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Physiological mechanisms of palm oil triglyceride stereospecificity on postprandial lipid metabolism: a review

Abstract

The role of dietary fat structure in modulating lipid metabolism has gained increasing attention, particularly regarding how triglyceride configuration influences postprandial responses. Palm oil, characterized by a distinctive stereospecific arrangement of fatty acids, provides a relevant model for examining these mechanisms. This study systematically evaluates the physiological mechanisms associated with triglyceride stereospecificity in palm oil and its influence on postprandial lipid metabolism through a qualitative synthesis of peer-reviewed international publications. The Systematic Literature Review (SLR) was conducted using a transparent PRISMA-guided process. Data collection was conducted exclusively through Scopus using sequential keyword optimization, followed by screening by publication year (2021-2026), English language, and open access/open archive availability; 41 eligible studies were included. Evidence was synthesized thematically across stereospecific fatty acid distribution, enzymatic digestion kinetics, lipid absorption and intestinal processing, chylomicron formation, comparative postprandial responses, and sources of variability. Overall, the reviewed evidence suggests that palm oil triglyceride structure may contribute to efficient digestion, absorption, and postprandial lipid transport through established physiological pathways. However, these interpretations should be read as qualitative and descriptive rather than as pooled effect estimates, because study designs, models, populations, and measured outcomes were heterogeneous. In conclusion, triglyceride stereospecificity appears to contribute to coordinated postprandial lipid metabolism within normal physiological ranges, while stronger confirmation will require standardized human studies and longer-term outcomes across diverse populations.

Keywords: palm oil, triglyceride stereospecificity, postprandial lipid metabolism, lipid digestion, chylomicron formation

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Introduction

As a vital part of human nutrition, dietary lipids are deeply involved in metabolic processes, energy production, and the maintenance of cellular integrity. Beyond their quantitative contribution, the qualitative characteristics of dietary fats, particularly their molecular structure, have been increasingly recognized as critical determinants of metabolic responses following ingestion. Postprandial lipid metabolism, which refers to the physiological handling of lipids after a meal, represents a dynamic process involving digestion, absorption, transport, and clearance of triglyceride-rich lipoproteins. This metabolic phase is of particular importance because it reflects real-life dietary exposure and has been associated with variations in lipid homeostasis under normal physiological conditions.[1] Consequently, understanding the determinants of postprandial lipid metabolism requires not only an assessment of total fat intake but also a detailed examination of triglyceride structure and composition.

In human diets, triglycerides serve as the principal lipid form, consisting of three fatty acids esterified at the sn-1, sn-2, and sn-3 positions of a glycerol backbone. This positional distribution, often referred to as stereospecificity, is not random in natural fats and oils and has significant implications for lipid digestion and metabolic fate. The hydrolysis of triglycerides in the small intestine is primarily catalyzed by pancreatic lipase, which preferentially removes fatty acids from the sn-1 and sn-3 positions, forming free fatty acids and 2-monoacylglycerol. Accordingly, fatty acids esterified at the sn-2 position tend to remain unaltered during digestion and are more likely to be absorbed intact and incorporated into chylomicrons. This enzyme-driven selectivity demonstrates the importance of fatty acid placement in shaping the efficiency of lipid uptake and subsequent metabolism.[2]

The physiological relevance of triglyceride stereospecificity has been widely explored in relation to different dietary fat sources. Alterations in the positioning of saturated and unsaturated fatty acids influence key processes such as micelle formation, enterocyte uptake, and lipoprotein assembly, which in turn determine postprandial lipid responses. As an example, the localization of unsaturated fatty acids at the sn-2 position is associated with improved absorption and efficient incorporation into circulating lipoproteins, whereas saturated fatty acids at the sn-1 and sn-3 positions are more likely to undergo hydrolysis and partial excretion depending on physiological conditions. These structural-functional relationships highlight the need to evaluate dietary fats not only based on their overall fatty acid composition but also on their molecular configuration.[3]

Recognized as one of the most prevalent vegetable oils worldwide, palm oil is characterized by a distinctive triglyceride configuration. Compared to many other fats, palm oil demonstrates a non-random arrangement of fatty acids, where saturated fatty acids such as palmitic acid predominantly occupy the sn-1 and sn-3 sites, while unsaturated fatty acids, particularly oleic acid, are preferentially positioned at the sn-2 site. This configuration has been consistently reported across compositional analyses and is considered a defining structural feature of palm oil triglycerides. The unique arrangement has attracted scientific attention due to its potential implications for lipid digestion kinetics and metabolic outcomes in the postprandial state.[4]

From a physiological viewpoint, oleic acid at the sn-2 position may support absorption through the 2-monoacylglycerol pathway, a major

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route for triglyceride re-synthesis in enterocytes. This mechanism can facilitate the incorporation of absorbed lipids into chylomicrons, followed by lymphatic transport and entry into the bloodstream.[5] In parallel, saturated fatty acids at the sn-1 and sn-3 positions may influence the rate of enzymatic hydrolysis and the profile of free fatty acids formed during digestion. These effects should be interpreted cautiously, because available studies differ in model systems, meal matrices, and outcome measures. The evidence therefore suggests physiologically plausible pathways rather than a uniform enhancement of digestion or absorption across all contexts.[6]

