



Review

Understanding the flavor dynamics of high-fat dairy products: Insights into mechanisms, aroma profiles, and sensory evaluation

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ABSTRACT

Cream, butter, and anhydrous milk fat are the most widespread high-fat dairy products produced and consumed globally, appreciated for their nutritional value and appealing flavor. For manufacturers, understanding the flavor of these products by closely examining their sensory attributes and chemical properties is crucial to maintaining high-quality flavors and ensuring consumer acceptance. This review provides a comprehensive and up-to-date analysis of the flavor aspects of these high-fat dairy products, focusing on the mechanisms of aroma-active compound formation, odor assessment methods (including extraction, qualitative analysis, identification, and chemometric approaches), and descriptive sensory evaluation techniques. Over 100 aroma-active substances have been identified in high-fat dairy products, with aldehydes, lactones, and ketones as significant contributors. These aroma-active substances formation occurs primarily through lipolysis, proteolysis, and fermentation. Advanced analytical techniques show promise for comprehensive flavor profiling; however, challenges remain in correlating instrumental data with sensory perceptions. Future research should focus on identifying trace off-flavors, improving extraction methods, and developing rapid, non-destructive quality control techniques to enhance sensitivity, real-time monitoring, portability, time efficiency, and visualization for a complete flavor profile. Additionally, these efforts will provide deeper insight into the factors contributing to flavor variations during processing, improve quality control, and enhance the marketability of innovative dairy products.

1. Introduction

High-fat dairy products, including sour cream, butter, and anhydrous milk fat, are widely consumed globally. Consumers particularly appreciate these products due to their unique nutritional and flavor characteristics (Lozano et al., 2007; Min et al., 2020). According to the database from the Food and Agriculture Organization of the United Nations statistics (FAOSTAT), global high-fat dairy product production from cow and buffalo milk for 2021/22 is estimated to be up to 7.7 million tons for butter, followed by ghee at 4.5 million tons and cream at 3.7 million tons. India leads in butter production at 13 %, followed by the United States at 12.2 %. India accounts for 84.4 % of the total ghee production, followed by Pakistan at 11.8 %. Germany predominantly produces cream at 14.8 %, followed by France at 12.9 %.

Based on the manufacturing processes illustrated in Fig.1S, the

industrial-scale production of three distinct types of butter involves the utilization of cream as the primary raw material to produce sour butter, made from cream inoculated with lactic acid bacteria (culture-based method); acidified butter, obtained by adding lactic acid to sweet cream (direct acid method); and sweet butter, derived from unfermented cream (concentrated methods) (Bondarchuk, 2018; Yu et al., 2018). These different types of butter are then clarified to produce anhydrous milk fat (AMF), Ghee, Samna, Sadeya, or Butter oil, varying names depending on the country's production process. These final products have consistently been central to global trade, mainly due to their favorable attributes of easy transportation, preservation, and storage. The flavor composition of these high-fat dairy products depends on factors such as region, animal species and feeding, season of production, manufacturing process, aroma extraction methods, and packaging conditions (Couvreux et al., 2006; Elbarbary et al., 2024a; Lozano et al., 2007; Widder et al., 1991).

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