Effects of Fermented Goat Milk Products on Lipid Profile: A Systematic Review

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Abstract. This systematic review evaluates the impact of fermented goat milk products on lipid profiles, focusing on total cholesterol (TC), triglycerides (TG), low-density lipoprotein (LDL), and high-density lipoprotein (HDL). Fermented goat milk is recognized for its unique nutritional properties, including medium-chain fatty acids, bioactive peptides, and probiotics that may contribute to lipid metabolism and cardiovascular health. Four studies were included in this review: one clinical trial and three animal studies. The findings indicate that fermented goat milk products may selectively reduce TC and TG levels, while their effects on LDL and HDL are limited or non-significant. The variability in outcomes across studies suggests that differences in product formulations, dosages, intervention durations, and populations may affect the results. Although the potential for fermented goat milk products to serve as functional foods in managing lipid disorders and reducing cardiovascular risk is promising, further high-quality research is necessary to confirm these benefits.

Keywords: Fermented goat milk, lipid profile, cholesterol, triglycerides.

1 Introduction

Fermented goat milk products have emerged as a focal point of nutritional research due to their distinctive composition and potential health benefits. Goat milk, unlike cow's milk, is recognized for its unique array of nutrients and bioactive compounds, including a higher proportion of medium-chain fatty acids (MCFAs) such as caproic, caprylic, and capric acids. These MCFAs have been associated with improved lipid metabolism and cardiovascular health [1]. In addition, goat milk contains beneficial fatty acids like oleic, stearic, and palmitic acids, which enhance its nutritional value and suitability for yogurt production [2].

The protein composition of goat milk, which includes α-, β-, and κ-caseins, β-lactoglobulin, and α-lactalbumin, closely resembles that of cow milk but presents distinct genetic variations across goat populations that influence its overall protein content [3]. Notably, goat milk is easier to digest and contains higher levels of vitamin B1 compared to cow's milk, providing 4.3% protein

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and 2.8% fat, versus 3.8% protein and 5.0% fat in cow's milk. The bioactive compounds in goat milk, such as peptides, further contribute to health by exerting antioxidant, immunomodulatory, antimicrobial, and therapeutic effects [4].

Goat milk is also a rich source of essential minerals, including calcium, potassium, and phosphorus. Compared to cow milk, goat milk contains higher levels of calcium and potassium, which are crucial for bone health and metabolic processes [5]. These minerals significantly enhance the nutritional value and potential therapeutic applications of goat milk [6]. Furthermore, goat milk's smaller fat globules, naturally homogenized structure, and higher content of MCFAs make it an ideal option for those with digestive sensitivities or lactose intolerance, improving digestibility and enabling the production of dairy products with superior nutritional profiles [2].

The fermentation process further modifies the biochemical profile of goat milk, enhancing the bioavailability and bioactivity of its components. Recent studies indicate that fermentation can alter the lipid profile of goat milk, potentially amplifying its positive effects on cardiovascular health [7]. These findings underscore the therapeutic potential of fermented goat milk products, which may exhibit anti-inflammatory, lipid-lowering, and immune-boosting properties. However, despite the well-documented benefits of goat milk, there is a limited understanding of how fermentation specifically affects its lipid profile and subsequent health outcomes.

Given the growing interest in dietary strategies to manage lipid disorders and reduce cardiovascular risk, a systematic review of the effects of fermented goat milk products on lipid profiles is critically needed. This review aims to consolidate and evaluate current research on how fermentation influences the lipid profile of goat milk products, examining both the underlying biochemical mechanisms and the clinical implications for lipid metabolism and cardiovascular health. By synthesizing the available evidence, this review seeks to clarify the role of fermented goat milk products in modulating lipid profiles, providing insights into their potential application in dietary interventions and public health strategies aimed at reducing cardiovascular disease risk.

2 Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to evaluate the effects of fermented goat milk products on lipid profiles. The following subsections outline the detailed methodology employed in the review process.

