RESEARCH ARTICLE

Tempeh Smoothie Consumption Reduces Triglyceride Levels and Body Mass Index of Menopausal Women

Asyifa Robiatul Adawiyah[1,*], Atik Kridawati[1,2], Sugeng Hadisaputra[3], Lili Indrawati[4], Nur Apriyan[1], Siska Darmayanti[5]

[1]Public Health Study Program, Faculty of Health Sciences, Universitas Respati Indonesia, Jl. Bambu Apus I No. 3, Jakarta 13890, Indonesia
[2]Public Health Postgraduate Program, Faculty of Health Sciences, Universitas Respati Indonesia, Jl. Bambu Apus I No. 3, Jakarta 13890, Indonesia
[3]Nursing Study Program, Faculty of Health Sciences, Universitas Respati Indonesia, Jl. Bambu Apus I No. 3, Jakarta 13890, Indonesia
[4]Hospital Administration Postgraduate Program, Faculty of Health Sciences, Universitas Respati Indonesia, Jl. Bambu Apus I No. 3, Jakarta 13890, Indonesia
[5]Prodia Clinical Laboratory, Jl. Alternatif Cibubur No. 136, Cimanggis, Depok 16954, Indonesia

*Corresponding author. Email: asyifarobiatuladawiyah@gmail.com

Received date: Oct 21, 2025; Revised date: Nov 18, 2025; Accepted date: Nov 23, 2025

Abstract

BACKGROUND: To reduce the risk of dyslipidemia, increasing the consumption of fiber-rich foods, such tempeh, is necessary. Tempeh contains abundant isoflavones that support lipid metabolism and vascular function, prompting researchers to develop methods for producing tempeh with more practical consumption compared to conventional tempeh. In current study, tempeh smoothie was produced and its effects on body composition and lipid profiles in menopausal women was evaluated.

METHODS: A quasi-experimental study was conducted including 16 menopause women as subjects. The tempeh smoothie was prepared using tempeh blended with water until smooth and creamy. The tempeh smoothie was consumed by the subjects five times a week for six weeks, and then the subjects' body composition and lipid profiles were measured before and after the intervention.

RESULTS: There were some improvements in subjects' body composition, specifically in muscle mass, and a few subjects shifted their body mass index (BMI) status from obesity to overweight. However, these changes were not statistically significant. Even though the consumption of tempeh smoothie did not improve total cholesterol level, which increased by 12.31 mg/dL); low-density lipoprotein (LDL) cholesterol, which increased by 32.81 mg/dL; and high-density lipoprotein HDL cholesterol, which decreased by 5.12 mg/dL; however, it is significantly reduced triglyceride levels by 75.00 mg/dL from baseline to post-intervention.

CONCLUSION: Consuming tempeh smoothie regularly shows a trend towards BMI reduction and a slight improvement in muscle mass among menopausal women. This consumption also significantly lowers the triglyceride levels, indicating that it might be potential in preventing dyslipidemia in menopausal women.

KEYWORDS: tempeh smoothie, menopausal women, body composition, lipid profile

Indones Biomed J. 2025; 17(6): 532-41

Introduction

Dyslipidemia is a condition marked by abnormalities in lipid metabolism, characterized by increased levels of total cholesterol, low-density lipoprotein (LDL) cholesterol, and/or triglycerides, along with decreased levels of high-density lipoprotein (HDL) levels.(1) Dyslipidemia is a metabolic syndrome that serves as a risk factor for cardiovascular disease, diabetes mellitus, obesity, and hypertension,

DOI: 10.18585/inabj.v17i6.3876

which are the largest group of non-communicable diseases according to the World Health Organization (WHO).(2) Cardiovascular disease, diabetes mellitus, and obesity were responsible for the deaths of 4.4 million people and the disabilities experienced by 98.62 million individuals. Notably, these conditions can frequently be linked to dyslipidemia.(3) The prevalence of dyslipidemia is higher in men than in women. However, after women reach menopause, their risk of developing dyslipidemia increases due to the decline in estrogen hormone production (4,5). A decrease of 91/5,000 in estrogen levels can increase the risk of sarcopenia in women.(6) The process of losing muscle mass and gaining body fat percentage typically begins during the perimenopause phase.(7) To reduce the risk of dyslipidemia, preventive measures can be taken based on the risk factors. WHO recommends emphasizing that a balanced diet is crucial, which includes limiting the intake of trans fats (8,9) and high-sugar foods, particularly those prevalent in ultra-processed foods (UPFs). Instead, one should aim to increase the consumption of fiber-rich foods, such as fruits, vegetables, nuts, and tempeh, to support optimal health.(10,11)

Tempeh contains isoflavones, which are a type of antioxidant that can help prevent high levels of oxidative stress, also known as reactive oxygen species (ROS). This is important in the development of neurodegenerative diseases, as well as cardiovascular diseases, cancer, and the aging process in humans, including dyslipidemia.(12) Isoflavone content in tempeh can help alleviate hot flashes and improve endothelial and vascular function.(13) Other than isoflavone, tempeh are also known to contain other significant components such as amino acids like methionine, threonine, valine, leucine, phenylalanine, and isoleucine, which contribute to muscle mass growth.(14)

Consuming tempeh regularly can lead to better body composition by increasing muscle mass and reducing body fat percentage.(15–17) These changes in body composition also positively affect lipid profiles, especially triglycerides and HDL (18), bringing them to optimal levels (19,20). The protein and fiber in tempeh help inhibit cholesterol absorption and enhance bile acid production in the intestine.(21) Consuming tempeh helps optimize blood glucose levels in the body due to its inulin content (22) that can stimulate the growth and metabolic activity of beneficial bacteria in the human colon thus stabilize blood glucose levels (23).