Despite the growing body of research on triglyceride stereospecificity, findings across individual studies remain heterogeneous. Variability in experimental design, subject characteristics, dietary composition, and analytical methods has led to differences in reported outcomes related to lipid digestion efficiency, chylomicron formation, and postprandial triglyceride levels. Some studies emphasize the role of triglyceride structure in modulating postprandial lipemia, while others indicate that total fat intake and overall dietary patterns may exert a more dominant influence. This inconsistency highlights the need for a systematic and integrative evaluation of available evidence to clarify the underlying physiological mechanisms and identify consistent patterns across studies.[7]

Furthermore, the interpretation of lipid metabolism in the context of specific dietary fats requires a balanced and evidence-based approach. Given the widespread use of palm oil in global food systems, scientific assessments should consider both its structural properties and its functional behaviour under physiological conditions without oversimplification. A nuanced understanding of how triglyceride stereospecificity interacts with digestive and metabolic processes is essential for accurately characterizing its role within broader dietary frameworks. Such an approach allows for a more comprehensive evaluation that reflects the complexity of lipid metabolism rather than relying on isolated parameters.[7,8]

Against this backdrop, an SLR offers a systematic and rigorous approach for compiling and analysing existing research with transparency and reproducibility. By systematically identifying, screening, and analysing peer-reviewed studies, the SLR approach enables the integration of findings across diverse study designs while minimizing bias. Significantly, the research utilizes only secondary data derived from published scientific sources, foregoing primary data collection methods including interviews, focus groups, or direct observations. This ensures methodological consistency and aligns with established standards for evidence-based synthesis in nutritional and metabolic research.

Therefore, this study aims to systematically evaluate the physiological mechanisms associated with triglyceride stereospecificity in palm oil and its influence on postprandial lipid metabolism by synthesizing evidence from peer-reviewed international publications. This review specifically seeks to determine the role of fatty acid positioning within palm oil triglycerides in modulating lipid digestion, absorption, and postprandial metabolic outcomes, while also exploring variations across diverse experimental scenarios.

To guide the analytical framework of this review, two research questions are formulated: RQ1: How *does the stereospecific positioning of fatty acids in palm oil triglycerides influence the physiological processes of lipid digestion, absorption, and chylomicron formation in the postprandial state?*

RQ2: *To what extent do postprandial lipid responses associated with palm oil triglyceride structure differ from those observed with other dietary fats under comparable experimental conditions?*

Literature review

This section is organized around the mechanisms required to answer the two research questions. First, it explains why the sn-1, sn-2, and sn-3 positions of triglycerides matter for digestion, absorption, and chylomicron formation (RQ1). It then narrows the discussion to palm oil's characteristic distribution of palmitic and oleic acids and explains why comparisons with other dietary fats should be interpreted within the context of meal composition, study design, and inter-individual variability (RQ2).

Structural organisation of triglycerides and stereospecificity

Triglycerides, or triacylglycerols, are the major form of dietary fat and consist of three fatty acids esterified at the sn-1, sn-2, and sn-3 positions of glycerol. Natural fats do not distribute fatty acids randomly across these positions. This stereospecific organization matters because pancreatic lipase preferentially hydrolyses the sn-1 and sn-3 ester bonds, whereas the sn-2 fatty acid is commonly retained as part of 2-monoacylglycerol during digestion.[9]

For RQ1, the key mechanistic link is therefore direct: fatty acids at sn-1 and sn-3 are more likely to be released as free fatty acids, while the sn-2 fatty acid is more likely to enter the absorptive pathway as 2-monoacylglycerol. Studies using pancreatic lipase hydrolysis and nuclear magnetic resonance support this positional conservation during digestion and absorption.[10]

Palm oil is relevant to this mechanism because palmitic acid is commonly concentrated at sn-1 and sn-3, while oleic acid is often enriched at sn-2. This makes palm oil a useful model for evaluating how positional structure, not only total fatty acid composition, may influence hydrolysis, micellar incorporation, enterocyte re-esterification, and postprandial lipid transport.[11]

Enzymatic mechanisms of lipid digestion

Dietary triglyceride digestion begins in the stomach and continues in the small intestine, where pancreatic lipase is the main enzyme governing sn-position-specific hydrolysis. By preferentially cleaving sn-1 and sn-3, pancreatic lipase generates free fatty acids and 2-monoacylglycerol, thereby connecting triglyceride structure to the absorptive intermediates considered in RQ1.[12]

Hydrolysis is also influenced by saturation, chain length, melting behaviour, and the physical form of the test meal. In palm oil, saturated fatty acids at sn-1 and sn-3 may slow early lipolysis compared with oils that are more unsaturated at these positions. However, existing evidence suggests that this difference is usually modest and does not necessarily translate into lower overall digestion under physiological conditions.[13]

The 2-monoacylglycerol intermediate is central because it links digestion to enterocyte uptake and re-esterification. Consequently, palm oil's sn-2 enrichment with oleic acid provides a plausible mechanism for efficient absorption, but the strength of this conclusion depends on the study model and whether outcomes are measured directly in humans, animals, in vitro systems, or compositional analyses.[14]

