

Tempe as a control for diabetes mellitus: consumer perceptions and feasibility

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Abstract. Tempe is a promising dietary option for diabetes mellitus (DM) sufferers due to its high dietary fiber and low glycemic index. This study aimed to assess the nutritional quality of tempe, its suitability as a high-fiber functional food per PerBPOM No. 1 of 2022, and DM sufferers' perceptions of its importance. Findings indicated that tempe met the Indonesian National Standards for moisture, protein, and fat, but its crude fiber content was above the standard (>2.5%). However, its dietary fiber content met high-fiber food standards (≥ 6 g/100 g). Initially, only 25% of respondents considered tempe essential for DM management, but after education, 69% recognized its importance, demonstrating that counselling enhances positive perceptions and tempe consumption. Age was significantly related to the portion of tempe per meal, and the frequency of tempe consumption increased with higher food expenditure. Education was also positively correlated with perceptions about the nutritional benefits of tempe, indicating that DM sufferers with higher education were more aware of the nutritional value and benefits of tempe. This condition shows the importance of education and counselling to the public in supporting the consumption of tempe as a functional food choice to control DM.

1 Introduction

The growing prevalence of diabetes mellitus (DM) sufferers in the world every year has been a severe health problem and needs more attention to be addressed. Indonesia is ranked 5th as a country with the highest number of DM sufferers, which is 19.5 million people according to data from International Diabetes Federation in 2021. The number of DM sufferers influences this large number at the regency/city level, increasing yearly. Based on the data from West Java Health Office in 2020, it was recorded that 21 of the 27 regencies/cities in West Java have an increasing number of DM sufferers, with the highest increase occurring in the Bekasi Regency.

A lifestyle involving unhealthy food consumption, sedentary daily life and obesity are factors that cause Type 2 DM [1]. DM is characterized by symptoms of hyperglycemia or high blood glucose levels [2]. Suppose DM sufferers are unable to control their blood glucose level. In that case, there is potential to increase the risk of heart disease, eye problems, nerve

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damage, and the emergence of foot wound infections, which lead to amputation [3]. DM control can be done by regulating food consumption through diet planning, including the schedule, amount and type of food consumed. Foods containing high fiber and low glycemic index are the right choice consumed by DM sufferers due to their role in controlling blood glucose levels [4-5]. One food commodity that meets these criteria is tempe [6].

Tempe's quality and nutritional content are essential to ensure the nutrients consumed to meet the dietary needs of DM sufferers. Tempe quality standards have been regulated in Indonesia National Standard (SNI) 3144:2015. There is also regulation to claim foods as high in dietary fiber food, namely Food and Drug Regulatory Agency Regulation (PerBPOM) No. 1 of 2022. The addition of safe and high-quality tempe to DM sufferers' diet menus has the potential to reduce the number of DM sufferers in Indonesia. DM sufferers' knowledge and understanding of Tempe's potential for DM treatment is essential in implementing tempe as a diet menu. Previous studies showed that there are still many nutritional problems (knowledge, awareness, diet compliance, and implementation) in DM sufferers. This condition causes the majority of DM sufferers not to apply the principles of nutritional consumption correctly.

The research focused on consumer knowledge and perception of Tempe's benefits for DM has never been done before. Therefore, this study was conducted to assess the nutritional quality of tempe, its suitability as a high-fiber functional food according to PerBPOM No. 1 of 2022 and DM patients' perceptions of its importance. The results of this study are expected to introduce soybean tempe as an antidiabetic functional food to be recommended in the diet menu of DM sufferers.

2. Materials and methods

2.1 Materials

The test materials used in this study were raw tempe products. As many as three leaf-packaged tempes and three plastic-packaged tempes were obtained from 6 different tempe's Small Medium Enterprises (SMEs) in Bekasi Regency.

2.2 Study design/setting

Tempe nutritional analysis was studied in Bekasi Regency and Laboratory of the Center for Standardization and Services for Agroindustry (BBSPJIA) from May to July 2023. This exploratory and descriptive study for consumer perception was conducted among DM patients visiting the diabetic treatment clinic, namely *Rumah Perawatan Indonesia* (RUMAT) and the primary health centre in Bekasi Regency, West Java, Indonesia, from August to October 2023.