In a previous study involving 13 elderly women, it was observed that 61.5% experienced a reduction in body fat percentage, 38.5% successfully decreased their total cholesterol levels, and 61.5% achieved a reduction in fasting blood sugar levels following tempeh consumption. Therefore, in this study, tempeh was processed into a ready-to-drink tempeh smoothie for more practical consumption, and then the effect of regular tempeh smoothie consumption was measured on body composition, lipid profile parameters, and fasting blood sugar levels in menopausal women, as a potential strategy for preventing dyslipidemia.

Methods

Research Design and Subjects Recruitment

A quasi-experimental and, prospective pre–post design, study was conducted involving 16 menopause women. The subjects were initially recruited from a community-based elderly health service in Bambu Hitam, Cipayung, Jakarta. Subjects were excluded from the study if they had history or current diagnosis of liver, kidney, thyroid, cardiovascular disease, cancer, diabetes mellitus, or stroke; had vegetarianism; and regularly usinge of estrogen therapy, supplements, or phytopharmaceutical drugs. Subjects who failed to consume the intervention for three consecutive days, developed any exclusion condition during the study, or did not complete blood collection were considered drop-outs. The protocol of this study was approved by the Health Research Ethics Commission at Universitas Respati Indonesia (No. 579/SK.KEPK/UNR/VIII/2024, dated August 14, 2024) prior to the initiation of the study.

Preparation of Tempeh Smoothie

Each serving of tempeh smoothie was prepared using 100 g of tempeh blended with 600 mL of water. The preparation involved cutting 100 g of tempeh into small cubes, boiling for approximately 5 minutes to reduce odor, then blending with water until smooth and creamy. The tempeh used in this study was produced under hygienic, standardized conditions following Good Manufacturing Practices (GMP) and certified under the Hazard Analysis and Critical Control Point (HACCP) food safety framework. Based high-performance liquid chromatography chromatograms (HPLC) analysis, the produced tempeh smoothie had an isoflavone content equivalent toof 49.737 mg for every 100 grams of fresh tempeh mixed with 600 mL of water. This level of isoflavones is sufficient to meet the daily needs of menopausal women, which range from 30 to 80 mg.(13)

Tempeh Smoothie Intervention

The intervention consisted of a 1-week run-in period and a 6-week treatment period. During the run-in period, subjects were asked to refrain from consuming soy or soy-based products while maintaining their regular diet and recording daily food intake. Baseline saliva and blood samples were collected at the end of this period. During the 6-week treatment period, subjects consumed tempeh smoothie daily, five days per week, for six consecutive weeks. The post-intervention samples were taken after this 6-week period ended.

Body Composition Measurement

Subjects' body composition was measured using a digital bioelectrical impedance analysis (BIA) scale (Omron HBF-702T; Omron, Kyoto, Japan), which provided data on body weight, body mass index (BMI), body fat percentage, muscle mass, and protein percentage. Subjects entered their height and age before the measurement, and results were automatically transmitted to a mobile application within approximately five to ten seconds.

Blood Collection and Lipid Profile Examination

As much as 20 mL venous blood samples were collected from each subjects before and after the six-week intervention following a fasting period of 10–12 hours. Blood was drawn by trained laboratory technicians and then centrifuged to obtain the serum, which was later stored at −20°C until the analysis. Lipid profile analysis included total cholesterol, triglycerides, HDL, and LDL level. All analyses were conducted at Prodia Clinical Laboratory, Jakarta, using standardized enzymatic colorimetric methods: specifically using enzymatic cholesterol oxidase-peroxidase aminoantipyrine (CHOD-PAP) method for total cholesterol measurement, glycerol phosphate oxidase-p-aminophenazone (GPO-PAP) methods for triglycerides measurement, and: homogeneous enzymatic assays methods for HDL and LDL cholesterol measurement using a Roche Cobas c501 analyzer (Roche Diagnostics, Mannheim,. Germany). Quality control procedures waswere performed following standard laboratory protocols with two levels of control sera analyzed daily to ensure analytical accuracy.

Statistical Analysis

Data analysis employed in this study wass descriptive statistics to provide insights into the key metrics such as mean, median, standard deviation, and range of values. To evaluate differences between the run-in and post-intervention phases, the distribution of data for each variable was initially assessed. A *p*-value<0.05 was considered indicative of significant differences among the variables analyzed. In a quasi-experimental design without a control group, effect size quantifies the magnitude of change independent of sample size and statistical significance. Effect size was calculated using Hedges' g to account for small sample bias (n=16). The small-sample correction factor 1-3/(4n-9) was applied. Effect sizes were interpreted using conventional thresholds (0.2: small, 0.5: moderate, 0.8: large).

Results

Subjects Characteristics

The average age of the female subjects who participated in this study was 54 years, with an age range of 50 to 59 years. The normality test analysis showed that parameters including BMI, the percentage of water, and basal metabolic rate (BMR) were not normally distributed (*p*<0.05), meanwhile, the percentage of body fat, protein levels, visceral fat, muscle mass, bone, body age, and all lipid profile parameters were normally distributed (*p*>0.05).

