Applied Science, Engineering and Management Bulletin [ASEMB]
ISSN: 3049-3005
Vol 2 Issue 3 (July-Sep 2025) |Pg:63-68

Impact of Probiotic-Fermented Almond Milk Yogurt on Endothelial Function and Cardiovascular Health

Hoang Trong Dung
Marie Curie School
dunghoang.mcs208@gmail.com

Abstract

Endothelial dysfunction serves as an early indicator of cardiovascular disease, and plant-based probiotic interventions show promise in preventive nutrition strategies. This research evaluates the consequences of daily feeding of probiotic-fermented almond milk yogurt on endothelial function and cardiovascular risk markers in individuals with moderate cardiovascular risk.A randomized-controlled trial (RCT) is conducted over 8 weeks, involving 60 participants aged 40-70 years with elevated cholesterol or borderline hypertension. Participants are randomly assigned to consume either 200 g/day of probiotic-fermented almond milk yogurt containing Lactobacillus plantarum and Bifidobacterium lactis or a placebo version without live cultures. Paired and unpaired t-tests, along with ANCOVA adjusted for baseline values, are used to compare changes between and within groups. A significance threshold is set at $p < 0.05$.Participants who consumed the probiotic-fermented yogurt showed a significant 12% improvement in FMD and a 10% increase in serum nitric oxide (NO) levels compared to the control group. LDL cholesterol is significantly reduced by 8.6%, and CRP decreases by 10.2%. VCAM-1 levels show a non-significant downward trend. No adverse events are reported, and compliance exceeds 95%.Probiotic-fermented almond milk yogurt significantly improves endothelial function and positively influences select cardiovascular biomarkers. These findings support its potential as a functional, plant-based dietary strategy for promoting cardiovascular health.

Keywords: *Probiotic Yogurt, Almond Milk, Endothelial Function, Cardiovascular Disease, Randomized Controlled Trial.*

1. Introduction

Cardiovascular diseases (CVDs) characterize a significant worldwide healthiness burden, with endothelial dysfunction being one of the earliest clinical disturbances and one of the key turning points in the CVD development process [1]. The vascular endothelium plays a critical role in maintaining vascular homeostasis by regulating vasodilation, thrombus formation, capillary permeability, and inflammatory responses within the vascular system. Impaired endothelial function is characterized by increased oxidative stress, inflammation, and decreased bioavailability of Nitric oxide (No), which contributes to the risk of atherosclerosis and other cardiovascular disease processes [2]. Nutritional approaches to restore endothelial integrity are becoming increasingly popular. Probiotics are gaining attention as a potentially helpful adjunct therapy, as several probiotic strains have shown lipid-modulating, anti-inflammatory, and antioxidant properties relevant to vascular health [3]. At the same time, with the rise of plant-based eating, dairy substitutes, like almond milk, are being explored for their cardioprotective nutrient profile. Fermenting almond milk with specific probiotics can enhance its bioactivity and provide a new functional food in cardiovascular management [4].

Aim: To evaluate the impact of daily consumption of probiotic-fermented almond milk yogurt on endothelial purpose and cardiovascular biomarkers in individuals with moderate cardiovascular risk through an eight-week randomized controlled trial design.

2. Related work

The connotationbetween dairy consumption and CVD outcomes were examined in patients with steadyangina pectoris. Higher milk consumption increased stroke and mortality risks, while cheese intake reduced Acute Myocardial Infarction (AMI) risk [5]. The analysis was incomplete due to probable dietary recall bias and the inability to establish causation due to observational design. Human breast milk-derived extracellular vesicles were tested for therapeutic effects on endothelial cell dysfunction. Results demonstrated reduced inflammatory markers and improved

