

PRESCRIPTION

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How Metabolomics Reveals **cardiac adaptation** to **Dietary Fat?**

By AP. Dr. Salfarina Ramli

Dietary fats are essential components of a healthy diet to provide energy, supply nutrients such as essential fatty acids, and facilitate the absorption of fat-soluble vitamins (A, D, E, and K). Palm oil and soybean oil are known as the most consumed dietary fats globally. These oils are common in food products such as cooking oils, margarine, baked goods, and processed foods, with soybean oil frequently serving as the primary oil in commercial salad dressings and mayonnaise. However, as new food products and recipes increasingly incorporate these oils, overall dietary fat intake may rise, requiring the body to adapt metabolically to utilize these nutrients.

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Blood vs organ metabolites

Understanding how dietary fat intake modulates metabolic pathways and contributes to physiological adaptation is therefore of considerable interest. Untargeted metabolomic profiling enables the detection of a broad range of metabolites. Utilizing the high sensitivity of liquid chromatography–mass spectrometry (LC–MS), the analysis can be performed on a variety of biological samples. The resulting LC–MS data are subsequently processed using bioinformatics tools, such as MetaboAnalyst, to identify meaningful metabolic shifts by comparing treated groups receiving dietary fat with control groups. To fully understand how the heart adapts to dietary fat intake, analyzing both circulating metabolites in the blood and intracellular metabolites in heart tissue is essential. Animal models provide an opportunity to investigate these metabolic responses in a controlled setting.



In addition to circulating metabolites in the blood, tissue samples from specific organs can also be collected for metabolomic analysis, enabling a more comprehensive understanding of tissue-specific metabolic adaptations to dietary intake. Importantly, to ensure physiological relevance, dietary exposure in animal studies should reflect realistic consumption patterns based on common dietary intake levels or established nutritional guidelines before biofluids and tissues are sampled for metabolite analysis. Table 1 shows selected metabolites and pathways relevant to cardiac metabolic function.



Pathway	Metabolites
Metabolites detected in heart tissue provide insight into the intracellular metabolic environment of cardiac tissue.	
TCA Cycle Flux	<ul style="list-style-type: none"> • Citrate, succinate, and fumarate. • This pathway indicates whether cardiac cells are efficiently converting fatty acids into energy through mitochondrial metabolism.
Glycine/serine metabolism	<ul style="list-style-type: none"> • Glycine, serine, and threonine. • Changes in these metabolites may indicate altered amino-acid utilization to support energy metabolism.
Glycerophospholipid Remodeling	<ul style="list-style-type: none"> • Phosphatidylcholines. • This reflects whether dietary fatty acids from the diet are being incorporated into cardiac cell membranes.
Metabolites detected in blood represent systemic metabolic responses occurring across multiple organs	
Primary Bile Acid Synthesis	<ul style="list-style-type: none"> • Cholic acid. • This reflects liver function and the efficiency of dietary fat digestion.
Butyrate Biosynthesis	<ul style="list-style-type: none"> • Butyrate, a short-chain fatty acid produced by gut microbiota. • Elevated levels often indicate a metabolically favorable gut environment.
Acylcarnitine Balance	<ul style="list-style-type: none"> • Palmitoylcarnitine and oleoylcarnitine. • Accumulation of these metabolites may indicate altered fatty-acid oxidation or mitochondrial overload.
Metabolites are detected in both blood and heart tissue. Some metabolic pathways can be detected in both compartments, but their interpretation differs depending on where they are measured.	
Linoleic/Arachidonic Acid Metabolism	<ul style="list-style-type: none"> • In blood sample: reflects dietary intake of fat such as soybean oil. • In heart tissue: may indicate local inflammatory signaling.
Sphingolipid Homeostasis	<p>Measured via ceramides.</p> <ul style="list-style-type: none"> • In blood sample: associated with metabolic syndrome risk. • In heart tissue: may indicate altered cardiac insulin signaling.

Table 1 is adapted from a study by (Kim & Rebholz, 2021) and (Zhan et al., 2026) that highlights pathways relevant to cardiac metabolic function.


