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Structured Lipids: Synthesis, Genetic Engineering, and Applications

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ABSTRACT

Lipids are essential to the human body, but some can be harmful. As a result, current research focuses on structured lipids (SLs), which are engineered to have specific fatty acid arrangements. These structural modifications can enhance both nutritional and physical properties. Fatty acids on the glycerol backbone can be rearranged through chemical, enzymatic, or genetic methods. Numerous studies have identified and characterized genes involved in SL biosynthesis. Among SLs, the medium-long-medium type is, particularly, valuable for its nutritional and therapeutic benefits. Considering the gap in comprehensive comparisons between chemical, enzymatic, and genetic-based synthesis methods, this review aims to highlight the methods used for SLs production. As health awareness grows, SLs are expected to play an increasingly important role in promoting human health, notably as nutraceuticals and functional foods, in clinical nutrition and therapeutics, in weight management, in infant formula, and as pharmaceutical carriers.

1 | Introduction

Lipids are essential components of a balanced diet, providing approximately 8.4 kcal/g of energy (Abed et al. 2018). Beyond their caloric value, lipids fulfill crucial physiological functions: for instance, they are integral to cell membrane structure, serve as energy reservoirs, protect cellular integrity, and aid the absorption of fat-soluble vitamins A, D, E, and K Ang et al. 2019; Zam 2015). Additionally, lipids have significant applications in industries such as cosmetics (e.g., waxes, essential oils), pharmaceuticals (e.g., drug delivery systems), and food processing (Zhou et al. 2022).

However, excessive consumption of certain lipids, particularly, those high in saturated (SFA) and trans fatty acids (TFA), has been linked to chronic diseases including obesity, cardiovascular disorders, cancer, atherosclerosis, hypertension, and diabetes (Abed et al. 2016; Cozentino et al. 2022; Trivedi and Singh 2005). In response to these health risks, dietary guidelines in many countries recommend that fats contribute only 20%–35% of total daily caloric intake (Zam 2020).

Structurally, dietary lipids are primarily composed of triacylglycerols (TAGs), which include four main types of fatty acids: SFAs, monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), and TFAs (Ang et al. 2019). Each type plays distinct physiological roles. For example, SFAs are necessary for bile acid synthesis but can also raise blood cholesterol levels by increasing low-density lipoprotein (LDL)