2.1 Eligibility criteria

This systematic review included experimental studies that examined the effects of fermented goat milk products on lipid profiles. The review focused on human and animal subjects. The interventions considered involved the consumption of fermented goat milk products, such as yogurt, kefir, and cheese. Studies were included regardless of the comparator, which could be other dairy products, a placebo, or no intervention. The primary outcomes assessed were changes in lipid profile parameters, including total cholesterol, low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides. Only full-text articles published in peer-reviewed journals in English were included in this review.

2.2 Information sources and search strategy

A comprehensive search was conducted across multiple electronic databases, including PubMed, Scopus, and Google Scholar. The search covered studies published from January 2000 to August 2024. The search terms used included a combination of keywords and Medical Subject Headings (MeSH) terms related to "fermented goat milk," "lipid profile," "cholesterol," and "triglycerides". Boolean operators (AND, OR) were applied to refine the search results.

2.3 Study selection

Two independent reviewers screened the titles and abstracts of all identified records against the eligibility criteria. Full-text articles of potentially relevant studies were then retrieved and assessed for final inclusion. Any disagreements between reviewers were resolved through discussion or consultation with a third reviewer.

2.4 Data extraction

Data from the included studies were extracted independently by two reviewers using a standardized data extraction form. The extracted information included study characteristics, such as the author(s), year of publication, country, study design, sample size, and duration of the intervention, as well as participant characteristics like age, sex, and baseline health status. Details of the interventions were also recorded, including the type of fermented goat milk product, dosage, frequency, and duration of consumption. Outcome measures focused on changes in total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides, while the results summarized the main findings related to lipid profile changes. Any discrepancies in data extraction were resolved through discussion, with a third reviewer consulted as necessary.

2.4 Data extraction

Data from the included studies were extracted independently by two reviewers using a standardized data extraction form. The following data were collected: 1) Study characteristics: Author(s), year of publication, country, study design, sample size, duration of intervention. 2) Participant characteristics: Age, sex, baseline health status. 3) Intervention Details: Type of fermented goat milk product, dosage, frequency, and duration of consumption. 4) Outcome Measures: Changes in total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides. 5) Results: Main findings related to lipid profile changes. Discrepancies in data extraction were resolved through discussion, with a third reviewer consulted as needed.

2.4 Risk of bias assessment

The risk of bias in the included studies was assessed using the Cochrane Risk of Bias Tool for randomized controlled trials and Systematic Review Centre for Laboratory animal Experimentation (SYRCLE) Risk of Bias Tool for animal studies. Each study was evaluated independently by two reviewers, with any disagreements resolved through discussion or consultation with a third reviewer.

2.4 Data synthesis

A qualitative synthesis of the results was performed due to the heterogeneity of the study designs, interventions, and outcome measures. The findings were grouped and summarized based on the type of fermented goat milk product, duration of consumption, and lipid profile

outcomes. Meta-analysis was considered but not conducted due to the variability in study methodologies and populations.

3 Results and Discussion

3.1 Study selection and characteristic

A total of 697 hits were retrieved from databases (2 in Pubmed, 12 in Scopus, 685 in Google Scholar) as potential papers for inclusion. The flow diagram of the study selection process is described in **Figure 1**. A total of 4 articles met the selection criteria of the present systematic review. Characteristics of the studies based on PICOS (population, intervention, comparison, outcome and study design) are shown in Table 1.