2.3 Proximate composition and dietary fiber analysis

The moisture, protein, fat and crude fiber contents of tempe samples were determined following the methods from the SNI 3144:2015. Dietary fiber analysis was conducted following the official method ascribed by the Association of Official Analytical Chemistry.

2.4 Study population/subject selection

A purposive sampling method was used to recruit 105 DM patients who participated in this study. The inclusion criteria in this study were Type 2 DM patients aged 20-79 years who

lived in Bekasi Regency, consumed medicine or insulin, were on a diet program, consumed tempe at least once a week, and agreed to be respondents. The exclusion criteria were Type 2 DM patients who did not consume tempe, lived outside Bekasi Regency, and did not agree to be respondents. The minimum number of participants, 100 people, was calculated using the Slovin Formula based on the total DM sufferers population in Bekasi Regency, which had a 90% confidence level.

2.5 Survey data collection

Data were obtained by completing a questionnaire through interviews. The questionnaire consisted of 4 sections, namely characteristics of subjects (gender, age, education level, occupation, amount of income per month, and long-suffering from DM), dietary pattern, tempe consumption pattern and DM patient's perception towards tempe. The questionnaire has been tested through a validity test on 30 respondents using Pearson correlation analysis (p-value <0.05) and a reliability test using Cronbach's Alpha (alpha value of 0.736).

2.6 Survey data analysis

The data entry and analysis were performed using the IBM Statistical Package for Social Science (SPSS) version 25. Descriptive statistics such as frequencies, percentages, and charts were used. Spearman's Rank Correlation was used as a statistical analysis to test the association between variables.

3 Result and discussion

3.1 Tempe feasibility evaluation

3.1.1 Tempe's quality evaluation based on SNI

Quality is one of the factors consumers consider when purchasing food products. Food quality can refer to sensory characteristics, nutritional value, functional quality, ethical and environmental considerations [7]. Products that have met quality standards and nutritional claims as beneficial for health can be developed as healthy food products by manufacturers. The quality of the tempe can be identified through the suitability of its nutritional content with the nutritional value requirements stated in the soybean tempe quality standard, namely SNI 3144:2015.

The results of nutritional content analysis from leaf-packaged tempe and plastic-packaged tempe in Table 1 showed that moisture, protein, and fat content in tempe met tempe quality standards with requirements for a maximum moisture content of 65%, minimum protein of 15% and minimum fat content 7%. However, the opposite result was obtained from crude fiber content, which produced 3.01% for leaf-packaged tempe and 3.58% for plastic-packaged tempe. This result did not meet the quality standard, which required a maximum of 2.5% for crude fiber content in tempe. High crude fiber is found in soybean epidermis. It causes an increase in a product's crude fiber content when soybean skins are added. Therefore, the unfulfilled crude fiber quality standard is caused by the incomplete separation of the skins from soybeans at the soybean peeling stage.

There was no significant difference between leaf-packaged tempe and plastic-packaged tempe for moisture, protein and crude fiber content. However, a significant difference was found in the fat content result. This condition is because the leaf packaging is light-resistant,

and aeration occurs since air can circulate, making oxygen exchange quick. This condition allowed the tempe mould to grow faster. Here, fatty acids will provide energy for mould growth [8]. Thus, leaf-packaged tempe had lower fat content than plastic-packaged tempe.

Table 1. Nutritional content of tempe.

No.	Parameters	Packaging Type		Quality Requirements (SNI 3144:2015)
		Leaf-Packaged Tempe	Plastic-Packaged Tempe	
1	Moisture content (%)	55.43±0.51 ^a	57.77±1.44 ^a	Maximum 65
2	Protein content (%)	16.03±0.64 ^a	15.63±0.42 ^a	Minimum 15
3	Fat content (%)	10.47±0.35 ^a	11.43±0.12 ^b	Minimum 7
4	Crude fiber content (%)	3.01±0.61 ^a	3.58±0.61 ^a	Maximum 2.5

Notes: Inline values followed by a different superscript showed significantly different ($p < 0.05$)

3.1.2 Tempe's dietary fiber content based on PerBPOM No. 1 of 2022

Dietary fiber is a complex polysaccharide generally found in plant cell and is resistant to the hydrolysis process by enzymes in the human intestine. Dietary fiber is different from crude fiber which cannot be hydrolyzed by chemicals such as sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH). In numerous epidemiological studies, dietary fiber helps to control blood glucose levels in DM sufferers. DM sufferers who consume foods containing high dietary fiber and low glycemic index can reduce postprandial glucose levels and HbA1c in the body. The hypoglycemic effect produced by dietary fiber can slow the rate of gastric emptying, slow glucose diffusion and reduce transit time, which results in shortened glucose absorption, thus affecting insulin secretion and glucose use by the liver [9].