vasorelaxation in obese mice [6]. The approach is limited by unclear identification of the specific active Extracellular Vesicles (EV) components and the absence of validation in human clinical cardiovascular conditions. Using UK Biobank data, milk type was linked to cardiovascular and all-cause mortality. Semi-skimmed, and soy milk were associated with lower risk levels [7]. Limitations include reliance on self-reported milk consumption and lack of biological mechanisms explaining the differential effects among milk subtypes.Cu2+-loaded casein microgels were developed to restore myocardial metabolism after infarction. The intervention improved cardiac function and promoted angiogenesis through metabolic regulation [8]. Despite promising results, the strategy remains limited to preclinical studies, with further human trials required to confirm safety and therapeutic efficacy. Clinical and observational studies suggest that full-fat dairy does not represent a risk issue for CVD even in the face of high saturated fatty acid content [9]. Protective effects can be linked to the dairy food matrix and the potential impact on inflammation and lipid metabolism. Heterogeneous data and the absence of interventional trials limit potential recommendations.Based on the Korean health survey data, milk consumption has been shown to lower 10-year cardiovascular disease risk, especially in older women, while soymilk showed no significant benefit [10]. The results are limited by the low frequency of soymilk consumption and residual confounding that could not be adjusted in this analysis.

3. Material and Methods

The 8-week randomized controlled design had 60 participants aged 40-70 years with borderline hypertension or elevated cholesterol. Each participant received 200 g/day of probiotic fermented almond milk yogurt with Lactobacillus plantarum and Bifidobacterium lactis. The primary variables were FMD, NO, LDL cholesterol, CRP, and VCAM-1; these were measured before and after the intervention to quantify changes in endothelial function and cardiovascular biomarkers. Figure 1 presents the methodology flow.