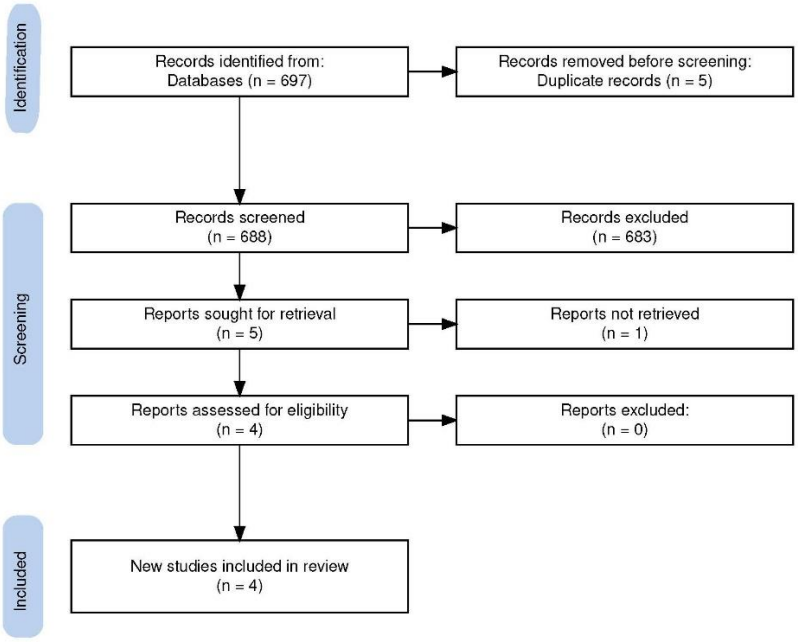

Fig. 1. Flow chart of the study selection proces.

Significant variability existed among the studies reviewed, including one randomized, placebo-controlled clinical trial in prehypertensive adults, two animal studies on rats and mice, and one experimental intervention in diet-induced obese mice. The total sample size across these studies comprised 50 human participants and 120 animals (rats and mice) to evaluate the effects of various fermented goat milk products on lipid profiles and related metabolic parameters.

In the clinical trial Lu et al. [8], 50 prehypertensive adults were enrolled and randomized to receive fermented goat milk (FGM) chewable tablets or a placebo for eight weeks. The primary outcomes were changes in blood pressure and lipid profile parameters. The study found a significant reduction in systolic and diastolic blood pressure in the FGM group compared to the

placebo group; however, no significant differences were observed in total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), or high-density lipoprotein cholesterol (HDL-C) levels, indicating no substantial impact on lipid metabolism over the study period.

In an animal study Altamimy et al. [9], 48 male rats with diet-induced non-alcoholic fatty liver disease (NAFLD) were treated with different doses of Saudi traditional fermented goat milk (oggtt). The primary outcomes included changes in serum and hepatic lipid levels. The study demonstrated that oggtt significantly reduced total cholesterol (TC), triglycerides (TG), and LDL-C in a dose-dependent manner and lowered hepatic free fatty acid (FFA) levels, suggesting a protective effect against NAFLD through lipid-lowering and antioxidant properties.

Another study, Marquez et al. [10], investigated the impact of FGM supplemented with various probiotic strains on lipid profiles and gut microbiota in 42 male C57BL/6 mice. The primary outcomes were triglyceride (TG) levels and changes in gut microbiota composition. The findings showed that FGM supplemented with a specific probiotic mix (Mix3: *Lactobacillus delbrueckii subsp. indicus* CRL1447 and CRL1472) led to a significant reduction in TG levels, whereas no significant effects were observed in total cholesterol (TC), LDL-C, or HDL-C levels. This suggests that FGM with specific probiotic strains selectively reduces triglycerides without broadly affecting other lipid fractions.

Lastly, in the study Nurliyani et al. [11], 30 male Sprague Dawley rats on a high-fat, high-fructose diet were administered goat milk kefir with or without porang glucomannan. The primary outcomes were changes in lipid profiles and hematological parameters. The results indicated significant reductions in total cholesterol (TC) and triglycerides (TG) levels in the group receiving kefir with glucomannan supplementation compared to the control group, while no significant changes were noted in HDL-C or LDL-C levels. These findings suggest that kefir combined with glucomannan effectively reduces certain lipid fractions, particularly TC and TG, but does not impact all components of the lipid profile.

Overall, these studies highlight the potential benefits of fermented goat milk products in selectively lowering specific lipid fractions, such as triglycerides and total cholesterol, while suggesting limited effects on other lipid parameters like HDL-C and LDL-C. Further research is necessary to elucidate the mechanisms involved and to assess the broader clinical implications of these findings for cardiovascular and metabolic health management.