Table 2 showed that dietary fiber content in leaf-packaged tempe was 7.42 g, and in plastic-packaged tempe, it was 7.96 g with no significant difference. The requirement for a food product to be claimed as a high dietary fiber food must have a dietary fiber content ≥ 6 g per 100 g food product according to PerBPOM No.1 of 2022. The results showed leaf-packaged tempe and plastic-packaged tempe had dietary fiber levels above 6 g. It indicated that tempe is proven to have high dietary fiber; thus, it is suitable as a functional food for DM sufferers.

Table 2. The dietary fiber content of tempe.

No.	Samples	Dietary Fiber Content (g/100g)	High Fiber Food Requirement (g/100g)
1	Leaf-Packaged Tempe	7.42±0.35 ^a	≥ 6
2	Plastic-Packaged Tempe	7.96±1.52 ^a	

Notes: Values along the same column followed by the same superscript are not significantly different ($p \geq 0.05$)

3.2 DM sufferer's perception of tempe

3.2.1 Demographic characteristic

One hundred five respondents who met the inclusion criteria participated in this study. Demographic information is presented in Table 3. More than half of the participants were

female and dominated by the age of 50-59 years (47%). For education level, most respondents were high school graduates (38%). Respondents were dominated by housewives (39%). In the category of food expenditure per month, the most significant number were those with income IDR 2.000.001-3.000.000 (43%). Respondents were all Type 2 DM, with the majority of those suffering from DM being <5 years (44%) and 5-10 years (39%).

Table 3. Demographic characteristics.

Variable	Number (people)	Percentage (%)
Gender:		
Male	45	43
Female	60	57
Age (years):		
20-29	1	1
30-39	4	4
40-49	18	17
50-59	49	47
60-69	30	29
70-79	3	3
Education Level:		
Elementary School	21	20
Junior High School	15	14
Senior High School	40	38
Diploma	4	4
Bachelor Degree	21	20
Master's Degree/Doctoral	4	4
Occupation:		
Labour	2	2
Housewife	41	39
Private Sector	9	9
Self-employee	13	12
Government Sector	8	8
Pensionary	16	15
Civil Servant	13	13
Unemployed	3	3
Food Expenditure (per month):		
≤ IDR 2.000.000	39	37
IDR 2.000.001-3.000.000	45	43
IDR 3.000.001-4.000.000	9	9
IDR 4.000.001-5.000.000	7	7
> IDR 5.000.000	5	5
Duration of Suffering from DM:		
< 5 years	46	44
5-10 years	41	39
> 10 years	18	17

3.2.2 Dietary pattern of DM sufferers

Knowledge, attitudes and self-care management are essential for DM sufferers to achieve treatment targets and prevent complications [10]. Diet implementation in DM sufferers aims to maintain glucose levels within normal limits. Reducing carbohydrate consumption is a

dietary step commonly recommended for DM sufferers because of the impact on blood glucose levels. Consuming low-carbohydrate foods aims to ensure carbohydrate intake is appropriately limited. Restricting carbohydrate consumption for DM sufferers in China has effectively reduced insulin doses for people with Type 2 DM [11]. Figure 1 shows that the diet program most frequently implemented by respondents was a low-sugar diet (56%) and a low-carbohydrate diet (48%). This result aligns with research conducted in Japan, where people with Type 2 DM tend to prefer diet programs that consume low-carbohydrate and low-calorie food menus [12].

Besides diet programs, diet frequency can also potentially affect DM sufferer's health. A study conducted in China showed that increasing diet frequency could reduce the risk of Type 2 DM [13]. The diet frequency of 6-7 times a week was the most frequently chosen by respondents (72%) in this study (Figure 2). This result indicates that most respondents understand the importance of following diet programs as part of self-care.

