frontiers | Frontiers in Animal Science

TYPE Review
PUBLISHED 06 May 2025
DOI 10.3389/fanim.2025.1566858

OPEN ACCESS

EDITED BY
Matteo Dell'Anno,
University of Milan, Italy

REVIEWED BY
Shengqian Sun,
Yantai Institute of Technology, China
Adriana Domínguez-Oliva,
Metropolitan Autonomous University, Mexico
Diego E. Peralta-Guevara,
Universidad Nacional José María Arguedas, Peru

*CORRESPONDENCE
Anete Freiberga
anete.freiberga@lbtu.lv

RECEIVED 25 January 2025
ACCEPTED 08 April 2025
PUBLISHED 06 May 2025

CITATION
Freiberga A, Ilgaza A, Strausa E, Ciprovica I and Zagorska J (2025) Snacks and ice cream as complementary dog feed: perspectives, trends, ingredients. *Front. Anim. Sci.* 6:1566858. doi: 10.3389/fanim.2025.1566858

Snacks and ice cream as complementary dog feed: perspectives, trends, ingredients

Anete Freiberga[1]*, Aija Ilgaza[1], Evita Strausa[2], Inga Ciprovica[3] and Jelena Zagorska[3]

[1]Latvia University of Life Sciences and Technologies, Faculty of Veterinary Medicine, Jelgava, Latvia, [2]Riga Technical University, Faculty of Engineering Economics and Management, Riga, Latvia, [3]Latvia University of Life Sciences and Technologies, Faculty of Agriculture and Food Technology, Jelgava, Latvia

This review explores the dog snack market, emphasizing pet ice cream as a growing sector with potential for further development. It examines current trends and production challenges in creating dog-friendly snacks that are safe and palatable. The review was conducted using a semi-systematic literature analysis from 2000 to 2024, evaluating over 65 full-text articles and other sources from major databases. Key topics covered include the types, ingredients, and functionality of dog snacks. Dog snacks are categorized by function and nutritional benefits, with a range of ingredients. The review identifies a gap in cooling dog snacks, highlighting ice cream as a promising product, noting that ice cream for dogs is different from classical ice cream and involves ingredients due to dogs' dietary needs. Functional ingredients like probiotics and prebiotics are discussed for their health benefits. The review underscores the importance of further research to meet pet owners' demands for safe, innovative, and functional dog snacks, particularly with respect to cooling treats and specialized dietary formulations. This research aligns with the growing trend toward pet wellness, reflecting owners' increasing interest in snacks that are not only enjoyable but also contribute to overall pet health.

KEYWORDS

frozen, snack, cooling, therapeutic benefits, functional nutrition

1 Introduction

The global pet food market, especially the dog snack segment, has experienced significant growth over the past decade. Driven by increasing pet ownership, the number of dogs in Europe has witnessed a notable increase to more than 92 million in 2021, heightened awareness of pet health, and the anthropomorphization of pets, the market has seen substantial innovations in product offerings. The sales of pet food in Europe have reached around 9.9 million tons in 2023 (Shahbandeh, 2024). The numbers of owners provided treats for dogs are significant and varied form 40% (Nielson et al., 2023) to 96% (White et al., 2016). Among animals, the dogs segment held the highest share of the pet

snacks market in the region, accounting for 47.2% in 2022 (Research and Markets, 2024). Dog snacks are broadly categorized into training treats, dental chews, and functional snacks that provide additional health benefits, such as joint support or digestive health (Calancea et al., 2024).

Dog snacks must be labeled as "complementary feed." This term refers to feed products that contain high levels of certain components but are only adequate for a complete daily diet when combined with other feed. Nearly all pet food manufacturers produce a range of dog snacks that differ in size, ingredients, flavor, and functions, as treats play a significant role in a dog's diet (Morelli et al., 2018). Dog treats not only have positive qualities, but can also have various drawbacks, recent studies summarize both advantages, disadvantages and risks that treat can cause in the dog's body starting from mental stimulation, decreasing dental calculus, dental plaque and gingivitis and ending with overweight, esophageal blockage, dental fractures and oral injuries and gastrointestinal blockage (Calancea et al., 2024). The 12% to 17% reduction in plaque coverage and thickness and the 20% to 35% reduction in calculus coverage in the current study were significant (Carroll et al., 2020). Daily feeding of the soft rawhide chew product resulted in statistically significant reductions in the formation of dental calculus (28.0%), dental plaque (19.0%), and gingivitis (46.0%) (Stookey, 2009). In study by Flint et al., 2023 effectiveness of different food-based enrichments were explored on engaging dogs, it was stated that long-lasting chew was found to improve emotional states in comparison to the other interventions tested.

There are snacks with functional properties, but there is a lack of dog snacks that have a cooling effect—which is crucial in the warm season. The canine thermoneutral zone varies depending on the breed with coat length, body size, and activity levels, all impacting the range. The critical temperatures proposed for dogs in general range from 15°C to 20°C at the lower end, to 30–35°C at the upper end (Carter et al., 2018). Dogs mainly regulate heat by panting and sweating only minimally through their paw pads (Johnson et al., 2006). Normal rectal temperature ranges in dog are 37.5-39.2°C (MSD Manual, 2024). Dogs are at risk of heat stroke when their body temperature exceeds normal limits, which can lead to organ damage and even be fatal. Activities like running or intense play, especially in warm environments, increase this risk (Robbins et al., 2017). Without proper cooling, dogs experience faster fatigue during physical activities, which can lower their endurance and performance (Zanghi et al., 2018). In Brachycephalic dogs, the inability to effectively cool through panting can result in dogs overheating at ambient temperatures as low as 21-22°C (Lilja-Maula et al., 2017).