3.2 Systematic review results

Total cholesterol (TC). The randomized clinical trial in prehypertensive adults [8] found no significant changes in TC levels after 8 weeks of consuming fermented goat milk (FGM) chewable tablets compared to the placebo group, indicating no impact on TC levels in this population. In contrast, research by Altamimy et al. [9], an animal study with high-fat diet (HFD)-fed rats, demonstrated a significant dose-dependent reduction in serum and hepatic TC levels with the administration of Saudi traditional fermented goat milk (oggtt), with the 5 mL dose producing a more pronounced reduction compared to the 2 mL dose. Research by Marquez et al. [10] observed no significant changes in TC levels across all groups of mice supplemented with different probiotic mixes in FGM, suggesting no effect on TC levels in this diet-induced obesity model. However, research by Nurliyani et al. [11] found that goat milk kefir supplemented with porang glucomannan significantly reduced TC levels in rats fed a high-fat,

high-fructose (HFHF) diet, with a more substantial reduction in the group receiving the kefir-glucomannan combination compared to kefir alone.

Triglycerides (TG). Lu et al. [8] reported no significant differences in TG levels between the FGM and placebo groups over the 8-week intervention period in prehypertensive adults, indicating that FGM did not impact TG levels in this context. In contrast, research by Altamimy et al. [9] showed that both doses of oggtt (2 mL and 5 mL) significantly lowered serum and hepatic TG levels in HFD-fed rats, with the 5 mL dose achieving a more substantial reduction, indicating a dose-dependent TG-lowering effect. Similarly, Marquez et al. [10] found a significant reduction in TG levels (35%) in mice supplemented with FGM containing Mix3 (*Lactobacillus delbrueckii subsp. indicus* CRL1447 and CRL1472) compared to the control group, while other probiotic mixes did not produce similar effects, suggesting a selective TG-lowering effect of specific probiotic strains in FGM. Nurliyani et al. [11] also observed a significant reduction in TG levels in the group treated with kefir supplemented with porang glucomannan compared to the HFHF control group, with effects comparable to simvastatin, a standard lipid-lowering medication.

Low-density lipoprotein cholesterol (LDL-C). Lu et al. [8] reported no significant changes in LDL-C levels between the FGM and placebo groups after the intervention, indicating no impact on LDL-C in the studied population. However, in research by Altamimy et al. [9], both doses of oggtt (2 mL and 5 mL) significantly decreased serum LDL-C levels in HFD-fed rats, with the higher dose (5 mL) showing a stronger effect, suggesting that oggtt can lower LDL-C levels in a dose-dependent manner. Marquez et al. [10] found no significant changes in LDL-C levels across all groups, including those supplemented with different mixes of FGM, indicating that FGM did not affect LDL-C levels in the diet-induced obesity murine model. Similarly, Nurliyani et al. [11] showed no significant changes in LDL-C levels in any of the treatment groups, including those receiving kefir, kefir with glucomannan, or simvastatin, compared to the HFHF control group, suggesting that the lipid-modifying effects of kefir with glucomannan did not extend to LDL-C.

Table 1. Characteristics of the studies included in the systematic review following PICOS (Population, Intervention, Comparison, Outcome and Study type) criteria