Intestinal absorption and lipid transport pathways

After enzymatic processing, lipid absorption depends on mixed micelles that carry free fatty acids and monoacylglycerols across the aqueous intestinal lumen. The stability and composition of these micelles are influenced by fatty acid saturation and positional origin within the triglyceride molecule.[9]

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The monoacylglycerol pathway accounts for a major share of triglyceride re-synthesis within enterocytes. In this pathway, 2-monoacylglycerol is reacylated and incorporated into triglycerides that are packaged into chylomicrons. This process explains why the sn-2 position has particular relevance for RQ1.[15]

Because palm oil commonly concentrates oleic acid at sn-2, it aligns with this absorptive pathway. Nevertheless, the available studies should be interpreted as showing a plausible and often observed mechanism rather than a universal increase in absorption efficiency, because absorption estimates vary with meal matrix, calcium content, metabolic status, and experimental model.[16]

Postprandial lipid metabolism and lipoprotein dynamics

Postprandial lipid metabolism refers to the transport and clearance of dietary lipids after absorption, mainly through chylomicrons and their remnants. Chylomicron assembly is influenced by the composition and structure of re-synthesized triglycerides, linking intestinal absorption to circulating triglyceride responses.[17]

Plasma triglyceride concentration, peak response time, and area under the curve (AUC or iAUC) are commonly used to describe postprandial lipemia. These outcomes reflect the combined effects of digestion, absorption, chylomicron secretion, and lipoprotein clearance; therefore, they cannot be attributed to stereospecificity alone without considering meal design and participant characteristics.[18]

In the context of palm oil, sn-2 unsaturated fatty acids may be preferentially incorporated into chylomicrons, while sn-1 and sn-3 saturated fatty acids are hydrolyzed and metabolized as free fatty acids. The available evidence is most appropriately interpreted as supporting normal postprandial lipid transport rather than demonstrating a uniquely superior metabolic response.[19]

Comparative perspectives on palm oil and other dietary fats

Comparative studies address RQ2 by asking whether the postprandial response to palm oil differs from responses to other dietary fats such as olive oil, soybean oil, rapeseed oil, or animal fats. Such comparisons are informative, but their interpretation is complicated by total fat dose, carbohydrate and protein content of the test meal, baseline metabolic status, and analytical method.[20]

Across controlled feeding contexts, reported differences in postprandial triglyceride levels are often modest and may fall within normal physiological or inter-study variability ranges. This indicates that triglyceride stereospecificity is one mechanistic contributor to postprandial outcomes, while total diet and host factors may be equally or more influential in some settings.[21]

For this reason, palm oil should be evaluated through both structural and physiological evidence. A balanced interpretation avoids treating palm oil as metabolically uniform across all meals and populations, while also recognizing that its stereospecific structure provides a useful framework for studying lipid digestion and transport.

Collectively, the theoretical literature shows that triglyceride stereospecificity can influence enzymatic hydrolysis, micelle formation, enterocyte uptake, and lipoprotein assembly. The evidence is strongest for the biochemical mechanism linking sn-position to digestion and absorption. It is more tentative for claims about systemic postprandial outcomes, where study design, population characteristics, and comparator fats create substantial heterogeneity.

Methodology

Adopting the PRISMA framework, this study applies a Systematic Literature Review (SLR) to provide a transparent, structured, and reproducible qualitative synthesis of evidence concerning palm oil triglyceride stereospecificity and postprandial lipid metabolism. The review followed sequential stages of identification, screening, retrieval, eligibility assessment, and inclusion. The year restriction was applied to the systematic review dataset; older foundational sources cited in the introduction or theoretical background were used only for contextual explanation and were not counted among the 41 studies included in the final synthesis.

Illustrated in Figure 1 is the PRISMA-based selection workflow, showing the structured process from the initial identification of articles to final inclusion. Scopus was selected as the sole database because it provides broad interdisciplinary coverage of food science, nutrition, biochemistry, lipid metabolism, agriculture, and palm-oil-related research, and because it allows consistent filtering by source type, language, publication year, and access status. The use of a single database improved reproducibility and traceability of the search process, but it may have excluded relevant studies indexed only in PubMed/MEDLINE, Web of Science, Embase, or regional databases; this is acknowledged in the limitations. The final Scopus search was conducted on 21 April 2026. In the identification stage, an initial query using the keyword combination "Palm Oil AND Lipid Metabolism" yielded 939 records. A tailored Boolean search strategy was then used to increase precision: ("palm oil" OR "palm olein") AND ("triacylglycerol" OR "triglyceride" OR "fatty acid positional distribution" OR "sn-2") AND ("postprandial" OR "postprandial lipemia" OR "lipid metabolism" OR "fat digestion" OR "fat absorption") AND (digestion OR absorption OR metabolism). Through this refinement, 735 articles were excluded because they did not address the defined scope, leaving 204 records for screening.