Reduction in BMI Trend and Increased of Muscle Mass Trend after Consumption of Tempeh Smoothie

Subjects' body distribution at baseline and post-intervention was provided in Table 1, while the mean comparison analysis and the effect size estimation was provided in Table 2. The BMI showed a slight decrease, from an average of 26.44 kg/m² prior to the intervention to 26.42 kg/m² following the intervention. Furthermore, the number of subjects classified as obese decreased from 7 to 5, which corresponds to a 31.30% reduction post-intervention. There was a slight increase in mean muscle mass, rising from 35.65 to 35.67 kg. The average percentage of body fat increased from 36.00 to 36.28%, while the rate of body water increased from 43.89 to 45.24%. It was noteworthy that body protein levels decreased marginally from an average of 15.07 to 14.85%. There was a positive change in the mean BMR, which increased from 1083 kcal to 1086.31 kcal. Additionally, the average levels of visceral fat increased from 7.56 to 7.75 post-intervention. No significant changes were observed in bone mass or body age among the subjects from baseline to post-intervention. From the overall assessment of body types, it was concluded that 1 out of 16 subjects achieved a successful transition from the obese category, which was characterized by normal muscle mass combined with a high percentage of body fat, to the thick-set category, which was defined by good muscle mass with a high percentage of body fat.

Figure 1 illustrated the distribution of subjects' body composition categories at baseline and post-intervention,

Table 1. Body composition distribution in the baseline and post-intervention.

Body Composition Characteristic	n (%)	
	Baseline	Post-Intervention
BMI (kg/m^2)		
Underweight (<18.5)	0 (0)	0 (0)
Normal (18.5–25)	7 (43.75)	7 (43.75)
Overweight (>25–27)	2 (12.50)	4 (25.00)
Obesity (>27)	7 (43.75)	5 (31.25)
Fat Percentage (%)		
Low	2 (12.50)	1 (6.25)
Normal	5 (31.25)	7 (43.75)
high	9 (56.25)	8 (50.00)
Water Percentage (%)		
Insufficient	7 (43.75)	6 (37.50)
normal	9 (56.25)	10 (62.50)
Protein Body Level (%)		
Insufficient	11 (68.75)	12 (75.00)
Normal	5 (31.25)	4 (25.00)
Good	0 (0)	0 (0)
BMR (Kcal)		
Reach the goal	6 (37.50)	6 (37.50)
Didn't reach the goal	10 (62.50)	10 (62.50)
Visceral Fat		
Normal (<10)	13 (81.25)	13 (81.25)
High (10–15)	3 (18.75)	3 (18.75)
Very high (>15)	0 (0)	0 (0)
Muscle Mass (kg)		
Insufficient	1 (6.25)	1 (6.25)
Normal	12 (75.00)	13 (81.25)
Good	3 (18.75)	2 (12.50)
Bone Mass (kg)		
Insufficient	0 (0)	0.00
Normal	16 (100.00)	100.00
Good	0 (0)	0.00
Body Type		
Skinny	0 (0)	0 (0)
Balanced Skinny	0 (0)	0 (0)
Skinny Muscular	0 (0)	0 (0)
Lacks Exercise	0 (0)	0 (0)
Balanced	6 (37.50)	6 (37.50)
Balanced Muscular	1 (6.25)	1 (6.25)
Obese	1 (6.25)	1 (6.25)
Overweight	6 (37.50)	5 (31.25)
Thick-set	2 (12.50)	3 (18.75)

mapped onto a standardized body type matrix integrating body fat ratio (vertical axis) and muscle ratio (horizontal axis). The vertical scale ranges from low to high body fat, while the horizontal scale progresses from insufficient to good muscle ratio. At baseline, 37.5% of subjects (n=6) were classified as overweight, positioned in the quadrant characterized by elevated body fat with normal muscle mass. In addition, 31.3% (n=5) were categorized as thick-set, representing individuals with both high body fat and relatively higher muscle mass. Following the intervention, the proportion of subjects classified as overweight decreased to 12.5% (n=2), and those categorized as thick-set declined to 18.8% (n=3). These shifts reflect a movement downward and rightward on the matrix, indicating reductions in body fat ratio accompanied by improvements in muscle ratio. The figure demonstrates a favourable transition in body composition, with subjects moving from higher-fat categories (overweight and thick-set) toward more balanced or muscular body types after the intervention.

Based on the Hedges' analysis, across all parameters, no statistically significant differences were observed between baseline and post-intervention measurements (p>0.05). However, several variables demonstrated small effect sizes, indicating minor but directionally consistent changes. BMI showed a negligible mean reduction (-0.16 kg/m²) with a small effect size (r=-0.14). Body fat percentage also decreased slightly (-0.28%) with a small effect size (g=0.28). Water percentage increased marginally (0.36%), although the effect was classified as trivial (r=-0.03). Protein body level exhibited a minor increase (0.22%) and a small effect size (g=0.35), suggesting a modest improvement in protein-related body composition. Basal metabolic rate showed a slight increase (3.12 kcal) with a small effect (r=-0.11). Visceral fat increased minimally (0.19 units) with a small effect size (g=-0.33). Muscle mass increased negligibly (0.02 kg), with a trivial effect size (g=-0.03), while bone mass rose by 0.01 kg (trivial effect, g=0.09). Body age decreased by 0.81 years with a small effect size (g=-0.27), suggesting a modest favorable shift.