Study reference / Country	Study design	Diagnosis (criteria)	Sample and population characteristics	Duration (weeks)	Intervention (type and dosage)	Outcomes (measurement instruments)	Main results
Lu et al (2017) (Taiwan) [8]	RCT	Prehypertension (Systolic 120-140 mmHg, Diastolic 80-100 mmHg)	25 subjects (15 males, 10 females) each group; Age: 30-65 years	8	Fermented goat milk (FGM) chewable tablets, 1.25 g/tablet, 6 tablets/day (3x daily after meals)	Lipid profile (TC, TG, HDL-C, LDL-C) using biochemical assays	No significant changes in lipid profile (TC, TG, HDL-C, LDL-C) levels after 8 weeks of FGM tablet intake; hypotensive effect observed was not correlated with changes in lipid profile
Altamimy et al (2022) (Saudi Arabia) [9]	Animal Study	High-fat diet-induced dyslipidemia	48 male Wistar albino rats; Age: 9 weeks, Weight: ~150 g	12	Oggtt (fermented goat milk) administered at 2 mL or 5 mL/day	Lipid profile (TC, TG, HDL-C, LDL-C) using biochemical assays	Reduction in TG and TC levels in oggtt-treated groups compared to control; no significant effect on HDL-C and LDL-C
Marquez et al (2024) (Argentina) [10]	Animal Study	Obesity (diet-induced)	42 adult male mice	10	Fermented Goat Milk supplemented with different lactobacilli mixes	Lipid profile (TC, HDL-C, LDL-C, TG) using biochemical assays	Significant reduction in TC and TG levels in all FGM groups compared to control; HDL-C and LDL-C remained unchanged
Nurliyani et al (2018) (Indonesia) [11]	Animal Study	Obesity (diet-induced)	30 male Sprague Dawley rats; Age: 8-12 weeks	4	Goat milk Kefir (3.6 ml/200 g body weight/day)	Lipid profile (TC, TG, HDL-C, LDL-C) using biochemical assays	Significant decrease in TC and TG levels, no significant changes in HDL-C and LDL-C

High-density lipoprotein cholesterol (HDL-C). Lu et al. [8] found no significant changes in HDL-C levels between the FGM and placebo groups throughout the study duration, indicating no effect of FGM on HDL-C in prehypertensive adults. Research by Altamimy et al. [9] did not specifically report on HDL-C levels, focusing instead on reductions in TC, TG, and LDL-C. Marquez et al. [10] observed no significant changes in HDL-C levels across all groups, including those supplemented with different probiotic mixes in FGM, indicating that FGM did not influence HDL-C levels in the diet-induced obesity model. Nurliyani et al. [11] also found no significant changes in HDL-C levels in any of the treatment groups, including those receiving kefir, kefir with glucomannan, or simvastatin, compared to the HFHF control group, suggesting that the intervention had no impact on HDL-C levels.

Overall, these findings suggest that certain fermented goat milk products, such as kefir with glucomannan or Saudi traditional fermented goat milk, show potential in selectively lowering total cholesterol and triglycerides, but their effects on other lipid fractions, such as LDL-C and HDL-C, are limited or non-significant. The variability in outcomes across different studies may be due to differences in formulations, dosages, intervention durations, and target populations or animal models. Further research is necessary to clarify the lipid-modifying potential of these fermented goat milk products and to optimize their use for cardiovascular and metabolic health.

3.3 Risk of bias assessment

The risk of bias assessment using the Cochrane Risk of Bias Tool (RoB 2) for the study by Lu et al. [8] indicated a low risk of bias across all domains. The study was well-randomized, although specific details about allocation concealment were not provided, but no systematic bias was evident. The study was double-blind, ensuring that neither participants nor investigators knew the group assignments, thus reducing performance bias. There was minimal dropout, and an intention-to-treat analysis was conducted, mitigating attrition bias. Outcomes were measured using validated and objective methods, with outcome assessors blinded to group allocations, and all planned outcomes were reported without evidence of selective reporting. In contrast, the risk of bias assessment using SYRCLE's Risk of Bias Tool for the animal study by Marquez et al. [10] indicated a high risk of bias. The study did not provide details on how the animals were randomized into groups, leading to concerns about selection bias, and there was no information on whether the animals were housed randomly, raising potential performance bias. Furthermore, there was no blinding for personnel and outcome assessors, increasing the likelihood of performance and detection biases. While there were no missing data, reducing attrition bias, and no indication of reporting bias, there remained an unclear risk of other biases due to insufficient details provided about environmental factors.

Similarly, the animal study by Altamimy et al. [9] was also assessed to have a high risk of bias due to similar concerns. The lack of randomization details indicated a high risk of selection bias, and there was no blinding of personnel or outcome assessors, leading to performance and detection biases. The study did not have issues with attrition or reporting bias, as all planned outcomes were reported and no data were missing, and there was a low risk of other biases since no external influences were reported. However, the study by Nurliyani et al. [11] also demonstrated a high risk of bias, with similar issues related to randomization, blinding, and housing practices. Randomization was not mentioned, contributing to a high risk of selection bias, and the lack of blinding for personnel and outcome assessors increased the risk of performance and detection biases. Despite reporting all outcomes with no missing data, the

study reported a low risk of other biases as no external factors that could influence the results were mentioned.