The accomplished diet frequency is closely related to the respondent's level of compliance. About 62% of respondents said they always obeyed the diet program. In comparison, another 34% of respondents answered that they sometimes obeyed, and only 4% admitted that they did not obey (Figure 3). Based on further interviews, it was discovered that patients who sometimes choose to obey and not obey were generally due to boredom with the diet menu they were eating and the desire to try other prohibited menus. Lack of discipline in controlling boredom and the desire to try prohibited foods can be an obstacle to achieving treatment targets and preventing complications.

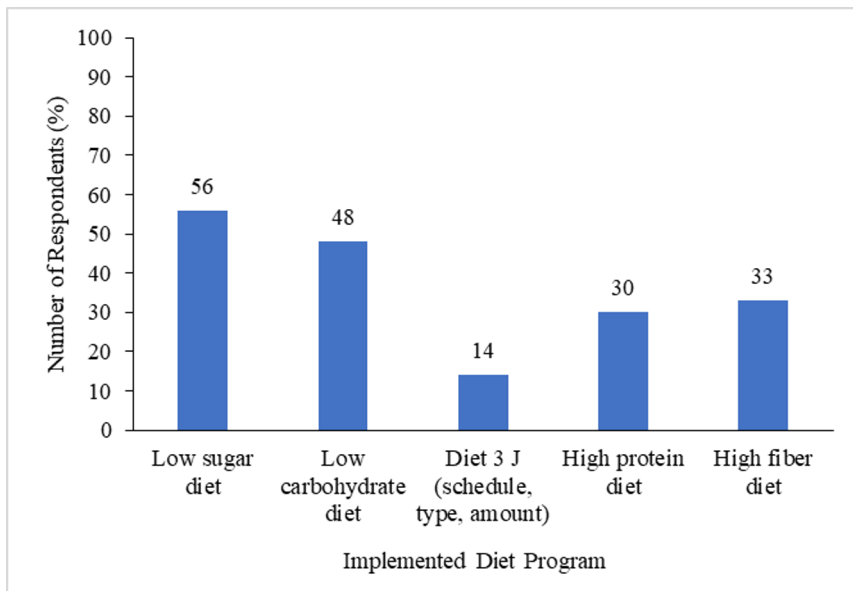


Fig. 1. Implemented diet program by DM sufferers.

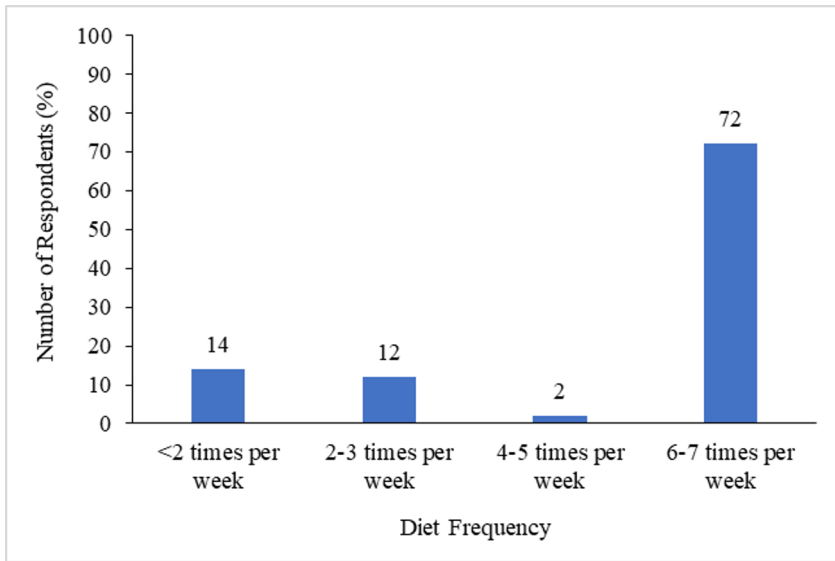


Fig. 2. Diet frequency of DM sufferers.