Although no statistically significant changes were observed, it was important to note that achieving substantial shifts in body composition within a 6-week treatment period tempeh-based dietary intervention is inherently challenging. Nevertheless, the small but consistent improvements across multiple parameters, including slight reductions in body fat and body age, along with modest increases in protein level, metabolic rate, and muscle mass, which indicate the early positive physiological adaptations. These subtle yet favorable trends suggested that the tempeh smoothie diet may contribute meaningfully to overall body composition when sustained over a longer period.

Consumption of Tempeh Smoothie Significantly Reduced Triglyceride Levels

The cholesterol profile results, detailed in Table 3, encompass the measurements of total cholesterol, HDL, LDL, and triglyceride levels. The average total cholesterol among subjects was recorded at 161.88 mg/dL prior to the

Table 2. Analysis of body composition at baseline and post-intervention, and the effect size estimates.

Body Composition Characteristic	Mean±SD	Min-Max	Mean Difference*	N	[a]Test Statistic	p-value	[b]Effect Size	Interpretation (Effect Size)
Body Mass Index (kg/m^2)								
Baseline	26.44±4.69	20.90–38.70	-	16	Z = -0.54	0.589	r = -0.14	small
Post-Intervention	26.42±4.30	21.40–38.00						
Body Fat (%)								
Baseline	36.00±6.09	25.90–50.60	-0.28	16	t = -1.17	0.259	g = -0.28	small
Post-Intervention	36.28±5.78	26.20–47.10						
Water Percentage (%)								
Baseline	43.89±6.09	25.90–50.60	-	16	Z = -0.114	0.909	r = -0.03	trivial
Post-Intervention	45.24±3.74	37.80–50.20						
Protein Body Level (%)								
Baseline	15.07±2.01	12.0–19.10	0.22	16	t = 1.47	0.160	g = 0.35	small
Post-Intervention	14.85±1.73	12.00–18.80						
Basal Metabolism Rate (Kcal)								
Baseline	1083.94±124.37	938–1432	-	16	Z = -0.426	0.670	r = -0.11	small
Post-Intervention	1086.31±119.95	934–1414						
Visceral Fat								
Baseline	7.56±2.50	4–13	-0.19	16	t = -1.38	0.188	g = -0.33	small
Post-Intervention	7.75±2.32	4–13						
Muscle Mass (kg)								
Baseline	35.65±3.91	29.96–45.54	-0.02	16	t = -0.11	0.911	g = -0.03	trivial
Post-Intervention	35.67±3.70	29.86–44.95						
Bones Mass (kg)								
Baseline	2.05±0.37	1.43–2.83	-0.01	16	t = -0.36	0.722	g = -0.09	trivial
Post-Intervention	2.06±0.31	1.62–2.79						
Body Age (years)								
Baseline	54.13±13.15	35–80	-0.81	16	t = -1.15	0.269	g = -0.27	small
Post-Intervention	54.94 ±13.01	35–80						

intervention, rising to 174.19 mg/dL post-intervention. Despite this increase, all subjects maintained total cholesterol levels within the normal range, indicating no significant clinical concern. In addition, the mean LDL value increased from 50.19 mg/dL to 83.00 mg/dL following the intervention, with two subjects ultimately classified within the high LDL category. Conversely, there was a decrease in the mean HDL value, which fell from 57.25 mg/dL to 52.13 mg/dL after the intervention. The triglyceride levels showed a marked improvement, decreasing from 270.44 mg/dL, which placed them in the high category, to 195.44 mg/dL, now within the normal range. This change was particularly significant as 8 subjects (50%) successfully transitioned from the high triglyceride category to normal (Figure 2). Although other subjects did not achieve a normal status, nearly all experienced reductions in their triglyceride levels. Table 4 showed that all lipid profiles demonstrated statistically significant differences (p<0.05) in total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides. Notably, only the triglyceride levels showed improvement, with a significant decrease of 75.00 mg/dL from baseline to post-intervention.

Figure 1. The distribution of subjects' body composition categories at baseline and post-intervention. The vertical scale ranges from low to high body fat, while the horizontal scale progresses from insufficient to good muscle ratio. The subjects changed their body type from overweight to thick-set.

Figure 2 illustrated the individual triglyceride trajectories from baseline to post-intervention across 16 subjects. Overall, all subjects demonstrated a reduction in triglyceride levels following the intervention, indicating a

Table 3. Lipid profile distribution at baseline and post-intervention.

Lipid Profiles Characteristic	n (%)	
	Baseline	Post-Intervention
Total Cholesterol		
Normal (<200 mg/dL)	16 (100.00)	16 (100.00)
High (≥200 mg/dL)	0 (0)	0 (0)
HDL Cholesterol		
Low (<30 mg/dL)	0 (0)	0 (0)
Normal (30–65 mg/dL)	16 (100.00)	16 (100.00)
High (≥66 mg/dL	0 (0)	0 (0)
LDL Cholesterol (<100 mg/dL)		
Normal (<100 mg/dL)	16 (100.00)	14 (87.50)
High (≥100 mg/dL)	0 (0)	2 (12.50)
Triglycerides		
Normal (<200 mg/dL)	1 (6.25)	8 (50.00)
High (≥200 mg/dL)	15 (93.75)	8 (50.00)

consistent downward trend across the subjects. Notably, 8 subjects showed post-intervention values that approached or crossed the designated normal threshold (200 mg/dL), suggesting a clinically meaningful improvement for these individuals. Although several subjects did not reach the normal range, each subjects experienced a measurable decline from baseline, reflecting a uniform beneficial effect of the intervention. This pattern strengthens the internal consistency of the findings, as no subjects exhibited a neutral or adverse response. The distribution of reductions also suggests that the intervention produced both statistically and clinically relevant improvements in triglyceride profiles at the individual level.