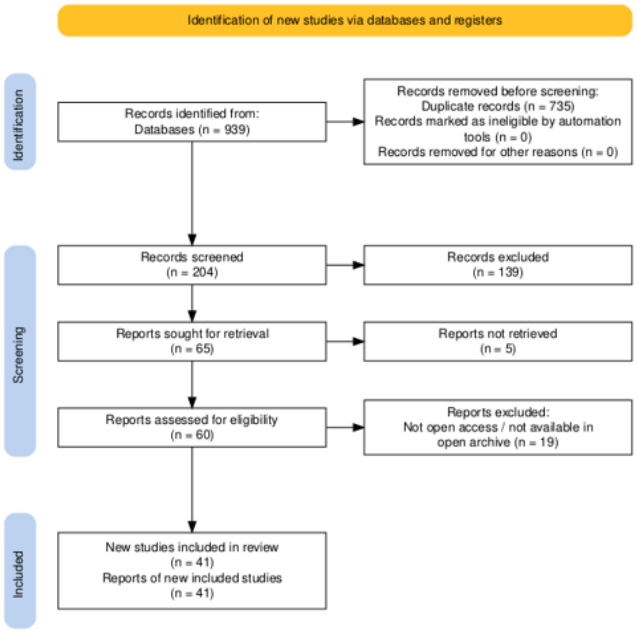

Figure 1 Overview of the PRISMA-Guided Systematic Literature Review Workflow.

Eligibility criteria were applied in a stepwise manner. Studies were included when they met all of the following criteria: (1) indexed in Scopus; (2) published between 2021 and 2026 for the systematic review dataset; (3) written in English; (4) available as open access

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or open archive full text; (5) focused on palm oil, palm olein, palm-based lipids, triglyceride/triacylglycerol structure, fatty acid positional distribution, digestion, absorption, chylomicron formation, or postprandial lipid metabolism; and (6) provided extractable mechanistic, experimental, clinical, animal, in vitro, compositional, or comparative evidence relevant to RQ1 or RQ2. Studies were excluded when they were duplicates, outside the year or language limits, unavailable for full-text assessment, not related to palm oil or lipid metabolism, focused only on non-lipid agronomic or industrial outcomes, or did not report outcomes relevant to triglyceride stereospecificity, digestion, absorption, chylomicron formation, or postprandial metabolic response. After temporal filtering, 139 articles were excluded, leaving 65 studies. English-language screening removed 5 studies, and access screening removed 19 studies that were not available through open access or open archive sources. The final dataset, therefore, comprised 41 publications for qualitative synthesis.

Data extraction was conducted using a structured matrix in manual tabulation. Extracted fields included author and year, study design or model, population or experimental system, dietary fat or comparator, triglyceride structural feature, digestion or hydrolysis outcome, absorption or bio accessibility outcome, chylomicron or lipoprotein outcome, postprandial triglyceride measure, and reported limitations. Because of heterogeneity in study populations, test meals, models, and outcome metrics, quantitative meta-analysis was not performed. The synthesis is therefore qualitative and thematic; numerical ranges are presented descriptively and should not be interpreted as pooled effect estimates.

Results

Following the systematic review, 41 peer-reviewed publications satisfying all eligibility criteria were incorporated. The evidence base included structural/compositional analyses of triglyceride positional distribution, in vitro digestion and bio accessibility models, animal feeding studies, controlled human postprandial or metabolic studies, and mechanistic reviews relevant to lipid processing. Populations and models therefore ranged from healthy adult participants and metabolically at-risk groups to rodents, aquatic or livestock species, cell-based systems, emulsions, and purified or blended oil matrices. Outcomes extracted included sn-position distribution, hydrolysis kinetics, free fatty acid and monoacylglycerol formation, micellar solubilisation, absorption or bio accessibility, chylomicron-related measures, plasma triglyceride peak response, iAUC, and modifiers such as BMI, metabolic status, calcium content, and mixed-meal composition.

An analysis of thematic distribution indicates that stereospecific distribution and structural characterization represented the most frequently addressed theme, appearing in approximately 32 of 41 studies (about 78%). Chylomicron formation and postprandial lipemia response appeared in approximately 30 studies (about 73%). Enzymatic digestion and hydrolysis kinetics appeared in approximately 27 studies (about 66%), absorption efficiency and intestinal lipid processing in approximately 25 studies (about 61%), comparative analyses with other dietary fats in approximately 23 studies (about 57%), and influencing factors or variability across study conditions in approximately 21 studies (about 52%). Many articles contributed to more than one theme, so these categories should be read as overlapping evidence domains rather than mutually exclusive study counts.

The predominance of structural and mechanistic evidence indicates that the strongest support in the dataset relates to biochemical pathways: sn-position distribution, enzymatic hydrolysis, and formation of absorbable lipid intermediates. Evidence concerning systemic postprandial outcomes is useful but more heterogeneous, because clinical and comparative studies differ in meal composition, participant characteristics, sampling windows, and lipid endpoints.

Themes related to variability and influencing factors were less frequent but important for interpreting evidence strength. Studies addressing BMI, metabolic status, meal composition, and inter-individual variability suggest that triglyceride stereospecificity acts within a broader physiological system rather than as a single independent determinant of postprandial lipemia. This finding supports a cautious narrative synthesis and avoids overstatement in the absence of quantitative meta-analysis.

Collectively, these thematic patterns indicate that current research on palm oil triglyceride stereospecificity is anchored mainly in mechanistic and structural-functional relationships, with a growing but heterogeneous body of evidence on postprandial outcomes. Table 1 summarizes the main evidence domains, study designs or models, outcomes, and relative interpretive strength. The subsections that follow use this evidence profile to link conclusions to the type and breadth of supporting studies.