The low risk of bias across all domains in the RCT by Lu et al. [8] enhances the credibility of its findings. The rigorous randomization, blinding, and comprehensive outcome reporting suggest that the results are reliable and can be confidently applied in clinical settings, indicating that the observed effects are likely due to the intervention rather than confounding factors. Conversely, the animal studies by Marquez et al. [10] and Altamimy et al. [9] exhibited a high risk of bias, particularly due to inadequate randomization, lack of blinding, and unclear housing conditions, raising concerns about the validity of their results. These methodological weaknesses suggest that the reported effects might be exaggerated or attributable to confounding factors rather than the intervention itself. Similarly, the study by Nurliyani et al. [11] suffered from high risk of bias, with limitations that diminish confidence in the reported benefits on lipid profiles and inflammatory markers. These findings should be interpreted cautiously, and further research with more rigorous study designs is necessary to confirm these effects.

Overall, the RCT by Lu et al. [8] is methodologically sound, making its findings reliable and applicable to clinical practice. In contrast, the animal studies by Marquez et al. [10], Altamimy et al. [9], and Nurliyani et al. [11] exhibit significant methodological weaknesses, resulting in a high risk of bias. To improve the reliability of future studies, particularly in animal research, rigorous randomization, blinding, and standardized housing practices should be implemented to reduce bias and allow for a more accurate assessment of the true effects of fermented goat milk on lipid metabolism and related health outcomes.

This systematic review evaluated the effects of various fermented goat milk products on lipid profiles across four studies involving both human and animal models. The studies explored the impact of fermented goat milk (FGM), kefir supplemented with glucomannan, and traditional fermented goat milk products on lipid parameters, such as total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). The findings suggest that these fermented goat milk products may have selective lipid-lowering effects, particularly on TC and TG, while showing limited impact on LDL-C and HDL-C. However, it is essential to consider the risk of bias in interpreting these results.

3.4 Total cholesterol

The impact of fermented goat milk products on total cholesterol (TC) levels varied among the studies. In Lu et al. [8], a randomized clinical trial in prehypertensive adults, there were no significant changes in TC levels after 8 weeks of FGM consumption. The study had a low risk of bias across all domains, which strengthens the reliability of its findings. The lack of effect may be attributed to the relatively normal baseline cholesterol levels of the participants and the short intervention duration (8 weeks), which might not have been sufficient to observe significant lipid changes [12]. In contrast, study by Altamimy et al. [9], an animal study with a high risk of bias due to inadequate randomization and lack of blinding, demonstrated a significant dose-dependent reduction in TC levels in rats treated with Saudi traditional fermented goat milk (oggtt). The observed effects could be due to the presence of bioactive peptides and medium-chain fatty acids in fermented goat milk, which modulate lipid metabolism by inhibiting cholesterol synthesis or enhancing cholesterol excretion [13]. The high risk of bias suggests that these findings should be interpreted cautiously, as the results may be influenced by confounding factors. Similarly, Nurliyani et al. [11] found that kefir supplemented

with porang glucomannan significantly reduced TC levels in rats on a high-fat, high-fructose diet. Despite this, the high risk of bias due to unclear randomization and lack of blinding suggests that further research is needed to confirm these effects in more rigorously designed studies [14]. Study by [10], which examined the impact of FGM with probiotic supplementation in obese mice, found no significant changes in TC levels. This study also had a high risk of bias due to similar methodological issues, highlighting the need for more robust experimental designs to clarify the cholesterol-lowering potential of FGM [15].