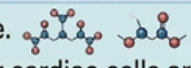
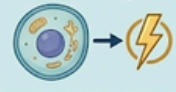
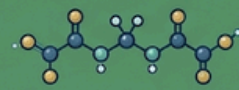


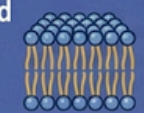
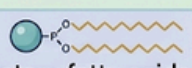
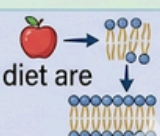
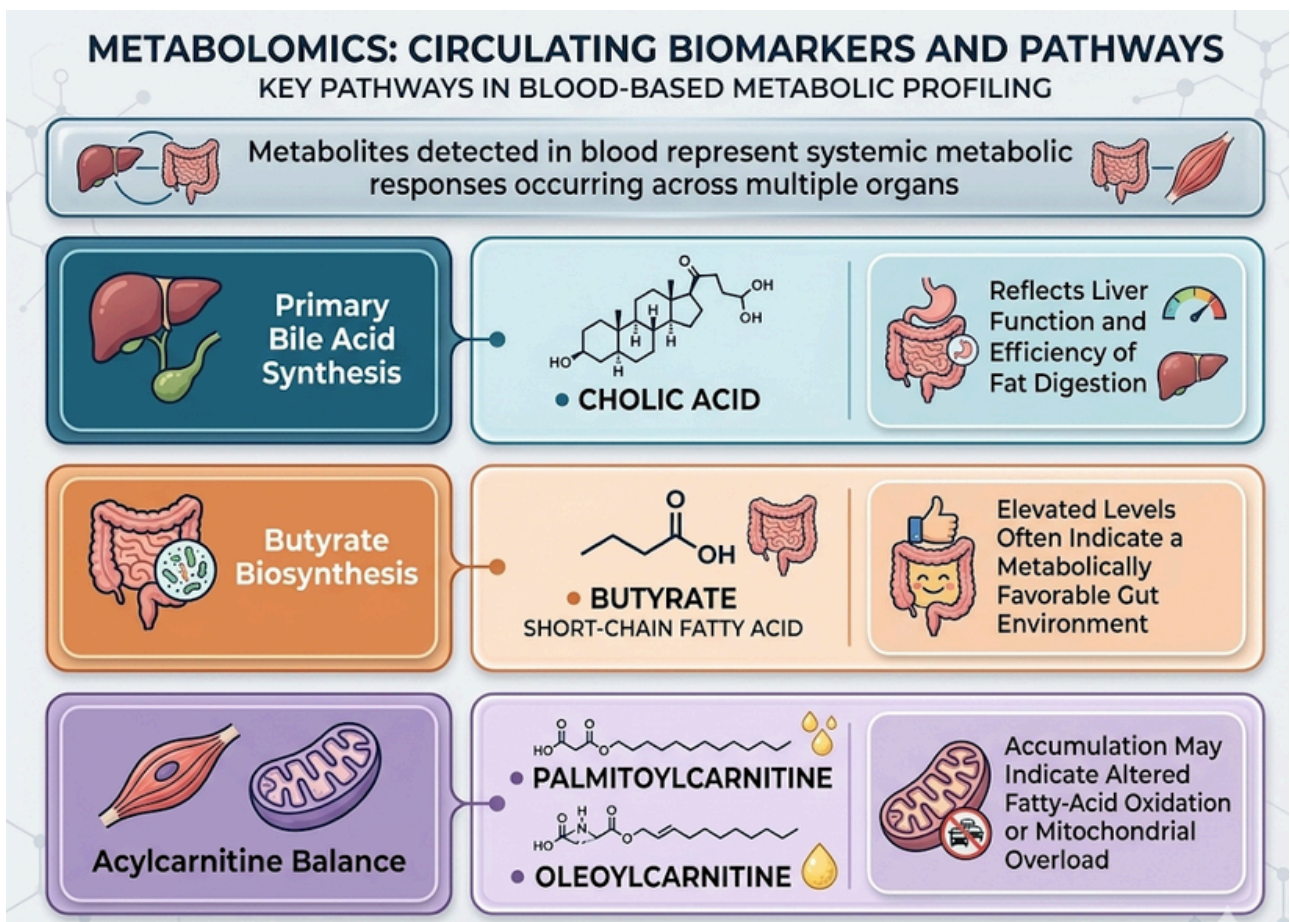
Pathway	Metabolites
<p>Metabolites detected in heart tissue provide insight into the intracellular metabolic environment of cardiac tissue. These are specific examples of metabolites and metabolic processes that can be detected via a tissue metabolomics screen.</p>	
<p>TCA Cycle Flux</p> 	<ul style="list-style-type: none"> Citrate, succinate, and fumarate.  This pathway indicates whether cardiac cells are efficiently converting fatty acids into energy through mitochondrial metabolism. 
<p>Glycine/serine metabolism</p> 	<ul style="list-style-type: none"> Glycine, serine, and threonine.  Changes in these metabolites may indicate altered amino-acid utilization to support energy metabolism. 
<p>Glycerophospholipid Remodeling</p> 	<ul style="list-style-type: none"> Phosphatidylcholines.  This reflects whether dietary fatty acids from the diet are being incorporated into cardiac cell membranes. 