Table 1 Evidence profile of the 41 included studies by thematic dom

Evidence Domain	Study Designs or Models Represented	Main Populations/Models and Outcomes Extracted	Interpretive Strength for This Review
Stereospecific fatty acid distribution	Compositional, lipidomic, and structural analyses; some mechanistic studies	Palm oil, palm olein, palm-based fractions, comparator oils; sn-1/sn-2/sn-3 distribution and fatty acid composition	Relatively strong for describing palm oil triglyceride structure because outcomes are directly measured
Enzymatic digestion and hydrolysis kinetics	In vitro digestion models, animal studies, and limited human-linked digestion/bioaccessibility studies	Hydrolysis rate, free fatty acids, 2-monoacylglycerol, bioaccessibility, and effects of saturation or matrix	Moderate mechanistic support; interpretation depends on model system and meal matrix
Absorption and intestinal processing	In vitro, animal, and human metabolic studies where available	Micelle formation, absorption efficiency, enterocyte re-esterification, and lipid bioavailability	Moderate support; high absorption is plausible, but should not be generalised as uniform across all conditions
Chylomicron formation and postprandial lipemia	Controlled feeding studies, clinical postprandial studies, animal studies, and mechanistic reviews	Chylomicron size/concentration, plasma triglyceride peak timing, iAUC, and lipoprotein responses	Moderate but heterogeneous evidence; strongest for normal physiological ranges, weaker for precise comparative effect size

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Comparisons with other dietary fats	Comparative feeding trials and animal/in vitro studies involving palm oil, olive oil, soybean oil, rapeseed oil, lard, and structured lipids	Peak triglycerides, iAUC, lipid profile markers, and tissue/metabolic outcomes	Cautious interpretation required; differences are often modest and influenced by diet and host factors
Influencing factors and variability	Studies examining BMI, metabolic status, meal composition, calcium content, and inter-individual variation	Modifier effects on digestion, absorption, lipemia, clearance, and response variability	Tentative but important; fewer studies isolate these factors directly

Stereospecific distribution of fatty acids in palm oil triglycerides

Across the reviewed literature, a recurring structural pattern of palm oil triglycerides was identified, characterized by a non-random distribution of fatty acids along the glycerol backbone. Reports from quantitative analyses indicate that 70-85% of saturated fatty acids, particularly palmitic acid (C16:0), are positioned at sn-1 and sn-3, while 60-80% of sn-2 is occupied by unsaturated fatty acids, chiefly oleic acid (C18:1).[22–24] This pattern differentiates palm oil from several other fats in which saturated fatty acids are either more evenly distributed or more concentrated at sn-2.

Compositional research has demonstrated that the total fatty acid content of palm oil is generally 44–45% palmitic acid, 39–40% oleic acid, 10–11% linoleic acid, and minor fractions (<5%) of stearic and other fatty acids.[25,26] The positional configuration of fatty acids, rather than total fatty acid content, is a major determinant of metabolic outcomes. Analytical methods such as pancreatic lipase hydrolysis and nuclear magnetic resonance (NMR) confirmed that more than 65% of oleic acid is consistently located at the sn-2 position in native palm oil triglycerides.[27,28]

This structural organization has been associated with differential digestion pathways, as the sn-2 fatty acid is preserved during lipolysis and directly absorbed as 2-monoacylglycerol. The reviewed studies indicate that this feature may contribute to efficient lipid assimilation without disproportionately elevating postprandial triglyceride levels under controlled dietary conditions.[29,30]

Enzymatic digestion and hydrolysis kinetics

The digestion of triglycerides is primarily mediated by pancreatic lipase, which exhibits positional specificity toward the ester connections at the sn-1 and sn-3 sites. Experimental studies included in the review reported that hydrolysis efficiency ranged from 65% to 90% depending on substrate composition and experimental conditions.[31,32] The presence of saturated fatty acids at the sn-1 and sn-3 positions in palm oil triglycerides has been shown to result in marginally slower hydrolysis rates compared to triglycerides enriched in unsaturated fatty acids at these sites.

Kinetic analyses demonstrated that the rate constant for lipolysis of palm oil-based triglycerides ranged between 0.015–0.032 min^{-1}, compared to 0.025–0.045 min^{-1} for oils with higher unsaturation levels at the sn-1,3 positions.[33,34] Despite this variation, the overall extent of digestion after 120 minutes remained comparable across different fat sources, with digestion completion exceeding 80% in most in vitro and in vivo models.[35]

Notably, oleic acid located at the sn-2 position favours 2-monoacylglycerol production, allowing more efficient micellar incorporation. Studies reported that up to 75–85% of digested lipid products from palm oil are present in absorbable forms, including free fatty acids and monoacylglycerols.[36,37] These findings indicate that while hydrolysis kinetics may differ slightly, the efficiency of lipid digestion remains within a comparable physiological range.