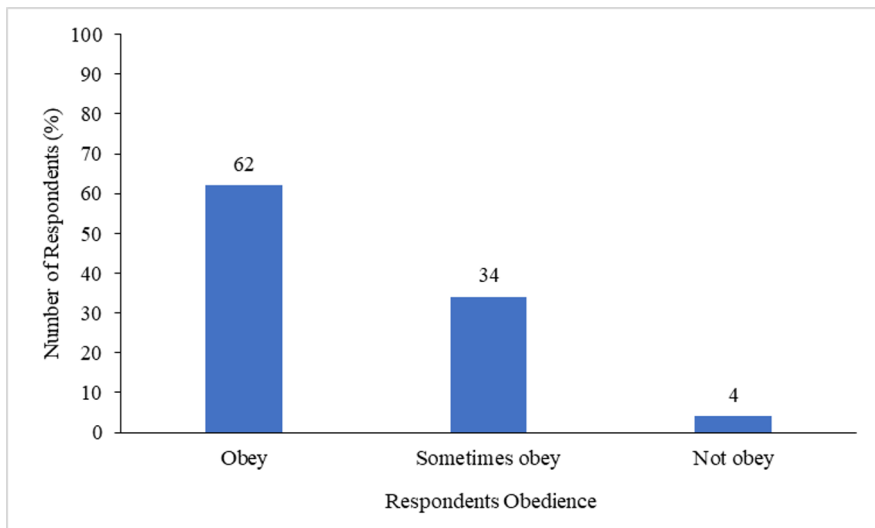


Fig. 3. DM sufferer's obedience to diet program accomplishment.

3.2.3 Tempe consumption pattern of DM sufferers

People's consumption patterns of food products can be seen from their willingness to allocate their expenses to the product. Figure 4 shows that 51% of respondents allocate \leq IDR 50.000 to buy tempe monthly. Meanwhile, another 31% of respondents allocated IDR 50.001 - 100.000 to purchase tempe per month, and only 18% allocated spending above IDR 100.000 for tempe. It shows that most respondents spent a deficient expenditure on tempe comparing to their food expenditure. This condition also shows the potential for tempe expenditure to increase.

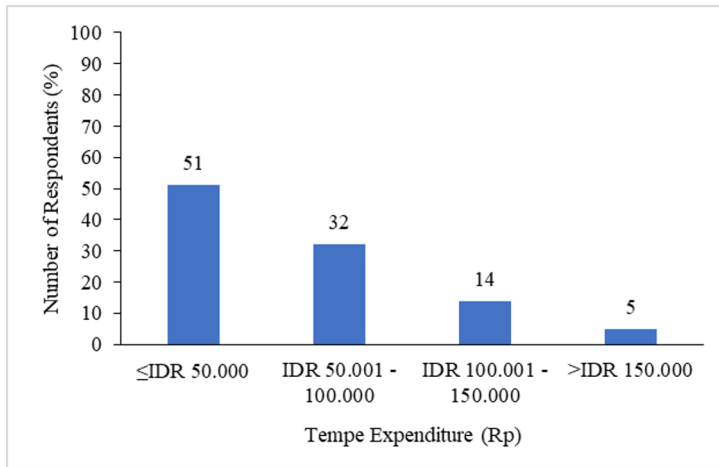


Fig. 4. Tempe expenditure of DM sufferers.

A study conducted in the United States on males and females showed that people who regularly consumed soy and isoflavones had a lower risk of developing DM than those who did not [14]. This result is due to the benefits of isoflavones in increasing insulin secretion and reducing insulin resistance in DM sufferers [15]. Tempe, a food product made from processed soybeans containing more isoflavones and dietary fiber than soybeans, is expected to become a functional food product often consumed by DM sufferers. The obtained result showed that the frequency of consuming tempe 2-3 times a week was the most chosen frequency by respondents (52%) (Figure 5). Only 21% of respondents consumed tempe 6-7 times a week. The low frequency of tempe consumption was probably due to respondents' low awareness of the importance of tempe for DM treatment.

