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Review

Multiscale structures of lipids in foods as parameters affecting fatty acid bioavailability and lipid metabolism ☆

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ABSTRACT

On a nutritional standpoint, lipids are now being studied beyond their energy content and fatty acid (FA) profiles. Dietary FA are building blocks of a huge diversity of more complex molecules such as triacylglycerols (TAG) and phospholipids (PL), themselves organised in supramolecular structures presenting different thermal behaviours. They are generally embedded in complex food matrixes. Recent reports have revealed that molecular and supramolecular structures of lipids and their liquid or solid state at the body temperature influence both the digestibility and metabolism of dietary FA. The aim of the present review is to highlight recent knowledge on the impact on FA digestion, absorption and metabolism of: (i) the intramolecular structure of TAG; (ii) the nature of the lipid molecules carrying FA; (iii) the supramolecular organization and physical state of lipids in native and formulated food products and (iv) the food matrix. Further work should be accomplished now to obtain a more reliable body of evidence and integrate these data in future dietary recommendations. Additionally, innovative lipid formulations in which the health beneficial effects of either native or recomposed structures of lipids will be taken into account can be foreseen.

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☆ This review is respectfully dedicated to the memory of Michel Ollivon, Research Director at CNRS (Châtenay-Malabry, France), outstanding physico-chemist specialist of lipid organization, recipient of the Hilditch Memorial Lecture award, who was the initiator of the network RMT LISTRAL. We are also sadly paying tribute to Jean-Luc Vendeuvre, Food Engineer at the French Pork and Pig Institute (IFIP, Maisons-Alfort, France), outstanding expert in meat products who participated actively in RMT LISTRAL and provided unpublished data for figures in the present review, who passed away during review submission.

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[1] RMT LISTRAL: Mixed Technological Network combining academic and industrial partners, devoted to the enhancement and divulgation of knowledge regarding structured dietary lipids.

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1. Introduction

Dietary lipids have long been considered as energy suppliers. In the frame of preventing metabolic diseases of nutritional origin and cardiovascular risk factors such as hypertriglyceridemia, excessive lipid intake should be avoided [1,2]. However, dietary lipids are also recognized to be essential for preserving health. For instance, the need for a balanced supply in both *n*-6 and *n*-3 polyunsaturated fatty acids (PUFA)[2] is now supported by dietary guidelines, while various other fatty acids (FA) present specific recommended intakes [3–5]. Altogether, optimizing the bioavailability of beneficial FA while preventing the development of excessive lipemia is important for human health. However, beyond FA composition, dietary fats and oils exhibit a huge molecular and supramolecular diversity as shown Fig. 1. Recent advances in nutrition research revealed that these various structures and the physical (liquid *vs* solid) states of lipids in food products can modulate FA release and bioavailability during digestion and their final metabolic fate. The location of FA on a triacylglycerol (TAG) or on a phospholipid (PL), their position on the glycerol backbone, the supramolecular arrangements of lipid molecules for instance in the form of emulsion droplets that vary according to their sizes, interfacial composition, and the amount of fat in crystallized state may impact on their digestibility and metabolism. This could modify their health impact.

The present review is focused on the recent available evidence showing that the structures of dietary fats and oils, viewed from the molecular to the food matrix scales can modulate FA bioavailability and lipid metabolism.

2. Intramolecular structure of triacylglycerols and fatty acid metabolism

The intramolecular structure of TAG corresponds to the position, or so-called regiodistribution, of the FA chains on the glycerol backbone (internal *sn*-2 position, external *sn*-1 and *sn*-3 positions; Fig. 1A). It has long been suspected to influence FA bioavailability and metabolism and thus, the nutritional impact of TAG. Several reviews on this topic highlighted conflicting results [6–15]. The different models used, the studied molecular species of TAG and their purity, the presence of other non-lipid components may explain this apparent inconsistency. However, most studies also indicate that the position of the acyl groups on TAG affects their hydrolysis and subsequent FA absorption, which can modify some cardiovascular risk factors [16]. We will first summarize the identified mechanisms; then the data obtained *in vitro*, in animal models or in humans either with natural lipid sources or with restructured TAG are more deeply reviewed.

2.1. The mechanisms linking FA bioavailability to TAG intramolecular structure

FA can be absorbed only when released from the TAG structures as non-esterified FA (free FA = FFA) or as 2-monoacylglycerols (2-MAG) after digestive lipolysis (Fig. 2). Accordingly, in animals and human infants, *sn*-2 esterified FA are efficiently absorbed as

[2] *Abbreviations:* FA, fatty acid(s); TAG, triacylglycerol(s); PL, phospholipid(s); ALA, alpha-linolenic acid; ARA, arachidonic acid; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acid(s); AUC, area under the curve; BMI, body mass index