3.5 Triglycerides

Fermented goat milk products demonstrated a more consistent effect on triglyceride (TG) levels across the studies, although the risk of bias must be considered. Lu et al. [8] reported no significant changes in TG levels in prehypertensive adults, suggesting that FGM alone may not effectively modify triglycerides in humans with normal or mildly elevated lipid profiles. This trial had a low risk of bias, supporting the validity of its findings. However, Research by Altamimy et al. [9], an animal study with a high risk of bias, showed a significant reduction in TG levels in a dose-dependent manner in HFD-fed rats treated with oggtt. While the results suggest potential mechanisms like enhanced bile acid excretion or reduced lipid absorption (El-Abasy et al., 2003), the high risk of bias due to lack of randomization and blinding reduces confidence in these findings. Study by Marquez et al. [10], another high-risk-of-bias study, identified a selective TG-lowering effect with specific probiotic strains (Mix3) in FGM, suggesting that particular combinations of probiotics may effectively reduce triglycerides by modulating gut microbiota and lipid metabolism pathways. Study by Nurliyani et al. [11], also with a high risk of bias, demonstrated a significant reduction in TG levels with kefir supplemented with porang glucomannan, comparable to the effects of simvastatin, a standard lipid-lowering medication. Although these findings suggest that combining prebiotics and probiotics could provide an effective dietary strategy for reducing triglycerides, the lack of methodological rigor limits the strength of the conclusions [16].

3.6 Low-density lipoprotein cholesterol

The effects on low-density lipoprotein cholesterol (LDL-C) levels were generally limited and complicated by varying levels of bias. Lu et al. [8] found no significant changes in LDL-C levels among prehypertensive adults consuming FGM, a finding supported by the study's low risk of bias. However, Research by Altamimy et al. [9], which had a high risk of bias, reported a significant decrease in LDL-C levels in a dose-dependent manner in rats treated with oggtt. The potential for fermented goat milk to reduce LDL-C through mechanisms like inhibition of hepatic cholesterol synthesis or increased LDL receptor expression intriguing but must be interpreted with caution given the study's methodological limitations. Marquez et al. And Nureliyani et al.[10,11], both with high risks of bias, found no significant changes in LDL-C levels, suggesting that not all formulations of FGM or kefir are effective for LDL-C reduction [17]. The lack of randomization, blinding, and other methodological weaknesses in these studies reduces the confidence in their findings and highlights the need for further research.

3.7 High-density lipoprotein cholesterol

The findings regarding high-density lipoprotein cholesterol (HDL-C) were consistent across studies, showing no significant changes, although all studies except Research #1 had a high risk of bias. Lu et al. [8] found no effect on HDL-C levels in prehypertensive adults consuming

FGM, a finding supported by its low risk of bias. Altamimy et al. [9] did not specifically report changes in HDL-C, focusing on reductions in TC, TG, and LDL-C. Marquez et al. And Nurliyani et al. [10,11] also observed no significant changes in HDL-C levels, and the high risk of bias in these studies suggests that any potential HDL-C-raising effects of FGM or kefir may require more rigorous investigation to be properly assessed. The absence of significant effects on HDL-C could be due to the short duration of interventions, the specific strains or formulations used, or other unaccounted confounding factors [18].

3.8 Potential mechanisms

The potential mechanisms by which fermented goat milk products exert their lipid-lowering effects can be attributed to several factors. Probiotics present in these products may modulate gut microbiota, enhancing the production of short-chain fatty acids (SCFAs) that inhibit cholesterol synthesis in the liver and increase fecal bile acid excretion [14]. Additionally, the presence of bioactive peptides may inhibit the activity of the enzyme HMG-CoA reductase, a key enzyme in cholesterol synthesis [19]. Fermented goat milk also contains medium-chain fatty acids that are more readily oxidized and less likely to be stored as triglycerides, thereby lowering blood TG levels. The inclusion of prebiotics, such as glucomannan, can further enhance these effects by promoting the growth of beneficial gut bacteria that regulate lipid metabolism [16].

The lipid profile commonly assessed in plasma testing includes HDL (High-Density Lipoprotein), LDL (Low-Density Lipoprotein), triglycerides, and total cholesterol levels. Cardiovascular health is considered suboptimal when levels of LDL, total cholesterol, and triglycerides are elevated, as these three components serve as markers of non-communicable diseases, such as cardiovascular disease, atherosclerosis, diabetes mellitus, and stroke.