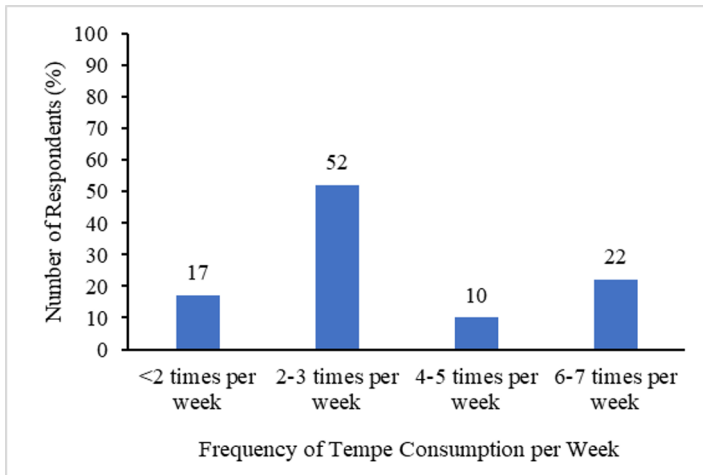


Fig. 5. Tempe consumption frequency per week of DM sufferers.

Consuming tempe is beneficial for repairing lipid profile and preventing free radicals at an affordable cost. Regular tempe consumption is recommended, at least 2-3 slices of medium size (100-150 gr) per day to prevent degenerative diseases in the body. Figure 6 shows that the majority of respondents consumed two slices of medium size (54%) and \geq three slices of medium size (30%) per day. These results show that most respondents have consumed tempe as the recommended amount. However, some other respondents (16%)

were known only to consume small amounts of tempe, namely one slice of medium size per day. The presence of respondents who still consume tempe in small quantities is known as due to the respondent's lack of preference for consuming tempe.

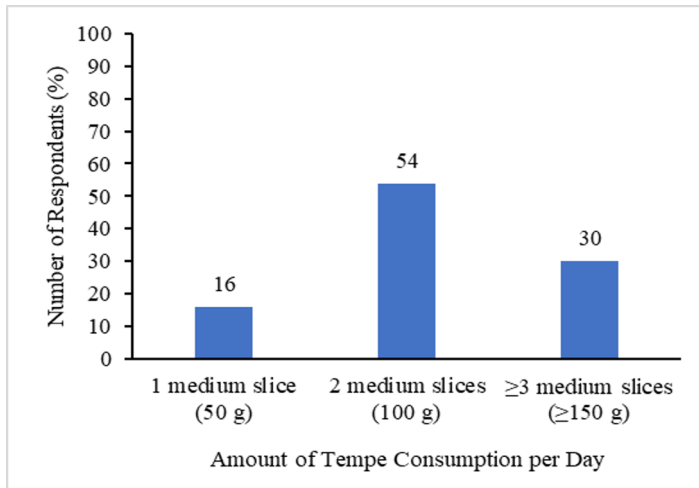


Fig. 6. Amount of tempe consumption per day of DM sufferers.

3.2.4 Consumer perceptions of tempe

The price of tempe in Bekasi Regency ranged between IDR 5.000-7.000 in weight, about 320 - 475 g. Regarding the current price of tempe on the market, it is known that almost half of respondents (49%) consider this price to be in the cheap category considering the current high prices of staple foods (Figure 7). About 45% of respondents answered that the price was in the medium category due to the increasing price compared to the price of tempe several years earlier. However, it was still relatively affordable. Only 6% of respondents answered expensive. This information shows that the current price of tempe is still affordable for most people.

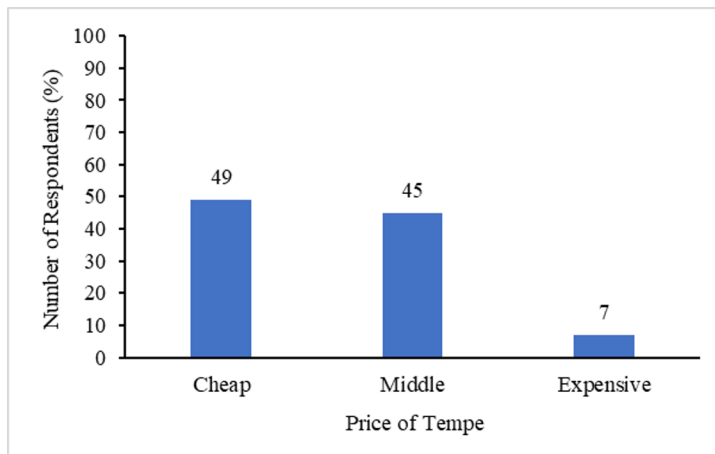


Fig. 7. DM sufferer's perception of current tempe price.

