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A 100-Year Review: Milestones in the development of frozen desserts[1]

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ABSTRACT

Ice cream has come a long way since the first snow cone was made. Innovations in a variety of areas over the past century have led to the development of highly sophisticated, automated manufacturing plants that churn out pint after pint of ice cream. Significant advances in fields such as mechanical refrigeration, chilling and freezing technologies, cleaning and sanitation, packaging, and ingredient functionality have shaped the industry. Advances in our understanding of the science of ice cream, particularly related to understanding the complex structures that need to be controlled to create a desirable product, have also enhanced product quality and shelf stability. Although significant advances have been made, there remain numerous opportunities for further advancement both scientifically and technologically.
Key words: ice cream, frozen dessert, microstructure, processing

INTRODUCTION

Frozen desserts developed over history in much the same way as most foods: our ancestors kept trying different things until they found something that worked. Although numerous origin stories exist, the first frozen desserts likely were made by flavoring snow or ice. This may have been intentional but may also have simply occurred by chance. It is not our intention to delve into truth or myth because the history of frozen desserts has been documented in numerous publications (e.g., Quinzio, 2009).

An enormous industry has grown up around standardized commercial products. Many of the advances in the ice cream industry have been driven by technological inventions. For example, improved methods of refrigeration, from ice harvesting to mechanical refrigeration, have significantly influenced the development of ice cream over the past century. Although chefs and entrepreneurs continually explore new frozen dessert ideas, as with many other foods, the development of high-quality products proceeded without much, if any, scientific understanding. In the past century, scientists have attempted to bring a better scientific understanding to such foods. We continue to conduct experiments on ice cream to better understand the scientific basis for this long-cherished treat in hopes of providing new and unique ways to deliver consumer satisfaction. In this review, we highlight advances and developments in ice cream and frozen desserts over the past century, with a focus on how the *Journal of Dairy Science* has played a role in that development. As the premier dairy journal, many of the important advances in the development of ice cream have unfolded in its pages over the past century (see Appendix Table A1).

MIX INGREDIENTS

Some hundred years ago, little consideration was given to the individual or collective contributions of the components of ice cream mix as they related to the actual structure–function relationships of finished ice cream products. Historically, milk, cream, and sugar were the fundamental ingredients of ice cream in its most rudimentary form. Flavored, frozen, and whipped into a popular dessert, there was little need to improve this successful formulation. However, as market pressures and economic opportunities arose, ice cream needed to change in many ways, including exhibiting stability over long-term frozen storage and responding to a more diverse population interested in issues such as changes in nutrient content. The gap between the readily manufactured, well-recognized version of ice cream as a conventional dessert and the need for ice cream to change to meet market demands spawned the ensuing century of research focused on bridging the significant knowledge gap of the scientific underpinnings of ice cream—arguably one of the most complex foods manufactured. Such complexity is manifest in several ways that to this day defy complete characterization. For instance, consider that ice creams contain or display multiple physical states and forms (including liquid, solid, and gas phases) and significant foam structure, solvent–solution interactions, and varying permuta-

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tions on emulsion structure. Collectively, these forms exhibit a diverse collection of physical and sensory attributes over a large temperature range. For example, ice cream mix must be sufficiently liquid at pasteurization treatment to flow through various heat exchangers at over 80°C, then be sufficiently malleable as a frozen foam to allow scooping or serving to occur at approximately −15°C, then remain rigid and stable to meet a long-term storage convention of 1 yr under freezing temperatures of −30°C. Add to this list a host of other critical factors that must be achieved, such as the bearing of an ever-increasing collection of inclusions and variegates and the ability to appropriately melt upon consumption and to provide a "comfort food" level of satiety and enjoyment to the imbiber. These and other attributes are achieved through specific processing and freezing parameters and by the deliberate addition or manipulation of various ingredients that are critical to the character of ice cream based on our knowledge of structure–function relationships involving dairy ingredients, sweeteners, stabilizers, emulsifiers, and a growing collection of other critical ingredients designed to meet the shifting demands on ice cream or related frozen dessert products. From quintessential backyard summer dessert to engaging the greatest minds in dairy foods science, the list of functional roles of ice cream ingredients can be described as either short and simple or long and complicated depending on the application and audience. Discoveries of the finer chemical and physical roles of ice cream ingredients have been the subject of routine research activities over the past century and are presented in this article.

Dairy-Based Ingredients

Given all of the potential states that dairy ingredients and components can take and the flexibility provided through mix standardizing technologies and compositional requirements, few dairy-based ingredients have not found their way into ice creams for a variety of functional, nutritional, and economic purposes. The dairy ingredient components—namely CN and whey proteins, milk fat, lactose, and mineral salts—each play roles of varying degrees of importance.

Because of the complex and heterogeneous nature of CN proteins and the native state of those proteins present in micellar form, the CN proteins and their derivatives have played numerous roles in frozen dessert characteristics (Goff et al., 1989; Chang et al., 1995; Alvarez et al., 2005). Whey and its derivatives have also been the source of investigations aimed at exploiting the unique properties of whey components and the known chemical or physical phenomena present in frozen desserts (Prindiville et al., 2000; Levin et al., 2016). An increased understanding of the role of milk proteins should parallel the degree to which high protein intake remains an important consumer interest (see Patel et al., 2006).

Milk fat plays many significant roles, including nutritional roles (e.g., caloric density, lipid-soluble vitamins), in the characteristics of frozen desserts. Milk fat is a solvent for flavors such as vanilla (Li et al., 1997) and affects the sensory and rheological properties of ice cream based on the physical forms that the milk fat assumes during the manufacturing processes (Kalab, 1985; Goff, 1997). The effects of freezing (Doan and Baldwin, 1936) and shear forces destabilize the relatively distinct dispersion of milk fat globules coated with an interfacial complex (referred to as the milk fat globule membrane) and result in the formation of aggregated, structure-imparting milk fat globule clusters typically referred to as full or partial coalescence (Goff, 1997) and flocculation, depending on the aggregate mechanism (Méndez-Velasco and Goff, 2012). The final connections between these mechanisms, their resulting milk fat–based structures, and the final rheological and sensory properties of the final product (Warren and Hartel, 2014) remain topics of interest, especially in frozen desserts that have novel compositions. There is continual interest in pursuing an improved understanding of the roles that milk fat plays in ice cream as a function of temperature, shear force, and the unique chemistries of novel frozen dessert mixes (e.g., the presence of surfactant molecules).

The presence of lactose in ice creams has been the source of various research activities. In general, the level of lactose in ice cream can be quite high, nearing 8%, resulting in concerns for those who experience lactose malabsorption issues. High lactose content is, in part, a function of the US standards of identity requiring that milk be fortified with milk fat and milk SNF above what is natively found in milk and the availability of lactose-rich ingredients designed to serve that purpose. These high lactose levels play a significant role in the overall freezing point depression of the serum phase of ice cream (Goff and Hartel, 2013) and contribute to a small degree to the overall sweetness of the frozen dessert. Excessive levels of lactose and abusive storage conditions can render lactose insoluble, resulting in the crystallization of lactose molecules and the concomitant sensory defect known as sandiness (Nickerson, 1954). Interest in reducing lactose and overall carbohydrate content in ice creams has been a current focus of inquiry, as has the inclusion of lactose derivatives such as polymerized lactose with reported prebiotic function (Tremaine et al., 2014; Balthazar et al., 2015).

Given that ice creams are, in essence, concentrated milk components, the mineral density—more specifi-