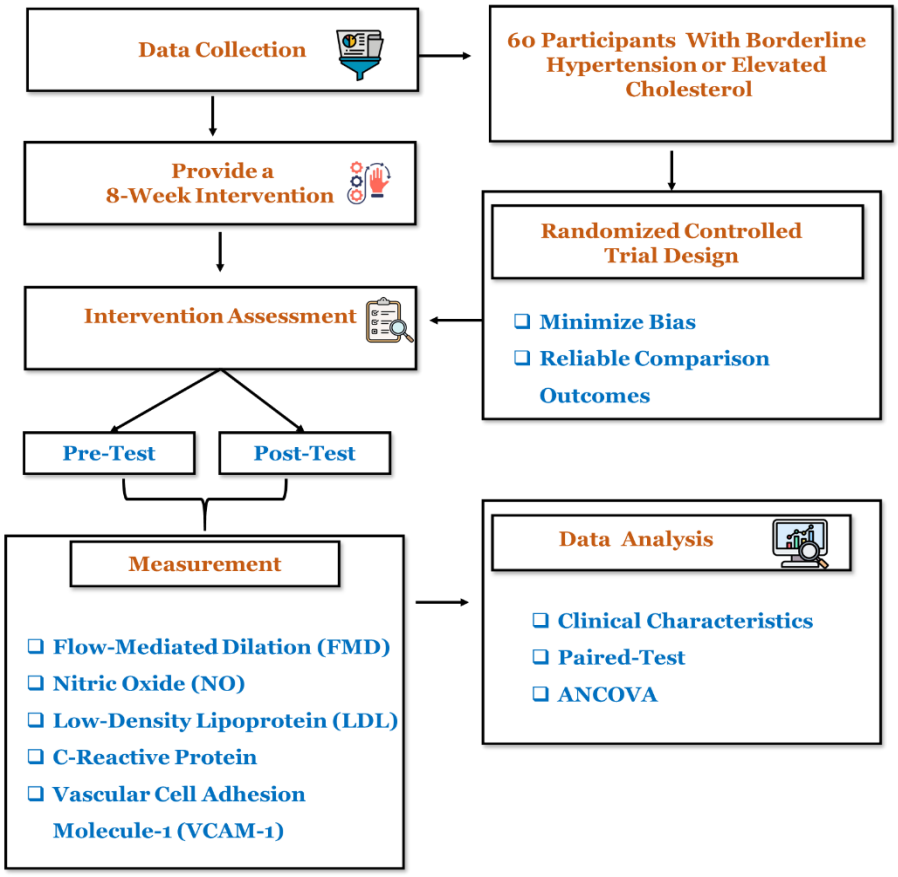

Figure 1: workflow of the cardiovascular research

3.1 Data Collection

The data were collected over 8 weeks from 60 participants aged 40 to 70 years with borderline hypertension or elevated cholesterol. Pre- and post-intervention measurements included: FMD, serum NO, LDL cholesterol, CRP, and VCAM-1. Participants consumed probiotic-fermented almond milk yogurt products on daily basis. All clinical and biochemical parameters were assessed at baseline and post-intervention. A randomized controlled trial (RCT) design was used to reduce bias and ensure a fair comparison of results. Participants were haphazardly allocated to a pretest and posttest that would either receive probiotic-fermented almond milk yogurt or a placebo. This design augmented the internal validity of the research, allowing researchers to feasibly assess the yogurt's impact on endothelial function and cardiovascular biomarkers in groups that were most similar at baseline.

3.2 Biomarker-Based Evaluation of Endothelial and Cardiovascular Function

Cardiovascular biomarkers are the FMD, NO, LDL cholesterol, CRP, and VCAM-1 as essential makers of endothelial function, lipid metabolism, and vascular inflammation. Evaluating them together provides an integrated assessment of vascular responsiveness and cardiometabolic profile allowing objective measurement of the physiological effects from ingesting probiotic-fermented almond milk yogurt.

FMD (Flow-Mediated Dilation): FMD is a non-invasive ultrasonographic assessment of endothelial and dependent vasodilation to shear stress. It measures NO bioavailability and vascular health. Reduction of FMD indicates endothelial dysfunction and a higher cardiovascular risk status. Changes in FMD values can be used as a functional marker of vascular response to nutritional or therapeutic factors.

Nitric Oxide (NO): NO functions as an important endothelial-derived signaling molecule for vasodilation, platelet aggregation inhibition, and vascular inflammation suppression. Changes in circulating NO concentration indicate endothelial functional status. Increased NO concentration indicates improved regulation of vascular tone and potentially improved responsiveness of endothelial function to dietary modification.

Low-density lipoprotein (LDL) Cholesterol: LDL cholesterol facilitates atherogenesis by breaching endothelial cell walls and stimulating plaque formation. Increases in LDL lead to heightened oxidative stress, foam cell generation, and endothelial damage. Assessing LDL cholesterol levels allows to evaluate lipid-associated cardiovascular risk and assess the lipid-lowering effect of functional or probiotic food interventions.

C - reactive protein (CRP): CRP is an acute-phase seditiousindicator synthesized in response to systemic inflammation and interleukin-6. The elevation of CRP levels is linked with endothelial dysfunction and the risk of cardiovascular events when these levels are elevated. The decrement in CRP concentrations indicates the possible reduction of vascular inflammatory processes and a sense of insight into the anti-inflammatory mechanisms of dietary interventions on endothelial health.

Vascular Cell Adhesion Molecule-1 (VCAM-1): VCAM-1 is an adhesion particle uttered by stimulated endothelial cells that assists leukocytes with adherence and transendothelial migration. While circulating VCAM-1 levels are not yet clinically available, levels above normally indicate endothelial inflammation and a likely early stage of atherogenesis. Measurements of VCAM-1 levels are a potential biomarker of the vascular inflammatory state and endothelial activation in inflammatory or dietary exposure.

3.3Data Analysis

IBM statistics SPSS version 25.0 was used to complete the statistical analysis. Data are described as mean ± standard deviation. Paired t-tests were performed to compare pre- and post-intervention values within participants; ANCOVA was used to regulate alterations in post-test values while controlling for pre-test values. A p-value < 0.05 was considered statistically significant. For all analyses, a 95% confidence interval was used to demonstrate the accuracy and robustness of the findings.