Respondent's knowledge of product nutritional content can significantly influence the frequency of tempe consumption. Based on Table 4, almost all respondents (97%) agreed with the statement 'tempe is a nutritious food and is beneficial for health'. However, after being asked further about the nutritional content of tempe, almost half of the respondents (45%) said they did not know. In comparison, the other 55% of respondents knew the nutritional content of tempe, including protein (51%), dietary fiber (3%) and antioxidants (1%) (Table 5). Thus, almost all respondents know tempe is a highly nutritious food, but almost half of them still do not know the nutritional content of tempe.

Table 4. DM sufferer's perception of tempe.

Statement	Answer	Number of Respondents (People)	Percentage (%)
Tempe is a nutritious food and beneficial for health	Agree	102	97
	Disagree	3	3
Total		105	100

Table 5. DM sufferer's knowledge about tempe nutrition.

Tempe Nutritional Content	Number of Respondents (People)	Percentage (%)
Protein	54	51
Antioxidant	1	1
Fiber	3	3
No idea	47	45
Total	105	100

Table 6. DM sufferer's knowledge about tempe's benefit for DM treatment.

The Role of Tempe for DM Treatment	Number of Respondents (People)	Percentage (%)
Reduce/stabilize blood glucose level	14	13
Fulfill protein needs	10	10
Accelerates the growth of new tissue in wounds	12	11
No idea	69	66
Total	105	100

Respondents' knowledge regarding the benefits of tempe for DM treatment is one of the factors that can influence respondents' decision to consume tempe. More than half of the respondents, namely 66%, answered 'do not know' about the benefits of tempe for DM treatment (Table 6). Another 44% of respondents already knew the benefits of tempe for DM treatment, with a distribution of 13% of respondents answered to reduce/stabilize blood glucose level, 12% of respondents said to accelerate the growth of new tissue in wounds, and another 10% of respondents commented to fulfill protein needs.

Table 7. DM sufferer's perception of tempe for DM treatment.

Question	Answer	Number of Respondents (%)
How important do you think it is to consume tempe for DM treatment?	Very important	25
	Important	49
	Less important	20
	Not important	7
Tempe contains protein, isoflavones and dietary fiber, which can reduce blood glucose levels. Therefore, it is recommended that DM sufferers consume tempe. After learning this information, how important is consuming tempe for DM treatment?	Very important	69
	Important	31
After knowing the information above, will you consume tempe more often than before?	Yes, I will more often consume tempe	87
	No, I will do the same as usual	13

Consumer perception of tempe products can be influenced by consumer expectations. Expectations or hopes for a product can be obtained when someone knows the benefits of the product they consume. Based on the data in Table 7, before being given information about the benefits of tempe for DM, only 25% of respondents thought that consuming tempe was very important for DM treatment. About 49% of respondents said it was necessary, 20% answered that it was less critical, and 7% said that temperature was not crucial for DM treatment.

Respondents were then given information about the benefits of tempe for DM treatment and then asked again regarding their opinion about the importance of tempe for DM treatment. There was a significant change in the respondents' answers. As a result, most respondents (69%) answered that it was essential, and the remaining 39% said it was necessary. No respondents chose not essential or not crucial after being given information about the benefits of tempe for DM treatment. Most respondents consumed tempe more often (87%) after knowing the information.

3.2.5 Relationship between variables

Respondent characteristics of age, education, income, food expenditure and duration of suffering from DM were statistically associated with dietary patterns. The analysis results in Table 8 show no significant correlation between age and each dietary pattern variable. A significant correlation was found between education, diet frequency, and diet obedience, with a positive Spearman Rank correlation coefficient. This correlation indicates that the higher the respondents' education level, the higher their frequency and obedience to carrying out the diet program.