Table 1 (a)



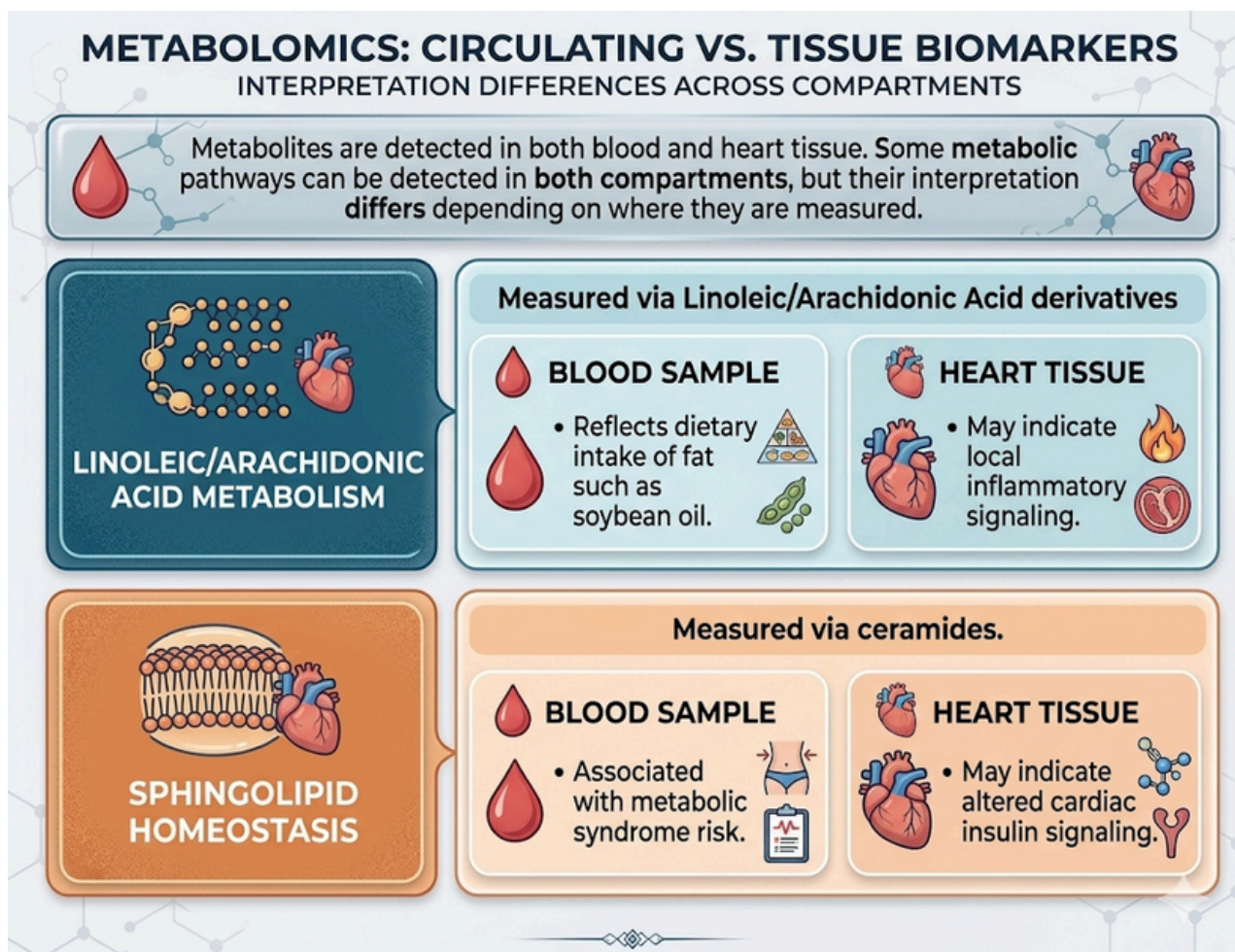


Table 1 is adapted from a study by (Kim & Rebholz, 2021) and (Zhan et al., 2026) that highlights pathways relevant to cardiac metabolic function.