4. Result and discussion

The intervention's effects on key cardiovascular and endothelial parameters were assessed by comparing pre-and post-intervention values. Significant changes were observed in vascular function, lipid profile, and inflammatory markers, indicating measurable physiological improvements following the intervention. Table 1 indicates baseline and post-intervention data for a total of 60 participants. Statistically significant enhancements were experimental in BMI, systolic and diastolic blood pressure, LDL cholesterol, CRP, NO, and FMD ($p < 0.05$) as demonstrated by carcinoid improvements in endothelial and subsequent cardiovascular function. VCAM-1 showed a non-significant decrease. No differences were made in demographics, physical activity, smoking status, or compliance. Taken together, the high level of adherence and lack of adverse events indicate that the intervention was found safe and practical in improving markers of cardiovascular health. Figure 2 shows the effects of the intervention and the characteristics of the participants. There were significant improvements in FMD, NO, LDL cholesterol, and CRP; there was a very small reduction in VCAM-1: (a) Gender was evenly distributed (b) 38.3% reported regular physical activity, (c) 15% were smokers, and (d) 95% reported high compliance with no negative safety events or complications.

Table 1. Clinical and Biochemical Characteristics Pre–Post

Variable	Total (N = 60)
Age (years), mean ± SD	56.0 ± 8.0
Male	31 (51.7%)
Female	29 (48.3%)
BMI (kg/m²), mean ± SD	26.9 ± 2.5
Systolic BP (mmHg), mean ± SD	136.2 ± 10.1
Diastolic BP (mmHg), mean ± SD	84.0 ± 6.3
LDL Cholesterol (mg/dL), mean ± SD	138.9 ± 12.8
CRP (mg/L), mean ± SD	3.9 ± 1.0
NO (µmol/L), mean ± SD	22.1 ± 4.5
FMD (%), mean ± SD	6.8 ± 1.2
VCAM-1 (ng/mL), mean ± SD	720 ± 55
Physical Activity ≥3x/week, n (%)	23 (38.3%)
Smoking Status (Yes), n (%)	9 (15.0%)
Compliance >95%, n (%)	57 (95.0%)
Adverse Events Reported, n (%)	0 (0.0%)

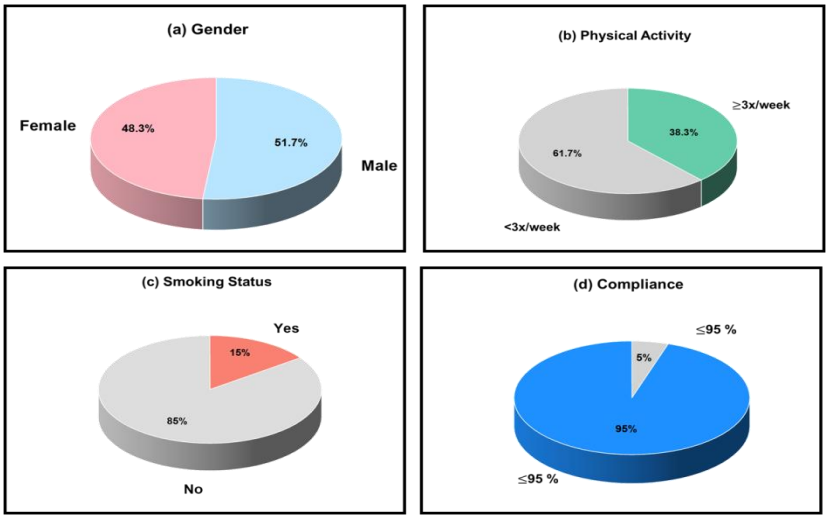

Figure 2: Participant Demographics of (a) Gender, (b) Physical Activity, (c) Smoking, and (d) Compliance

Table 2 demonstrates significant enhancements in endothelial and inflammatory markers, specifically FMD, NO, LDL, and CRP, which point to improved vascular function and inflammation reduction. VCAM-1 had a small non-significant reduction. Figure 2 displays the same general directional changes, providing more evidence of the beneficial modulation of cardiovascular biomarkers by the probiotic-fermented almond milk yogurt as a potential modulator of endothelial and cardiometabolic health.

