Food Science and Processing
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Perspective

Kinetic Models for Lipid Digestograms Need to Be Unwrapped: A Research Perspective

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How To Cite: Sopade, P.A. Kinetic Models for Lipid Digestograms Need to Be Unwrapped: A Research Perspective. *Food Science and Processing* **2025**, *1*(1), 1. https://doi.org/10.53941/fsp.2025.100001.

Received: 27 March 2025
Revised: 12 June 2025
Accepted: 18 June 2025
Published: 24 June 2025

Abstract: Food digestibility is a major consideration in formulating, developing, and processing foods for health and nutrition. Lipid digestion is important for nutrient supplies, and with in vitro digestion procedures widely used, the results from which are described by kinetic models, there is a need for an in-depth understanding of these kinetic models. With more than 10 kinetic models reported for lipolysis, the relative computational characteristics of these models together are yet to be fully unwrapped along a detailed comparative approach. Kinetic models in amylolysis and proteolysis have been detailedly studied, and a study on kinetic models for lipolysis will complement the other macronutrients to better understand food digestion. A comprehensive review, in a follow-up study, is required to fill this research vacuum and guide researchers on kinetic models for lipolysis.

Keywords: Gallagher-Corrigan model; Gompertz model; Li-McClements model; Logistic model; Sopade objective procedure (objective logarithm of slope); Weibull model

1. Background

Lipids, a topmost food macronutrient, are important in health and nutrition [1] for their contribution of essential fatty acids (e.g., omega-6 fatty acids), association with phytochemicals and fat-soluble vitamins (e.g., lycopene), and implication in lifestyle issues (e.g., obesity). Natural and processed foods contain lipids, the digestibility of which is topical to better understand existing food systems and develop more foods and food ingredients that will meet various dietary preferences and regulations. With the global population growth, this is more critical for food and nutrition security to align with the United Nations Sustainable Development Goals [2].

2. Lipid Digestion

Lipids are digested to free fatty acids and associated intermediate products such as diacylglycerols and monoacylglycerols [3]. For its relative advantages (simplicity, economics, etc.), various studies exist on in vitro lipid digestion that, like in vitro protein and starch digestions, correlate well with in vivo lipid digestion [4]. In vitro lipid digestion, therefore, offers great insights into in vivo lipid digestion to better understand food systems in the gastrointestinal tract. Using different procedures and product-measurement techniques, it is common to report digested lipids (free fatty acids)-time profiles, lipid digestograms, for the kinetics of lipolysis [5,6]. The kinetics are subsequently modelled with theoretical, semi-empirical, and empirical equations to obtain lipid digestion parameters for quantitative analyses that better probe lipolysis mechanisms.

3. Kinetic Models for Lipolysis

Some models reported for lipolysis include the first-order kinetic [6] (Zhao et al., 2024), Gompertz [3], Weibull [5], logistic [7], Gallagher-Corrigan [5], Giang [8], and two-term exponential [9] models. Some non-

conventional models have been reported in lipolysis, but importantly, the following models, identified with the author(s) that published them, uniquely incorporate physical properties of lipid substrates; the Li-McClements [10], Gaucel [11], and Sarkar [12] models.

Although Verger [13] applied the classical Michaelis-Menten model in lipolysis, the model is generally unsuitable or not widely used for in vitro digestion [14–17] because of its computational limitations for and the nature (multienzymes, concentrations, etc.) of in vitro digestion. Interests in computational characteristics of kinetic models for lipolysis exist to guide choosing appropriate models for lipase-substrate treatments. Okuro et al. [9] examined the first-order kinetic and two-term (double first-order) exponential models. González et al. [5] compared the Weibull and Gallagher-Corrigan models. In examining the characteristics of the Li-McClements model [10], Gaucel et al. [11] modified it to propose the comparable Gaucel model and opined the suitability of both models for lipid digestograms. Sarkar et al. [18] essentially examined the suitability of the Li-McClements [10], Gaucel [11], Sarkar [12], and first-order kinetic [6] models for lipolysis. Giang et al. [8] compared the Li-McClements [10] and Giang [8] models to obtain different predictions of their experimental data. For comparative analyses, Zhao et al. [6] predicted their experimental data with lipolysis rates from slopes at different digestion times and the first-order kinetic model.

Relatively, slope changes have been rarely used in lipolysis, unlike in amylolysis and proteolysis, where logarithm of slope [19], especially objective logarithm of slope, the Sopade Objective Procedure [17,20] has been objectively used to classify mono- and multi-phasic digestograms. This has prevented curve fittings of digestograms for consistency between and within laboratories. Modelling lipid digestograms would benefit from the Sopade Objective Procedure to ensure the above kinetic models for lipolysis are appropriately applied. While multiphasic lipid digestograms have been inferred with the multi-term kinetic models, namely the Gallagher-Corrigan [5] and two-term exponential models [9], no clear guidelines are available to classify lipid digestograms as presented. Guidelines to classify protein and starch digestograms are available, in addition to the computational characteristics of kinetic models for amylolysis and proteolysis [17,20,21]. Sopade and co-workers [16,17,21] uniquely examined the characteristics of more than 10 kinetic models, including some of the ones above, separately for protein and starch digestograms. Their studies included two-term non-exponential, and three-term exponential and non-exponential models for bi- and tri-phasic protein and starch digestograms that revealed rapid-slow, slow-rapid, rapid-slow-rapid, rapid-slow-slow, slow-rapid-rapid, and slow-rapid-slow digestion phenomena. We are unaware of a similar study in lipolysis involving all the kinetic models above and more possible models for a holistic approach to modelling food digestograms. Understanding the computational characteristics of kinetic models for describing lipid digestograms, in a follow-up study, will assist researchers to objectively choose appropriate models for practical parameters that adequately predict lipid digestion in food systems. Such will aid appropriately developing lipid-based foods with defined digestibility properties for human health, nutrition, and wellness.

4. Conclusions and Future Considerations

The computational characteristics of the existing kinetic models for lipolysis are better examined to understand how they describe lipid digestograms with practical digestion parameters. There will be a need to objectively classify lipid digestograms into mono- and multi-phasic ones, with a view to correctly applying the models across laboratories. Some of models might be modified to appropriately describe lipid digestograms with practical boundary conditions, while clarifying the conventional meanings of some of the parameters to be better understood and applied. For example, times to digest half of maximum digestible lipids, important in lipolysis possibly because of lipid chemistry, have not been clearly defined or derived for all the models for lipolysis, and these need to be investigated for the intended tag. A follow-up study is, therefore, required to achieve these, unwrap kinetic models for lipolysis, in line with existing understandings of modelling protein and starch digestograms. Such will benefit researchers in food digestion for consistent analyses and inferences between and within laboratories, thereby universalising the subject area.

Author Contributions

P.A.S.: conceptualization, methodology, software, data curation, formal analysis, writing—original draft preparation, visualization, investigation, validation, writing—reviewing and editing.

Funding

This research received no external funding.

Data Availability Statement

The author has no permissions to share the published or public data used or inferred.

Conflicts of Interest

The author declares no conflict of interest.

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