Conclusion

Correlating metabolites detected in blood and cardiac tissue may transform our understanding of dietary exposure and cardiac metabolic adaptation. By linking systemic metabolic signals in the circulation with intracellular metabolic responses in heart tissue, researchers can better understand how dietary components influence cardiovascular metabolism. This integrative perspective helps bridge the gap between nutrition science and cardiovascular pharmacology. In this way, metabolomics allows researchers to move beyond simply measuring nutrients toward understanding how the body functionally adapts to diet.

Reference

1. Kim, H., & Rebholz, C. M. (2021). Metabolomic Biomarkers of Healthy Dietary Patterns and Cardiovascular Outcomes. In *Current Atherosclerosis Reports* (Vol. 23, Number 6). <https://doi.org/10.1007/s11883-021-00921-8>
2. Zhan, J., Wang, J., Jiang, L., Li, J., Li, J., Cao, J., Du, Y., Yan, T., Jia, Y., & He, B. (2026). Moringa oleifera leaves water extract as a novel therapeutic agent for hyperlipidemia prevention: Integrated analysis of bioactive components and metabolic regulatory pathways. *Food Research International*, 225. <https://doi.org/10.1016/j.foodres.2025.118101>



QUIZ Time

Question 1

Which of the following best explains the advantage of analyzing both blood and heart tissue in metabolomic studies of dietary fat intake?

- A. Blood and heart tissue provide identical metabolite profiles, improving data consistency
- B. Blood analysis alone is sufficient to understand organ-specific metabolic adaptations
- C. Combining blood and heart tissue analysis enables assessment of both systemic and tissue-specific metabolic responses
- D. Heart tissue analysis replaces the need for bioinformatics tools such as MetaboAnalyst

Correct Answer :

C. Combining blood and heart tissue analysis enables assessment of both systemic and tissue-specific metabolic responses. Blood reflects circulating, systemic metabolites, while heart tissue provides insight into intracellular, organ-specific metabolic changes. Combining both allows a more comprehensive understanding of metabolic adaptation to dietary fat intake.

Question 2

When cardiac cells efficiently convert fatty acids into energy via mitochondrial metabolism, which metabolite pattern best indicates increased TCA cycle flux?

- A. Decreased levels of citrate, succinate, and fumarate
- B. Accumulation of citrate with reduced succinate and fumarate levels
- C. Increased levels of citrate, succinate, and fumarate
- D. Increased lactate with decreased TCA cycle intermediates

Correct Answer :

C. Increased levels of citrate, succinate, and fumarate. Elevated levels of key intermediates such as citrate, succinate, and fumarate, indicating active mitochondrial metabolism in cardiac cells

Question 3

Which of the following metabolites present in the blood best indicates dietary intake of fat such as soybean oil?

- A. Ceramide
- B. Linoleic acid
- C. Cholic acid
- D. Butyrate

Correct Answer :

B. Linoleic acid is a major omega-6 fatty acid abundant in soybean oil and can be detected in the blood following dietary intake, making it a suitable biomarker of fat consumption.

ABOUT

Author



Associate Professor Dr. Salfarina Ramli received her PhD training in the field of pharmacognosy from the College of Public Health Sciences, Chulalongkorn University, Thailand focussing on optimization of antioxidant in vitro assays and standardization of medicinal plants. During her training years, she was given an opportunity to develop expertise in the application of liquid chromatography–mass spectrometry (LC–MS) in pharmacognosy through her training with her host scientist in the Faculty of Pharmacy, Meijo University, Japan. Her ongoing collaboration with researchers from the Medicinal Plants Innovation Center, Mae Fah Luang University, Thailand since 2021 expands her knowledge and skill in bioinformatics platforms, particularly in understanding the efficacy of medicinal plants combination or recipes through network pharmacology. This experience broadened her research perspective and her interest in understanding the adaptation to dietary changes at biological systems level. Building on this interest, she is currently part of multidisciplinary research project supported by Kewpie Corporation. This opportunity has allowed her to further expand her knowledge with a current interest on understanding biological adaptation to consumed foods by monitoring systemic and organ-specific metabolites using animal model.