermented soybean tempe. The fifth subset contains sword bean tempe with 24-hour and 36-hour fermentation.

Table 14. Duncan test of ABC factors

Interaction	n	Subset					
		1	2	3	4	5	6
A2B1C1	2	158,5					
A2B2C1	2	158					
A2B1C2	2	155,5					
A2B2C2	2		151,5				
A3B1C1	2			114			
A3B2C1	2			112			
A3B2C2	2				102		
A3B1C2	2				100		
A1B1C1	2					23,5	
A1B1C2	2						17
A1B2C1	2						14
A1B2C2	2						14

Table 14 shows that the effect of the ABC factor interaction consists of 6 subsets. Each subset indicates a significant difference from each group containing ABC interaction factor treatments. The

subsets in question are subset 1 (tempe tunggal inoculated with yeast fermentation for 24 hours, tempe tunggal inoculated with yeast + wheat fermentation for 24 hours, and tempe tunggal inoculated with yeast fermentation for 24 hours), subset 2 (tempe tunggal inoculated with yeast + wheat fermentation for 36 hours), subset 3 (soybean tempe inoculated with yeast + wheat fermentation and yeast fermentation for 24 hours), subset 4 (soybean tempe inoculated with yeast + wheat fermentation and yeast fermentation for 36 hours), subset 5 (koro Pedang tempe inoculated with yeast fermentation for 24 hours), and finally subset 6 (soybean tempe inoculated with yeast + wheat fermentation for 24 hours and 36 hours).

It turns out that cowpea tempe can last for 156 hours or about 6.5 days. As seen in Figure 1. the mycelium is quite evenly spread, and the color, smell, and texture also look good. The addition of wheat flour to wheat flour does not cause a significant effect, but if the fermentation time is longer, the durability of the tempe will decrease. The characteristics of cowpea are very similar to soybeans, and the protein content is almost the same. Therefore, the effect of the inoculum will be more visible along with the effect of the fermentation time.

Figure 1. Cowpea tempe

Mixing flour and yeast turned out to have only a moderate effect on sword bean tempe. Figure 2 shows that although the smell is good, the texture of the sword bean is not dense enough, and the mycelium is not spread to all sides, so that the color of the beans is still visible. Sword bean tempe is less durable because the protein content in the sword bean is very high, affected by the carbohydrate content in the flour, thus accelerating the development of microorganisms in the yeast.

Figure 2. Koro Sword tempe

Soybean tempe is still the best in terms of texture, color, and aroma, as seen in Figure 3, while soy tempe can generally last for 107 hours or around 4.5 days.

Figure 3. Soybean tempe

The average durability of tempe from the experiments that have been carried out is 93.3 hours, or almost 4 hours. In terms of the bean variation factor, the longest-lasting tempe and the sword bean tempe cannot last long. When viewed from the length of fermentation, tempe with a fermentation time of 24 hours can last longer than the 36-hour one. Regarding the length of fermentation, in the first 24 hours, on average, the tempe is ready to eat, but the texture that is formed is not perfect. In the next 12 hours, the tempe looks perfect in terms of color (mycelium covers the entire surface of the beans), texture, and aroma. Meanwhile, based on the inoculum, there is no real difference so it is said that the durability of tempe is considered the same. From its physical form, soybean tempe is indeed better in terms of color, mycelium tightness, odor, and texture than sword bean tempe and sword bean tempe. However, in terms of taste, the sword bean tempe tastes more-savory, has more protein, and absorbs spices better. Tempe may have great potential as a substitute for soybeans as the main raw material for tempe.

4. CONCLUSION

Experiments conducted using 3 treatment factors indicated that variations of beans, inoculum, fermentation, interaction of beans with inoculum, interaction of beans with fermentation, and interaction of 3 factors simultaneously had a significant effect on the durability of the tempe produced. Tempe that lasted a long time was tempe from cowpeas that was given yeast inoculum and fermented for 24 hours. It is highly recommended to try to commercialize tempe from cowpeas because it has a long shelf life.

REFERENCE

[1] A. Romulo and R. Surya, "Tempe: A traditional fermented food of Indonesia and its health benefits," *Int J Gastron Food Sci*, vol. 26, p. 100413, Dec. 2021, doi: 10.1016/j.ijgfs.2021.100413. https://doi.org/10.1016/j.ijgfs.2021.100413

[2] D. R. Setiawan, H. N. Tunjungsari, and A. Azizah, "Bioavailability and bioactive compounds in tempeh: A review," *Int J Food Prop*, vol. 25, no. 1, pp. 2109–2123, 2022.

[3] D. H. Maskar, K. Anwar, I. N. Prasetyo, I. Kusumawati, and M. Ridha, "Studi Kasus: Perspektif Generasi Muda Terhadap Tempe Melalui Sosial Media," *Binawan Student Journal*, vol. 4, no. 3, 2022. https://doi.org/10.54771/bsj.v4i3.800

[4] Kemendag RI, "Buka RAT Gakoptindo, Mendag Zulkifli Hasan: Perkuat Organisasi, Sejahterakan Perajin Tahu Tempe," DKI Jakarta, Jun. 2023.

[5] BPS, "Rata-Rata Konsumsi per Kapita Seminggu Beberapa Macam Bahan Makanan Penting, 2007-2023," Konsumsi dan Pendapatan.

[6] NFA, "NFA Apresiasi Pengrajin Tahu Tempe dan Dorong Penguatan Ekosistem Kedelai Nasional," Jakarta, Apr. 2023.