A significant correlation was also seen in the relationship between income, food expenditure, and diet frequency. These results showed that the higher the income and food expenditure, the higher the diet frequency being implemented. This information means that a better family's financial condition will increase the frequency of carrying out diet programs. The duration of suffering from DM significantly correlated with diet frequency and obedience. The Spearman Rank coefficient value obtained shows that respondents who have

suffered from DM for a longer time tend to have a higher frequency of carrying out a diet program ($R_s=0.316$) but have lower obedience in carrying out a diet program.

Table 8. Relationship between respondent characteristics and dietary patterns.

Variable	Dietary Pattern (p-value)	
	Diet Frequency	Respondent Diet Obedience
Age	0.147	0.377
Education Level	0.007**	0.048*
Income (per month)	0.000**	0.249
Food Expenditure	0.001**	0.874
Duration of Suffering from DM	0.001**	0.036*

Notes: *Statistically significant different ($p<0.05$)

*Statistically highly significant difference ($p<0.01$)

There was no significant correlation between age, education, income, food expenditure and duration of suffering from DM with tempe expenditure (Table 9). A significant correlation was obtained between age and the amount of tempe consumption per day, which shows that the higher the respondent's age, the greater the amount of tempe consumption per day. A significant correlation was also shown in the Relationship between food expenditure and the frequency of tempe consumption, so it was known that the higher the respondent's food expenditure, the higher the frequency of tempe consumption. This correlation indicates that respondents with better financial conditions tend to increase the frequency of tempe consumption.

Table 9. Relationship between respondent characteristics and dietary patterns.

Variable	Tempe Consumption Pattern (p-value)		
	Tempe Expenditure	Tempe Consumption Frequency	Amount of Tempe Consumption per Day
Age	0.832	0,657	0,038*
Education Level	0,975	0,425	0,547
Income (per month)	0,216	0,322	0,464
Food Expenditure	0,074	0,046*	0,419
Duration of Suffering from DM	0,686	0,806	0,885

Notes: *Statistically significant ($p<0.05$)

The Spearman Rank correlation test results showed that age, income and food expenditure did not significantly correlate with all consumer perception variables towards tempe. In Table 10, the level of education could have been more optimistic, with the perception of tempe as a nutritious food that is beneficial for health and knowledge of the nutritional content of tempe. These results indicate that DM sufferers with higher levels of education tend to assess tempe as a nutritious food that is beneficial for health and have knowledge about the nutritional content of tempe.

A negative correlation was obtained between the length of time suffering from DM, knowledge of the benefits of tempe for DM, and perceptions of the importance of consuming tempe for DM. These results indicate that respondents who have a more extended history of suffering from DM tend to have lower knowledge regarding the benefits of tempe for DM and have a lower perception of the importance of consuming tempe for DM.

Table 10. Relationship between respondent characteristics and dietary patterns.

Variable	DM Sufferers Perception of Tempe (p-value)			
	Perception 1	Perception 2	Perception 3	Perception 4
Age	0,878	0,493	0,857	0,398
Education Level	0,030*	0,043*	0,135	0,866
Income (per month)	0,233	0,869	0,131	0,785
Food Expenditure	0,241	0,571	0,437	0,754
Duration of Suffering from DM	0,154	0,110	0,026*	0,023*

Notes: *Statistically significant ($p < 0.05$)

Perception 1: Perception of tempe as nutritious food and beneficial for health

Perception 2: Knowledge of tempe nutritional content

Perception 3: Knowledge of tempe's benefit for DM treatment

Perception 4: Perception of the importance of tempe consumption for DM treatment

4 Conclusion

The results of the analysis of the nutritional content of tempe in leaf packaging and plastic packaging show that the moisture, protein and fat content obtained meets the tempe quality standards in SNI 3144:2015. Analysis of crude fiber content in both types of tempe did not meet SNI quality standards, namely a maximum of 2.5%. The dietary fiber content in tempe has met the standard as food with high dietary fiber, namely a minimum of 6 g per 100 g of product. About 66% of DM sufferers did not know the benefits of tempe for DM treatment, and only 25% considered tempe to be very important for DM treatment before counselling. After education regarding the benefits of tempe for treating DM, 69% of respondents considered tempe to be very important for DM, indicating that education could increase respondents' perceptions of the benefits of tempe as an antidiabetic functional food. It shows the importance of education and counselling to the public in supporting the consumption of tempe as a functional food choice to control DM.

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