Absorption efficiency and intestinal lipid processing

Following enzymatic digestion, lipid absorption occurs primarily in the small intestine through micellar solubilization and enterocyte uptake. The reviewed studies reported that the absorption efficiency of dietary fats generally exceeds 90%, with palm oil demonstrating absorption rates between 92% and 97% under normal physiological conditions.[38,39]

The process is highly influenced by how fatty acids are stereospecifically positioned along the triglyceride backbone. The sn-2 monoacylglycerol pathway accounts for approximately 70–80% of triglyceride resynthesis in enterocytes, highlighting the importance of sn-2 fatty acid retention.[40,41] Given that palm oil predominantly contains oleic acid at this position, the absorbed lipid intermediates are enriched in monounsaturated fatty acids, which are efficiently re-esterified into triglycerides.

Studies using isotopic labelling techniques indicated that the incorporation efficiency of sn-2 fatty acids into chylomicron triglycerides ranges from 60% to 75%, suggesting a preferential metabolic pathway for these molecules.[42,43] Minimal formation of calcium soaps from saturated fatty acids at sn-1 and sn-3 has been observed at typical dietary calcium levels, promoting high lipid bioavailability.[44]

Chylomicron formation and postprandial lipemia response

The formation of chylomicrons represents a critical step in postprandial lipid metabolism, facilitating the transfer of dietary lipids from the intestinal lumen to peripheral tissues. Across the reviewed clinical studies, peak postprandial triglyceride levels were typically observed between 2 and 4 hours after fat ingestion, with concentrations ranging from 1.2 to 2.5 mmol/L depending on meal composition and subject characteristics.[45,46]

Comparative analyses indicated that palm oil consumption resulted in postprandial triglyceride responses that were broadly similar to those observed with other commonly consumed fats. The incremental area under the curve (iAUC) for triglycerides ranged between 2.5 and 5.8 mmol·h/L across studies, with no consistent evidence of exaggerated lipemic response.[47,48]

Chylomicron particle size and concentration were also evaluated, with findings suggesting that particle diameter ranged from 75 to 120 nm, and total particle concentration increased by approximately 2- to 4-fold postprandially.[49,50] Unsaturated fatty acids located at sn-2 contribute to optimal chylomicron assembly and release, ensuring effective lipid transport.

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Comparative metabolic responses relative to other dietary fats

A substantial portion of the reviewed studies conducted comparative analyses between palm oil and other dietary fats, including olive oil, soybean oil, and animal fats. These comparisons revealed that postprandial triglyceride responses were influenced more by total fat intake and meal composition than by fat source alone.

Quantitative comparisons showed that differences in peak triglyceride levels between palm oil and other vegetable oils were generally within a narrow range of ±0.2–0.4 mmol/L.[51,52] Similarly, differences in iAUC values were typically less than 10–15%, indicating comparable metabolic responses across fat types.[53]

In controlled feeding trials, substitution of palm oil with unsaturated oils resulted in modest variations in lipid profiles; however, these differences were not consistently statistically significant across all studies.[54,55] It is suggested that palm oil, when included in a balanced diet, exhibits metabolic effects that are consistent with normal physiological functioning.

Influencing factors and variability across study conditions

The reviewed studies highlighted several factors that contribute to variability in postprandial lipid responses, including age, body mass index (BMI), metabolic status, and meal composition. For instance, individuals with higher BMI (>25 kg/m²) exhibited 15–30% higher postprandial triglyceride levels compared to normal-weight individuals.[56,57]

Meal composition was also identified as a key determinant, with mixed meals containing carbohydrates and proteins influencing gastric emptying and lipid absorption rates. Studies reported that the addition of carbohydrates could increase postprandial triglyceride levels by approximately 10–20% due to insulin-mediated effects on lipid metabolism.[58,59]

Furthermore, inter-individual variability accounted for up to 40% of differences in postprandial responses, reflecting genetic and physiological diversity.[60–62] Despite these variations, the structural characteristics of palm oil triglycerides consistently demonstrated predictable digestion and absorption patterns across different study settings.

In summary, the 41 included studies suggest that the stereospecific positioning of fatty acids in palm oil triglycerides influences digestion, absorption, and postprandial metabolism through plausible physiological mechanisms. The evidence is strongest for the structural and enzymatic pathway linking sn-position to hydrolysis and 2-monoacylglycerol formation. Evidence for equivalent or different systemic postprandial responses relative to other fats is more context-dependent, as study design, meal composition, population characteristics, and outcome definitions strongly influence variability.

Because this review did not perform quantitative meta-analysis, all reported percentages, concentration ranges, and differences between fat sources should be interpreted as descriptive indicators of the reviewed evidence rather than pooled estimates of effect size.

Discussion

The synthesis of 41 peer-reviewed studies provides a structured analytical basis for addressing the research questions formulated in this systematic literature review. By integrating findings across compositional, in vitro, animal, clinical, comparative, and mechanistic studies, this discussion examines how the stereospecific positioning of fatty acids in palm oil triglycerides may influence lipid digestion, absorption, and chylomicron formation, and evaluates whether available evidence supports differences from other dietary fats. The interpretation is based on qualitative synthesis of secondary data and therefore emphasizes patterns of evidence rather than pooled quantitative effects.