Both total cholesterol and HDL cholesterol experienced statistically significant, yet adverse, changes. Post-intervention total cholesterol levels showed a significant increase (Mean Difference: -12.31 mg/dL; t=-2.24; *p*=0.041), characterized by a moderate effect size (Hedges' g=0.53). Similarly, HDL levels significantly decreased (Mean Difference: 5.13 mg/dL; t=2.30; *p*=0.036), also yielding a moderate effect size (g=0.54). These moderate effect sizes suggest that the intervention exerted a discernible, non-trivial negative influence on these two parameters. The most pronounced changes, quantified by large effect sizes, were observed in LDL and triglycerides. LDL levels demonstrated a highly significant and substantial increase post-intervention (Mean Difference: -32.81 mg/dL; t=-5.67; *p*<0.001).

This adverse change was supported by a large effect size (g=-1.34), indicating that the intervention caused a profound and clinically relevant elevation in circulating LDL cholesterol. In contrast, triglycerides showed a highly significant and favorable reduction post-intervention (Mean Difference: 75.00 mg/dL; t=7.58; *p*<0.001). The magnitude of this improvement was exceptionally strong, evidenced by a very large effect size (g=1.79) (Table 4). This result confirms the intervention's superior effectiveness in reducing triglycerides levels compared to its effect on other lipid components.

Discussion

In Indonesia, soybeans are processed into tempeh, tofu, soy sauce, tauco, and soy milk. Among these soy products, tempeh contains the highest amount of isoflavone aglycones, providing better bioavailability than the other soy products.(24) Raw tempeh contains ~20 mg of isoflavones per 100 grams (body weight), whereas tofu and soy milk have lower isoflavone contents, with 28 mg per 100 grams, respectively.(25) The tempeh smoothies used in this study contained 49.7 mg/100 gr which include 92.31 µg/2gr daidzein; 20.53 µg/2gr glycitein; 142.87 µg/2gr genestein. Table 5 compares

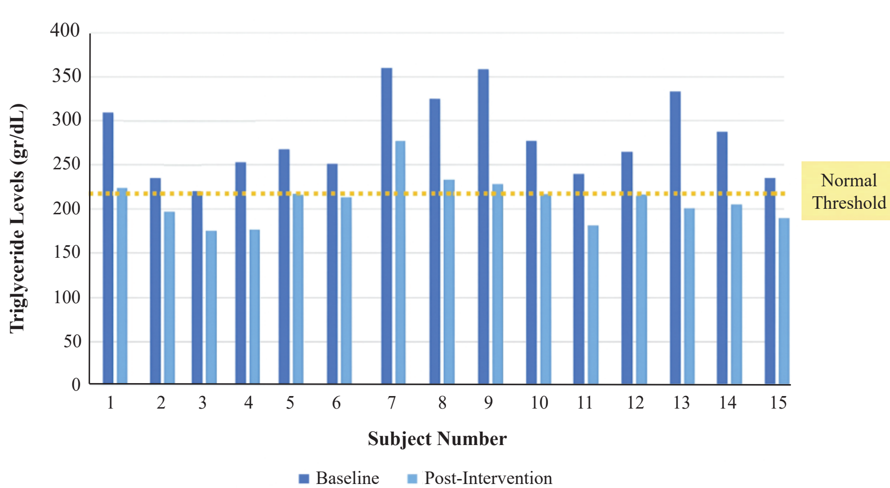

Figure 2. A comparison of triglyceride levels at the baseline and after the intervention.

Table 4. Analysis of variations in lipid profiles at baseline and post-intervention.

Body Composition Characteristic	Mean±SD	Min-Max	Mean Difference*	N	[a]Test Statistic	*p*-value	[b]Effect Size	Interpretation (effect size)
Total Cholesterol (<200 mg/dL)								
Baseline	161.88±14.05	126–185	-12.31	16	t = -2.24	0.041	g = -0.53	Moderate
Post-Intervention	174.19±20.03	136–200						
HDL Cholesterol (30–65 mg/dL)								
Baseline	57.25±7.69	45–67	5.13	16	t = 2.30	0.036	g = 0.54	Moderate
Post-Intervention	52.13±8.55	35–65						
LDL Cholesterol (<100 mg/dL)								
Baseline	50.19±14.10	31–70	-32.81	16	t = -5.67	<0.001	g = -1.34	Large
Post-Intervention	83.00±22.05	34–113						
Triglycerides (<200 mg/dL								
Baseline	270.44±50.41	198–360	75.00	16	t = 7.58	<0.001	g = 1.79	Very Large
Post-Intervention	195.44±31.64	150–271						

the component of raw/conventional tempeh with the tempeh smoothie used in current study.