Yogurt contains macronutrients such as carbohydrates, proteins, and fats. These macronutrients can influence the lipid profile in the blood. Fat-rich foods generally contain triglycerides, cholesterol, and fatty acids. As a result, an increase in the consumption of fatty foods will elevate the levels of triglycerides and cholesterol in the blood.

Before fats are absorbed by the small intestine, a digestive process occurs that includes the degradation of cholesterol esters, phospholipids, and triglycerides, producing monoglycerides, free fatty acids, cholesterol, and glycerol. These substances are then re-esterified within the cells of the small intestine, where they are mixed with proteins to form chylomicrons.

Chylomicrons enter the lymphatic system and subsequently the bloodstream, where they are hydrolyzed by the enzyme lipoprotein lipase into free fatty acids and chylomicron remnants. The chylomicron remnants then enter the liver, where their protein composition is altered to form VLDL (Very Low-Density Lipoprotein). VLDL is then released by the liver into the circulation and further hydrolyzed by lipoprotein lipase, converting it into IDL (Intermediate-Density Lipoprotein).

IDL can undergo further changes in protein and cholesterol composition, resulting in the formation of LDL. IDL is converted to LDL primarily when it circulates in the blood for a longer period (not immediately taken up by the liver), losing triglycerides through the activity of hepatic lipase, thus becoming richer in cholesterol. The role of LDL in transporting cholesterol to peripheral tissues underscores this process. High cholesterol levels in the blood will accelerate LDL formation. Consequently, an excessive load on the liver's fat metabolism capacity leads to

the persistence of LDL in the blood. Therefore, long-term consumption of fatty foods will increase LDL levels in the blood.

Yogurt contains lactose, a sugar composed of glucose and galactose. Glucose can be converted into VLDL through de novo lipogenesis in the liver. When glucose consumption is excessive, Acetyl CoA does not enter the Krebs cycle but is instead used for fatty acid synthesis. The fatty acids produced are then combined with glycerol 3-phosphate to form triglycerides. These triglycerides can be stored in the liver in their original form or incorporated into VLDL. As previously explained, VLDL converts to IDL, and when circulating in the blood for an extended period, IDL becomes LDL. Therefore, high glucose consumption may increase the risk of elevated triglyceride and LDL levels.

3.9 Implications for clinical use

The findings suggest that fermented goat milk products, particularly when combined with specific probiotics or prebiotics, may offer a beneficial dietary strategy for lowering total cholesterol and triglycerides, especially in individuals with elevated baseline levels or metabolic disorders. However, their limited impact on LDL-C and HDL-C indicates that these products may be more effective as adjunctive therapies rather than standalone treatments for dyslipidemia. Given the high risk of bias in most studies, clinicians should consider the specific formulation, dosage, and patient profile when recommending these products, especially for individuals at risk for cardiovascular diseases [20].

3.10 Recommendations for future research

Future research should focus on designing studies with rigorous methodologies to reduce bias, such as proper randomization, blinding, and adequate sample sizes. Larger and more diverse human trials are needed to confirm the findings and determine the optimal combinations, dosages, and intervention durations of fermented goat milk products. Studies should also investigate the specific mechanisms by which these products affect lipid metabolism to better understand their potential roles in managing dyslipidemia. Additionally, research should examine the long-term effects of these interventions and their interactions with other dietary and lifestyle factors to develop comprehensive guidelines for their clinical use.

4 Conclusion

The studies suggest that fermented goat milk products, particularly those combined with specific probiotics or prebiotics, may selectively reduce total cholesterol and triglycerides, but their effects on low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) are limited or non-significant. However, due to the high risk of bias in most animal studies, these findings must be interpreted with caution. The evidence indicates a potential for these products to be used as adjunctive dietary therapies for cardiovascular and metabolic health, but further high-quality research is essential to confirm these benefits and optimize their use in clinical practice.

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