[7] D. Mayasari, T. Ekowati, and M. Handayani, "Preferensi Pelaku Industri Tempe Terhadap Kualitas Bahan Baku Kedelai di Kecamatan Semarang Selatan, Kota Semarang," *Mimbar*

Agribisnis : Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis, vol. 9, no. 1, p. 741, Jan. 2023, doi: 10.25157/ma.v9i1.8969. https://doi.org/10.25157/ma.v9i1.8969

[8] Y. A. Purwanto and Weliana, "Kualitas Tempe Kedelai pada Berbagai Suhu Penyimpanan," *Journal of Agro-based Industry*, vol. 35, no. 2, pp. 106–112, 2018. https://doi.org/10.32765/wartaihp.v35i2.4297

[9] Badan Standardisasi Nasional, "SNI 3144:2015 Tempe Kedelai," Badan Standardisasi Nasional. Accessed: Sep. 19, 2024. [Online]. Available: https://bsn.go.id/main/bsn/detail/11

[10] T. S. K. Putri, "Pengaruh Jenis Substrat dan Lama Inkubasi Terhadap Karakteristik Inokulum Tempe yang Diberi Penambahan Saccharomyces cerevisiae," Universitas Lampung, Bandar Lampung, 2022.

[11] Y. Sapitri, U. S. Hastuti, and A. Witjoro, "Pengaruh Ragi Tempe dengan Variasi Substrat Kacang Tunggak (Vigna unguiculata) dan Kacang Kedelai (Glycine max (L) Merill.) serta Dosis Ragi Tempe terhadap Kualitas Tempe," *Jurnal Ilmu Hayat*, vol. 2, no. 1, p. 1, 2018, [Online]. Available: http://journal2.um.ac.id/index.php/jih/index

[12] H. P. Ratri, "Kadar Protein dan Kualitas Tempe Koro Pedang," Universitas Muhammadiyah Surakarta, Surakarta, 2016.

[13] D. R. Aisya, L. Mulyani, M. Yulianti, and A. Achyar, "Pembuatan Tempe dari Kacang Tanah (Arachis hypogea L.) dengan Variasi Lama Fermentasi terhadap Kualitas Tempe," in *SEMNAS BIO UIN Syarif Hidayatullah Jakarta*, 2022.

[14] A. Safitry, M. Pramadani, W. Febriani, A. Achyar, and R. Fevria, "Uji Organoleptik Tempe dari Kacang Kedelai (Glycine max) dan Kacang Merah (Phaseolus vulgaris)," in *Prosiding SEMNAS BIO Universitas Negeri Padang*, 2021.

[15] Nadilla, "Pengaruh Penggunaan Daun Jati (Tectona grandis) Terhadap Lama Fermentasi dan Uji Organoleptik Tempe," UIN Ar-Raniry Darussalam, Banda Aceh, 2018.

[16] Saono S, Hull RR, and Dhamcharee B., *A Concise Handbook of Indigenous Fermented Foods in the Asia Countries*. Jakarta,Indonesia: Indonesian Institute of Sciences, 1986.

[17] W. P. Rahayu, R. Pambayun, U. Santoso, L. Nuraida, and Ardiansyah, "Tinjauan Ilmiah Proses Pengolahan Tempe Kedelai," in *Perhimpunan Ahli Teknologi Pangan Indonesia (The Indonesian Association of Food Technologists)*, 1st ed., Palembang: Patpi, 2015, ch. 1. [Online]. Available: http://patpi.or.id

[18] N. V. Pramaisshela, R. Indriati, and R. Firliana, "Sistem Pemilihan Bahan Baku Tempe Berkualitas," in *Seminar Nasional Inovasi Teknologi*, Kediri, Jul. 2020.

[19] N. Aliyah, W. Mushollaeni, and L. Tantalu, "Pembuatan Tempe Kacang Tunggak (Vigna Unguiculanta) Dengan Variasi Lama Fermentasi Menggunakan Inokulum Tempe," *Journal of Comprehensive Science (JCS)*, vol. 3, no. 1, pp. 62–78, Jan. 2024, [Online]. Available: https://jcs.greenpublisher.id/index.php/jcs/article/view/589

[20] E. L. Hutapea, "Enkapsulasi Konsentrat Protein Tempe Kacang Koro Pedang (Canavalia ensiformis) Menggunakan Gum Arab dan Maltodekstrin pada Berbagai Suhu Spray Drying," Universitas Padjadjaran, Sumedang, 2023.

[21] E. S. P. Surbakti, S. D. Agus, and A. N. Komang, "Pengaruh Jenis Substrat Terhadap Pertumbuhan Rhizopus oligosporus DP02 Bali dalam Pembuatan Ragi Tempe," *Jurnal Ilmu dan Teknologi Pangan*, vol. 11, pp. 92–99, 2022. https://doi.org/10.24843/itepa.2022.v11.i01.p10

[22] S. A. Kinanti, "Hubungan Kualitas Bahan Baku dan Tenaga Kerja Dalam Proses Produksi dengan Kualitas Produk Tempe Segar pada UMKM Rumah Tempe Indonesia," UIN Syarif Hidayatullah, Tangerang Selatan, 2024.

[23] A. B. Surbakti, S. P. Rahayu, S. Mehuli, and R. B. Ginting, "Sistem Aplikasi Logika Fuzzy untuk Optimasi Ragi Tempe pada Proses Fermentasi Tempe Kedelai Menggunakan Metode Fuzzy Mamdani," *Jurnal Ilmiah Simantek*, vol. 4, no. 2, pp. 146–160, 2020.

[24] Kurniaji, "Pengaruh Beda Dosis Pakan Malam Hari terhadap Pertumbuhan dan Kelangsungan Hidup Ikan Lele Dumbo Menggunakan Metode RAL," Institut Teknologi Statistika dan Bisnis Muhammadiyah Semarang, Semarang, 2022.