The analysis of body composition reveals that the metabolic activity was effective at the individual level, even though the group means for body fat and muscle mass remained statistically unchanged. The qualitative classification (Figure 1) provides strong evidence of favorable body recomposition. The significant movement of subjects out of the high-fat categories (overweight decreased from 37.5% to 31.3%; thick-set increased from 12.5% to 18.8%) confirms a shift toward healthier body compositions.(26)

Crucially, the observed transition of individuals from overweight (high fat, normal muscle) to thick-set (high fat, good muscle) demonstrates a preferential anabolic stimulus being provided by the intervention.(27,28) The most critical finding of this study is the highly selective, yet potent, effect of the 6-week tempeh intervention on the subjects' lipid profiles. While all lipid markers showed statistically significant changes ($p<0.05$), only the massive reduction in triglycerides (Mean reduction of 75.00 mg/dL; Hedges's g=1.79, $p<0.001$) represented a clinically favorable outcome. This finding confirms the established efficacy of soy-based products, particularly fermented ones like tempeh, in addressing hypertriglyceridemia.(29) However, the intervention failed to yield net improvement across the entire lipid panel, as evidenced by the significant and undesirable increase in LDL cholesterol and total cholesterol, alongside a significant decrease in HDL cholesterol.(30) This issue presents a major challenge to the overall cardiovascular benefit of the intervention (31), requiring a deeper exploration of the underlying biomechanisms involving tempeh and the perimenopausal state. This paradox emphasizes a key challenge in utilizing isoflavones: their selective biological action. The level of hormonal modulation achieved by tempeh was potent enough to regulate enzymes linked to triglycerides clearance but was evidently insufficient to fully compensate for the age-related decline in hepatic LDL receptor expression.(29) The substantial reduction in triglycerides can be attributed primarily to the high content of isoflavones (genistein and daidzein) and dietary fiber in tempeh (32,33), amplified by the fermentation process (34). Isoflavones act as ligands for peroxisome proliferator-activated receptor alpha (PPARα). PPARα is a nuclear receptor central to fatty acid catabolism. Its activation by isoflavones enhances the transcription of genes involved in mitochondrial and peroxisomal oxidation (fatty acid breakdown) in the liver.(35) This accelerated catabolism directly reduces the pool of fatty acids available for hepatic very low-density lipoprotein (VLDL) synthesis, which is the precursor of circulating triglycerides.(36) Isoflavones may also inhibit key lipogenic enzymes, such as fatty acid synthase (FAS), thereby suppressing *de novo* lipogenesis in the liver.(37) The net effect is a significant reduction in the synthesis and secretion of VLDL particles, leading to the observed very large decrease in serum triglycerides.(38)

In this study, there is no control group, and the intervention was only administered to one group, which means there is no comparison available. Additionally, the subjects did not live together, such as in a nursing home or dormitory, resulting in varied food consumption among them. However, this potential bias was minimized by providing all subjects with a food diary during the tempeh smoothie consumption process. For further studies, the elucidation of the molecular mechanisms underlying the discrepancy between triglycerides and other lipid profile parameters as well as the development of fortified tempeh

Table 5. Comparison between conventional tempeh and tempeh smoothie used in this study.

Component / Property	Conventional Tempeh (Typical Values)*	Tempeh smoothie (Used in This Study)	Remarks / Bioactive Benefits
Form & Processing	Solid cake; fermented for 36–48 h at 30–37°C (39)	Blended into liquid form (100 g tempeh + 600 mL water), filtered, and homogenized	Increases digestibility and bioavailability of bioactives
Isoflavones (total)	~20 mg/100 gr (mainly daidzein, genistein, glycitein) (39,40)	Equivalent to 49.7 mg/100 gr (92.31 µg/2gr daidzein; 20.53 µg/2gr glycitein; 142.87 µg/2gr other isoflavones)	more effective for menopausal health (30–80 mg/day)
Isoflavone form	Mixed glycoside and aglycone (25)	Higher proportion of aglycones due to fermentation and mechanical breakdown	Improved intestinal absorption and bioavailability
Protein and peptides	19–21% protein; moderate levels of short peptides (25,40)	Enhanced release of bioactive peptides during blending and cell wall disruption	Contributes to muscle synthesis, lipid regulation, antioxidant activity
L-Arginine	~3–5 g/100 g (25)	Present, potentially more bioavailable in liquid matrix	Acts as vasodilator via nitric oxide (NO) pathway; improves lipid oxidation
Inulin & Dietary Fiber	Present in small amounts (25)	Retained in soluble fraction; acts as prebiotic	Improves gut microbiota and glucose metabolism
Antioxidant Activity	Moderate (25)	Enhanced due to the release of phenolic compounds and isoflavone aglycones	Supports anti-inflammatory and anti-dyslipidemic effects
Ease of Consumption	Requires chewing, less suitable for older adults (25)	Smooth liquid, easy to digest and absorb	Suitable for menopausal women or those with reduced chewing ability
Shelf-life & Safety	Depends on hygienic handling (39)	Produced under GMP & HACCP-certified process	Ensures microbial safety and standardized quality

formulations or combinations with other cholesterol-lowering agents to achieve an optimal and cardiovascularly protective lipid profile should be focused on.

Conclusion

The results of the current study shows tempeh smoothie's positive effect on triglyceride-rich lipoprotein clearance, evidenced by a highly substantial and statistically significant reduction in triglycerides, with an effect size indicating the superiority of the intervention. Regarding the body composition, although it is not statistically significant, however it shows promising trends in BMI reduction and a minor increase in muscle mass. Therefore, the produced tempeh smoothie might have some potential as a nutraceutical agent for the management of isolated hypertriglyceridemia within the menopausal women population.