Table 2. Paired T-test results for Endothelial Function Biomarkers

Parameter	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Percentage	p-value
FMD (%)	6.8 ± 1.2	7.6 ± 1.3	+11.8%	<0.001
NO (µmol/L)	22.1 ± 4.5	24.3 ± 4.8	+9.95%	0.004
LDL Cholesterol (mg/dL)	138.9 ± 12.8	126.9 ± 11.4	−8.6%	<0.001
CRP (mg/L)	3.9 ± 1.0	3.5 ± 0.9	−10.2%	0.005
VCAM-1 (ng/mL)	720 ± 55	705 ± 58	−2.1%	0.078

Note: p < 0.05 indicates statistical significance

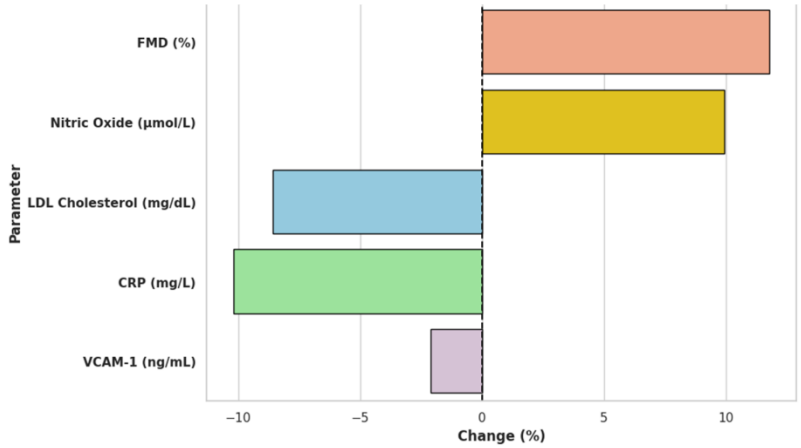

Figure 3. Percentage Change in Cardiovascular Biomarkers after Intervention

Table 3 showed the ANCOVA additional statistical support for the post-test changes after controlling for baseline variability. Adjusted means show similar trends compared with the t-tests, which provides evidence to determine the impact of the intervention on vascular health. The F-values suggest moderate to large effect sizes for FMD, NO, LDL, and CRP. The decrease of VCAM-1 is not significant, but it have a downward tendency. This additional evidence supports the causation of cardiovascular health changes due to the probiotic.

Table 3. ANCOVA Results Adjusted for Pre-Test Baseline Values

Parameter	Pre-Test	Post-Test Mean	F-value	p-value
FMD (%)	6.8	7.5	8.46	0.005
NO (µmol/L)	22.1	24.2	6.91	0.011
LDL Cholesterol (mg/dL)	138.9	127.1	10.78	0.002
CRP (mg/L)	3.9	3.5	4.44	0.039
VCAM-1 (ng/mL)	720	707	2.01	0.161

Note: p < 0.05 indicates statistical significance

The results indicate that related to endothelial function, NO availability, and lower levels of LDL cholesterol and CRP levels explain a significant advantage to vascular health and indicate lower levels of inflammation. These findings point to a possible protective cardiovascular effect of plant-based probiotic approaches as functional diets and support

their effectiveness in changing prospective measures of early cardiovascular risk and endothelial dysfunction with influence on cardiometabolic health.

5. Conclusion

The probiotic-fermented almond milk yogurt produced significant increases in endothelial function, and NO levels, along with reductions in LDL cholesterol and CRP, suggesting possible benefits for cardiovascular health and anti-inflammatory risk factors. Randomized controlled trials are important to providing stronger internal validity. However, the brief duration, lack of long-term follow-up, and limited demographic diversity are notable drawbacks. Future studies should concentrate on long-term, multi-center RCTs to validate these results and evaluate long-term impacts on endothelium health, including cardiovascular wellness.