Mechanistic influence of triglyceride stereospecificity on lipid digestion and absorption (Addressing RQ1)

The findings indicate that triglyceride stereospecificity is an important mechanistic determinant of lipid digestion processes. The configuration of palm oil triglycerides, with saturated fatty acids commonly concentrated at sn-1 and sn-3 and unsaturated fatty acids enriched at sn-2, is compatible with the positional preference of pancreatic lipase.[63,64] Hydrolysis at sn-1 and sn-3 releases free fatty acids and can preserve the sn-2 fatty acid as 2-monoacylglycerol, a major intermediate in intestinal lipid absorption.[65]

Across in vitro, animal, and mechanistic studies, digestion efficiency commonly exceeds 80%, suggesting that saturated fatty acids at sn-1 and sn-3 do not necessarily prevent overall lipid breakdown.[66,67] However, hydrolysis rates may be lower for palm oil triglycerides than for oils with greater unsaturation at sn-1 and sn-3, and these kinetic differences appear to depend on physicochemical properties, emulsion structure, and experimental conditions.[68]

Retention of sn-2 fatty acids during digestion provides a plausible explanation for efficient intestinal handling of palm oil-derived lipids. The 2-monoacylglycerol pathway accounts for approximately 70-80% of triglyceride re-synthesis in enterocytes, underscoring the importance of sn-2 positioning in determining metabolic fate.[69] In palm oil, oleic acid enrichment at sn-2 may improve micellar incorporation and uptake, but the conclusion should be considered moderate rather than definitive because direct human absorption evidence is less abundant than mechanistic or model-based evidence.[70]

Role in chylomicron formation and lipoprotein assembly (Addressing RQ1)

Following intestinal absorption, triglyceride re-esterification and chylomicron assembly represent critical steps in postprandial lipid metabolism. Placement of fatty acids at specific stereospecific sites dictates the composition of reassembled triglycerides and thereby modulates chylomicron structural and functional attributes.[71]

The reviewed evidence indicates that fatty acids occupying the sn-2 position can be preferentially incorporated into chylomicron triglycerides, with reported efficiencies ranging from 60% to 75% under varying experimental circumstances.[72,73] In palm oil, enrichment of chylomicrons with monounsaturated fatty acids, particularly oleic acid, is therefore a plausible mechanism for efficient lipoprotein assembly and release.

Available clinical and experimental studies show chylomicron responses after palm oil intake that are generally consistent with normal physiological postprandial transport. In the reviewed evidence, postprandial increases in chylomicron concentration are typically observed within 2-4 hours after ingestion, and particle size distributions are generally within expected physiological ranges.[74,75]

Taken together, the chylomicron evidence supports a moderate conclusion: palm oil triglyceride stereospecificity appears compatible with coordinated lipid transport, but current evidence does not justify claiming a uniquely enhanced chylomicron response compared with

all other dietary fats.

Postprandial lipid dynamics and metabolic response patterns (Addressing RQ1)

The influence of triglyceride stereospecificity may extend to overall postprandial lipid dynamics. Across available clinical studies, plasma triglyceride concentrations typically peak between 2 and 4 hours after fat ingestion, with reported values varying according to meal composition, dose, baseline metabolic status, and sampling schedule.[76]

Palm oil triglyceride structure may contribute to this pattern by modulating the rate at which lipid digestion products appear in circulation. Sn-2 fatty acids can be absorbed and incorporated into chylomicrons, promoting a regulated rise in plasma triglycerides followed by lipoprotein lipase-mediated clearance. This interpretation is physiologically plausible but should be evaluated alongside non-structural determinants such as total fat load and carbohydrate content.

Some studies report differences in peak timing or magnitude compared with other fats, but these differences are generally modest and fall within normal inter-study variability. Therefore, the evidence does not consistently show that palm oil triglyceride stereospecificity produces disproportionately elevated postprandial lipemia under controlled dietary conditions.[77]

Comparative analysis of palm oil and other dietary fats (Addressing RQ2)

In addressing the second research question, the comparative evidence suggests that postprandial lipid responses associated with palm oil are often broadly comparable to those observed with other dietary fats under similar experimental conditions. Reported differences in peak triglyceride levels are usually small, frequently within approximately +/-0.2-0.4 mmol/L, although study design and comparator fat strongly influence interpretation.[78]

Similarly, iAUC differences are commonly reported as less than 10-15% across studies comparing palm oil with oils rich in monounsaturated or polyunsaturated fatty acids. Because this review is qualitative, these values should be interpreted as descriptive ranges from individual studies rather than pooled estimates.

Some variability is observed in lipid clearance rates, with oils higher in polyunsaturated fatty acids sometimes showing faster triglyceride clearance. However, these differences are often confounded by meal composition, insulin response, baseline metabolic status, and analytical method, rather than being attributable to triglyceride structure alone.

Overall, the comparative evidence supports a cautious conclusion: palm oil generally exhibits postprandial metabolic behaviour within the range observed for other commonly consumed dietary fats, while triglyceride stereospecificity contributes to, but does not solely determine, the response.

Influence of modulating factors and inter-study variability

A key observation across the reviewed studies is the influence of modulating factors on postprandial lipid metabolism. Body mass index, age, metabolic status, dietary calcium, fat dose, and meal composition contribute to response variability and may explain differences across studies.

For example, individuals with elevated body mass index often show higher postprandial triglyceride responses than individuals within normal weight ranges, regardless of fat source. Similarly, carbohydrate-containing mixed meals can alter lipemia through insulin-mediated effects on lipid clearance and gastric emptying.