Acknowledgments

The authors would like to express their sincere gratitude to the Department of Research and Community Service, Universitas Respati Indonesia, for their valuable support and contributions to this research. Special thanks to Prof. Tri Budi Rahardjo, Restikanimgrum, Salsabila Qurrotu'ain and Muhammad Zaidan for their guidance and assistance throughout the project. This research was supported by the Ministry of Education, Culture, Research, and Technology, Republic of Indonesia. Research grant number: 1005/LL3/AL.04/2025, dated June 4, 2025.

Authors Contribution

ARA was responsible for coordinating the entire research project, including ethics, all phases of the research, data analysis, and publication. AK served as the lead coordinator for the Tempe research project, provided essential coordination for all stages of the research. SH and LI were responsible for measuring body composition and collecting blood samples for cholesterol and fasting blood sugar assessments, both prior to and following the intervention. NA diligently recorded measurements at these intervals, conducted data analysis, and facilitated the publication process. SD meticulously reviewed the data analysis results and ensured the manuscript met all necessary standards for completeness. All authors actively participated in the preparation of this manuscript, contributing their expertise and insights.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

References

1. Bereda G. Pathophysiology and management of dyslipidaemia. Biomed J Sci Tech Res. 2022; 43(2): 34369–75.
2. Schwartz LN, Shaffer JD, Bukhman G. The origins of the 4 × 4 framework for noncommunicable disease at the World Health Organization. SSM Popul Health. 2021; 13: 100731. doi: 10.1016/j.ssmph.2021.100731.
3. Global Burden Disease [Internet]. Institute for Health Metrics and Evaluation: 2021 [cited 2025 Mar 30]. Available from: https://vizhub.healthdata.org/gbd-results/.
4. Zimodro JM, Mucha M, Berthold HK, Gouni-Berthold I. Lipoprotein metabolism, dyslipidemia, and lipid-lowering rherapy in women: A comprehensive review. Pharmaceuticals. 2024; 17(7): 913. doi: 10.3390/ph17070913.
5. Kusuma BWA, Dwiningsih SR, As'adi A, Wahyuningsih SPA. Liposome-based nanoparticles encapsulating vitamin D3 attenuate IL-6 and TNF-α in a menopausal mouse model. Indones Biomed J. 2025; 17(5): 484–92.
6. Geraci A, Calvani R, Ferri E, Marzetti E, Arosio B, Cesari M. Sarcopenia and menopause: The role of estradiol. Front Endocrinol. 2021; 12: 682012. doi: 10.3389/fendo.2021.682012.
7. Coelho-Júnior HJ, Marques FL, Sousa CV, Marzetti E, Aguiar SDS. Age- and sex-specific normative values for muscle mass parameters in 18,625 Brazilian adults. Front Public Health. 2024; 11: 1287994. doi: 10.3389/fpubh.2023.1287994.
8. Meiliana A, Wijaya A, Ticle RA. Peroxisome proliferator–activated receptors and the metabolic syndrome. Indones Biomed J. 2009; 1(1): 4–31.
9. Novita BD, Wedharga IGPA, Tjahjono Y, Wijaya H, Theodora I, Ervina M, *et al.* Modified high-fat high-sucrose diet promotes obesity and alters colonic cytokines. Indones Biomed J. 2025; 17(5): 456–64.
10. Brial F, Chilloux J, Nielsen T, Vieira-Silva S, Falony G, Andrikopoulos P, *et al.* Human and preclinical studies of the host–gut microbiome co-metabolite hippurate as a marker and mediator of metabolic health. Gut. 2021; 70(11): 2105–14.
11. Chopra AK. Dietary management of dyslipidemia. Indian Heart J. 2024; 76(Suppl 1): S65–72.
12. Teoh SQ, Chin NL, Chong CW, Ripen AM, How S, Lim JJL. A review on health benefits and processing of tempeh with outlines on its functional microbes. Future Foods. 2024; 9: 100330. doi: 10.1016/j.fufo.2024.100330.
13. Taku K, Melby MK, Kronenberg F, Kurzer MS, Messina M. Extracted or synthesized soybean isoflavones reduce menopausal hot flash frequency and severity: Systematic review and meta-analysis of randomized controlled trials. Menopause. 2012; 19(7): 776–90.
14. Koutsilieris M, Philippou A, Atherton PJ, Black KE, Matkin-Hussey P. The impact of protein in post-menopausal women on muscle mass and strength: A narrative review. Physiologia. 2024; 4(3): 266–85.
15. Somekawa Y, Chiguchi M, Ishibashi T, Aso T. Soy intake related to menopausal symptoms, serum lipids, and bone mineral density in postmenopausal Japanese women. Obstet Gynecol; 2001; 97(1): 109–15.
16. Anderson JJB, Anthony MS, Cline JM, Washburn SA, Garner SC. Health potential of soy isoflavones for menopausal women. Public Health Nutr. 1999; 2(4): 489–504.
17. Radhakrishnan G, Rashmi, Agarwal N, Vaid NB. Evaluation of isoflavone rich soy protein supplementation for postmenopausal therapy. Pak J Nutr. 2009; 8(7): 1009–17.
18. Hall WL, Vafeiadou K, Hallund J, Bugel S, Reimann M, Koebnick C, *et al.* Soy-isoflavone-enriched foods and markers of lipid and glucose metabolism in postmenopausal women: interactions with genotype and equol production 1-3. Am J Clin Nutr. 2006; 83(3): 592–600.
19. Greany KA, Nettleton JA, Wangen KE, Thomas W, Kurzer MS. Consumption of isoflavone-rich soy protein does not alter homocysteine or markers of inflammation in postmenopausal women. Eur J Clin Nutr. 2008; 62(12): 1419–25.
20. Messina M, Duncan A, Messina V, Lynch H, Kiel J, Erdman JW. The health effects of soy: A reference guide for health professionals. Front Nutr. 2022; 9: 970364. doi: 10.3389/fnut.2022.970364.
21. Blanco Mejia S, Messina M, Li SS, Viguiliouk E, Chiavaroli L, Khan TA, *et al.* A Meta-analysis of 46 studies identified by the FDA demonstrates that soy protein decreases circulating LDL and total cholesterol concentrations in adults. J Nutr. 2019; 149(6): 968–81.
22. Misiakiewicz-Has K, Maciejewska-Markiewicz D, Szypulska-Koziarska D, Kolasa A, Wiszniewska B. The influence of soy isoflavones and soy isoflavones with inulin on kidney morphology, fatty acids, and associated parameters in rats with and without induced diabetes type 2. Int J Mol Sci. 2024; 25(10): 5418. doi: 10.3390/ijms25105418.
23. Rao M, Gao C, Xu L, Jiang L, Zhu J, Chen G, *et al.* Effect of inulin-type carbohydrates on insulin resistance in patients with type 2 diabetes and obesity: A systematic review and meta-analysis. J Diabetes Res. 2019; 2019: 5101423. doi: 10.1155/2019/5101423.
24. Haron H, Ismail A, Azlan A, Shahar S, Peng LS. Daidzein and genestein contents in tempeh and selected soy products. Food Chem. 2009; 115(4): 1350–6.
25. Romulo A, Surya R. Tempeh: A traditional fermented food of Indonesia and its health benefits. Int J Gastron Food Sci. 2021; 26: 100413. doi: 10.1016/j.ijgfs.2021.100413.
26. Gangitano E, Barbaro G, Gnessi L, Iacobellis G, Lubrano C. Epicardial fat thickness is increased in menopausal patients in comparison with premenopausal patients with similar excess weight: A cross-sectional study. J Transl Med. 2025; 23(1): 401. doi: 10.1186/s12967-025-06335-3.
27. Sipilä S, Törmäkangas T, Sillanpää E, Aukee P, Kujala UM, Kovanen V, *et al.* Muscle and bone mass in middle-aged women: role of menopausal status and physical activity. J Cachexia Sarcopenia Muscle. 2020; 11(3): 698–709.
28. Silva TR, Oppermann K, Reis FM, Spritzer PM. Nutrition in Menopausal women: A narrative review. Nutrients. 2021; 13(7): 2149. doi: 10.3390/nu13072149.
29. Wang Y, Jones PJH, Ausman LM, Lichtenstein AH. Soy protein reduces triglyceride levels and triglyceride fatty acid fractional synthesis rate in hypercholesterolemic subjects. Atherosclerosis. 2004; 173(2): 269–75.
30. Lukito AA, Bakri S, Kabo P, Wijaya A. The mechanism of coronary artery calcification in centrally obese non-diabetic men: Study on the interaction of leptin, free leptin index, adiponectin, hs-C reactive protein, bone morphogenetic protein-2 and matrix gla protein. Mol Cell Biomed Sci. 2020; 4(2): 88–93.
31. Leonard LM, Choi MS, Cross TWL. Maximizing the estrogenic potential of soy isoflavones through the gut microbiome: Implication