Reference

1. Areche, F.O., Cáceres, C.G.M., Quispe, V.I., Jorge, J.L.C., Llatasi, F.G.C., Ticona, D.C.P., Vilca, O.M.L., Rivera, T.J.C., Huaman, J.T., Huaman, C.W.T. and Condori, J.M.B., 2025. Optimizing protein quality and bioactive peptide production in almond-based dairy alternatives through lactic acid fermentation and enzyme-assisted hydrolysis for cardiovascular health benefits. *Journal of Food Science and Technology*, pp.1–20. https://doi.org/10.1007/s13197-024-06188-6
2. Tekin, M., Gokdemir, M., Toprak, E., Silahli, M., Energin, H. and Gokmen, Z., 2023. The hemodynamic effects of umbilical cord milking in term infants: a randomized controlled trial. *Singapore Medical Journal*, 64(7), pp.439–443. https://doi.org/10.11622/smedj.2022041
3. Katheria, A.C., Law, B.H.Y., Poeltler, D., Rich, W., Ines, F., Schmölzer, G.M. and Lakshminrusimha, S., 2023. Cardiac and cerebral hemodynamics with umbilical cord milking compared with early cord clamping: A randomized cluster crossover trial. *Early Human Development*, 177, p.105728. https://doi.org/10.1016/j.earlhumdev.2023.105728
4. Pokal, A., Kraft, J., Taormina, V.M., Michalski, M.C., Vors, C., Torres-Gonzalez, M. and Bruno, R.S., 2024. Whole-Milk Dairy Foods and Cardiometabolic Health: Dairy Fat and Beyond. *Nutrition Research*. https://doi.org/10.1016/j.nutres.2024.03.010
5. Van Parys, A., Sæle, J., Puaschitz, N.G., Anfinsen, Å.M., Karlsson, T., Olsen, T., Haugsgjerd, T.R., Vinknes, K.J., Holven, K.B., Dierkes, J. and Nygård, O.K., 2023. The association between dairy intake and risk of cardiovascular disease and mortality in patients with stable angina pectoris. *European Journal of Preventive Cardiology*, 30(3), pp.219–229. https://doi.org/10.1093/eurjpc/zwac217
6. Cho, Y.E., Chen, S., Crouch, K., Shutt, D., Kaufman, J. and Singh, B., 2024. Human breast milk EVs mitigate endothelial dysfunction: preliminary study. *bioRxiv*, pp.2024–05. https://doi.org/10.1101/2024.05.20.594769
7. Zhou, J., Wu, Z., Lin, Z., Wang, W., Wan, R. and Liu, T., 2023. Association of milk consumption with all-cause mortality and cardiovascular outcomes: a UK Biobank based large population cohort study. *Journal of Translational Medicine*, 21(1), p.130. https://doi.org/10.1186/s12967-023-03980-4
8. Hong, X., Tian, G., Dai, B., Zhou, X., Gao, Y., Zhu, L., Liu, H., Zhu, Q., Zhang, L., Zhu, Y. and Ren, D., 2024. Copper-loaded milk-protein derived microgel preserves cardiac metabolic homeostasis after myocardial infarction. *Advanced Science*, 11(35), p.2401527. https://doi.org/10.1002/advs.202401527
9. Torres-Gonzalez, M. and Bradley, B.H.R., 2023. Whole-milk dairy foods: biological mechanisms underlying beneficial effects on risk markers for cardiometabolic health. *Advances in Nutrition*, 14(6), pp.1523–1537. https://doi.org/10.1016/j.advnut.2023.09.001
10. Ha, A.W., Kim, W.K. and Kim, S.H., 2023. Intakes of milk and soymilk and cardiovascular disease risk in Korean adults: A study based on the 2012–2016 Korea National Health and Nutrition Examination Survey. https://doi.org/10.3746/jkfn.2023.52.5.522