These findings highlight the importance of interpreting triglyceride stereospecificity within a broader physiological context. Palm oil structure may shape the pathway of lipid handling, but the magnitude and duration of postprandial response are jointly determined by structural, dietary, and host-related factors.

Integrated interpretation of findings

The integrated interpretation is that palm oil triglyceride stereospecificity contributes to postprandial lipid metabolism through recognized digestive and absorptive pathways. The evidence is strongest for structural distribution and the enzymatic logic of sn-1/sn-3 hydrolysis and sn-2 retention. It is moderate for absorption and chylomicron formation, where several model systems support the pathway but direct human evidence remains less consistent. It is more tentative for comparative systemic outcomes, because differences from other dietary fats are generally modest and highly dependent on study context.

Accordingly, the review distinguishes strong conclusions from tentative conclusions. Stronger conclusions can be made about palm oil's non-random triglyceride structure and its compatibility with pancreatic lipase specificity. More cautious conclusions should be made about the extent to which this structure changes postprandial triglyceride peaks, iAUC, or long-term metabolic risk compared with other dietary fats.

This distinction is important because the review did not conduct a quantitative meta-analysis. Claims about digestion, absorption, and postprandial lipid response are therefore framed as evidence-supported patterns across study types, not as statistically pooled estimates.

For applied nutritional interpretation, the findings indicate that molecular structure should be considered alongside total diet, food matrix, and individual metabolic status. Palm oil's triglyceride configuration is mechanistically relevant, but it should not be interpreted in isolation from dietary pattern or participant characteristics.

These evidence gaps are addressed below by linking the limitations in search scope, access criteria, study heterogeneity, and absence of meta-analysis to specific future research priorities. This distinction keeps the current conclusions proportionate to the available evidence and clarifies which claims require confirmation in standardized human studies.

Limitations and future research directions

This review has several limitations that affect interpretation. First, the systematic search relied exclusively on Scopus. Although this improved reproducibility and captured a broad interdisciplinary literature, it may have missed relevant articles indexed only in PubMed/MEDLINE, Web of Science, Embase, or regional databases. Second, the systematic review dataset was restricted to 2021-2026; this emphasized recent evidence but may have excluded older primary studies that remain relevant to lipid digestion mechanisms. Third, the open access/open archive requirement enabled full-text assessment but may have introduced access-related selection bias.

A further limitation is that the synthesis was qualitative. The included studies varied in design, species or population, fat dose, comparator oil, meal matrix, sampling duration, and outcome definition. Therefore, estimates such as hydrolysis efficiency,

absorption rate, peak triglyceride level, and iAUC are descriptive ranges rather than pooled effect sizes. These limitations mean that mechanistic conclusions are stronger than claims about comparative clinical magnitude or long-term metabolic impact.

Future research should address these gaps directly. Priority should be given to well-powered human postprandial trials comparing palm oil with defined comparator fats under standardized test-meal conditions; direct stereospecific analysis of test fats before intervention; harmonized measurement of plasma triglycerides, chylomicron particles, iAUC, and clearance; inclusion of diverse metabolic phenotypes; and longer-term studies linking acute postprandial responses to cardiometabolic markers. Lipidomic profiling and personalized nutrition approaches may help clarify why responses vary across individuals and meal contexts.

Conclusion

The qualitative evidence from 41 studies indicates that the stereospecific placement of fatty acids in palm oil triglycerides contributes to postprandial lipid metabolism through recognized physiological pathways. The preferential placement of saturated fatty acids at sn-1 and sn-3, together with oleic acid enrichment at sn-2, is consistent with pancreatic lipase specificity and with formation of 2-monoacylglycerol as an absorptive intermediate.

The strongest conclusion concerns the mechanism: palm oil triglyceride structure provides a plausible basis for efficient hydrolysis, micellar incorporation, enterocyte re-esterification, and chylomicron assembly. However, claims about high absorption or uniform postprandial effects should be framed cautiously because study models, meal matrices, and participant characteristics vary substantially.

For postprandial response, the reviewed evidence suggests that triglyceride responses after palm oil intake generally occur within expected physiological ranges and often peak within the typical 2-4 hour postprandial window. The available evidence does not consistently show atypical or disproportionately elevated postprandial lipemia under controlled dietary conditions.

Comparisons with other dietary fats suggest that differences in peak triglyceride levels and iAUC are usually limited and context-dependent. These differences appear to be shaped not only by stereospecificity but also by total fat dose, meal composition, comparator oil, metabolic status, and study design.

Overall, triglyceride stereospecificity should be viewed as an important structural determinant of lipid digestion and transport, but not as the sole determinant of systemic postprandial metabolism. The conclusions are strongest for structural and mechanistic pathways, moderate for absorption and chylomicron formation, and more tentative for comparative clinical magnitude and long-term metabolic outcomes.

Future research should therefore prioritise standardized human postprandial designs, direct measurement of triglyceride positional distribution, harmonized lipid and chylomicron endpoints, diverse participant groups, and long-term follow-up. These steps would address the main gaps identified in this review and clarify how palm oil triglyceride stereospecificity interacts with individual metabolic contexts.

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Conflicts of interest

The author declares there is no conflict of interest.

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