for cardiometabolic health in postmenopausal women. Nutrients. 2022; 14(3): 553. doi: 10.3390/nu14030553.

32. Jassi HK, Jain A, Arora S, Chitra R. Effect of soy proteins Vs soy isoflavones on lipid profile in postmenopausal women. Indian J Clin Biochem. 2010; 25(2): 201–7.
33. Moradi M, Daneshzad E, Azadbakht L. The effects of isolated soy protein, isolated soy isoflavones and soy protein containing isoflavones on serum lipids in postmenopausal women: A systematic review and meta-analysis. Crit Rev Food Sci Nutr. 2020; 60(20): 3414–28.
34. Ali NM, Yeap SK, Yusof HM, Beh BK, Ho WY, Koh SP, *et al.* Comparison of free amino acids, antioxidants, soluble phenolic acids, cytotoxicity and immunomodulation of fermented mung bean and soybean. J Sci Food Agric. 2016; 96(5): 1648–58.
35. Patel RP, Barnes S. Isoflavones and PPAR signaling: A critical target in cardiovascular, metastatic, and metabolic disease. PPAR Res. 2011; 2010: 153252. doi: 10.1155/2010/153252.
36. Probosari E, Dewi SN, Alfadila TI, Handayani EN, Rizkita MS, Candra A, *et al.* Sorghum-soybean flour enteral formula reduces blood glucose, cholesterol, triglycerides, LDL, and increases HDL and albumin in hyperglycemic rats. Mol Cell Biomed Sci. 2025; 9(1): 13–21.
37. Ahmad MF, Haidar MA, Naseem N, Ahsan H, Siddiqui WA. Hypoglycaemic, hypolipidaemic and antioxidant properties of Celastrus paniculatus seed extract in STZ-induced diabetic rats. Mol Cell Biomed Sci. 2023; 7(1): 10–7.
38. Wang Y, Jones PJH, Ausman LM, Lichtenstein AH. Soy protein reduces triglyceride levels and triglyceride fatty acid fractional synthesis rate in hypercholesterolemic subjects. Atherosclerosis. 2004; 173(2): 269–75.