The anthropomorphization trend presents opportunities for the pet care industry to cater to a customer base that values products fostering pet-human bonding and well-being and has driven demand for premium and functional snacks (Baritugo et al., 2023) that emphasize the quality of ingredients and nutritional benefits. Pet owners now seek transparency in ingredient sourcing, sustainable production methods, and eco-friendly packaging. There are different review focusing on analysis of the dog's snack market, however the studies regarding ice-cream formulation and quality are limited.

This review aims to provide an overview of the current trends, nutritional considerations, and future directions in the driven dog snack market, special attention delivered for pet ice creams, the ingredients commonly used in pet ice cream production and the considerations involved in their selection, with a focus on ensuring safety, palatability, and nutritional and functional adequacy for pets.

2 Materials and methods

This review employed the monographic method and was conducted in English, following a semi-systematic approach. It provides a summary of existing literature on dog snacks and the raw materials used in ice cream production from 2000 to 2024 from all over the world. In our publication, we included studies and reviews mentioning dog treats, the raw materials used to make them, and their effects on canine health. Research databases of scientific papers, including ScienceDirect, Web of Science and Scopus, were explored to analyze key functions of dog snacks, the ingredients used in their production, their functionality, and the current snack market, encompassing a broad spectrum of published studies on dog snacks. Key search terms included "dog snacks" (65 articles), "ice cream with low sugar content" (80 articles), "dessert with low sugar content" (13 articles), "ingredients for ice cream production," (134 articles) and "functional" (544 articles) yielding 65 full-text articles, book chapters and internet resources for this review. In parallel with scientific articles, research has been carried out on snack market research, evaluating the trade market and internet resources by guiding key words. The authors also utilized various synonyms: pets-dog-canine, ice cream - frozen dessert, snack - treat to ensure comprehensive literature coverage.

3 Results and discussion

Table 1 shows a detailed overview of the most common types of dog snacks and their composition. The information given in the table was taken from the sources, without modifying of correcting the text.

Some of snacks are rich in a proteins and carbohydrates, but some contain functional ingredients as antioxidants, glucosamine, omega-3 fatty acid, fiber and lactic acid bacteria, different vitamins and minerals. As shown in Table 1, there are various types of snacks: bites, sticks, chews and biscuits, however there is no category specifically designed to cool dogs down during the warm seasons. This could represent a promising niche for dog snack manufacturers to explore.

3.1 Main ingredients used in the snack production

Table 2 summarizes the characteristics of dog snacks in the European market. Chemical composition of snacks varied within wide limits: fats from 0.5 to 30.2 g per 100 g; proteins from 0 to 84.0

TABLE 1 The characteristics and ingredients of dog snacks.

Type of the snack	Ingredients	Examples	References
Training treats	proteins: chicken, turkey, beef, peas, lentils; carbohydrates: rice, oats, potatoes; flavors: natural flavor enhancers like liver, peanut butter	freeze-dried liver bites; soft mini-bites with chicken or fish	de Castro et al., 2021
Dental chews	texturizing agents: potato, rice, cellulose; flavoring: chicken, beef; functional ingredients: chlorophyll, parsley, mint; antioxidants: vitamin E, rosemary extracts	rawhide-free dental sticks; dental chews with chlorophyll and parsley	Carroll et al., 2020
Joint health treats	glucosamine, chondroitin; omega-3 fatty acids (fish oils); turmeric, green-lipped mussel	soft chews with glucosamine and chondroitin; fish oil treat	Baritugo et al., 2023
Digestive health treats	prebiotics: inulin, fructooligosaccharides other than inulin; probiotics: *Lactobacillus* spp.; fiber: pumpkin, sweet potato, psyllium; enzymes	pumpkin-based chews; probiotic dog biscuits with added fiber	Yang and Wu, 2023
Immune-boosting snacks	vitamins: C, E; minerals: zinc, selenium; blueberries, cranberries, spinach; β-glucans	antioxidant-rich treats with blueberries; snacks with β-glucans	Rutherfurd-Markwick and Thomas, 2016; Khoo et al., 2005
Natural and organic treats	organic meat: chicken, beef; plant-based ingredients: sweet potato, carrots; antioxidants: vitamin E, rosemary extract	organic dog biscuits with chicken and sweet potato; freeze-dried organic liver treats	Thatcher et al., 2010
Grain-free and allergen-free treats	alternatives to grain: peas, chickpeas, lentils, sweet potatoes; animal-based ingredients: duck, lamb, fish	grain-free biscuits with chickpeas and duck; limited-ingredient treats with lamb and sweet potato	Khoo et al., 2005

Data in the table were selected in the period from 10.09.2024. to 20.11.2024. The information given in the tables is taken from the sources, without modifying or correcting the text.

g per 100 g; carbohydrates from 0 to 0.5 g per 100 g, fiber from 0 to 61.9 g per 100 g. Several tendencies were observed, freeze-dried snacks were rich in fat, using as main ingredient meat and meat by-products significantly increase protein content, but snack for chewing stand out with high fiber content. It should be noted that the carbohydrate content is not indicated for most snacks, however according to the ingredients list it should appear in a chemical composition.

The inclusion of fiber, probiotics, prebiotics, minerals and vitamins in the ice cream formulation makes it functional. Therefore, it's important to understand what can be used as ingredients for ice cream development, keeping in mind that the main goal is to develop a product with functional and cooling properties, but also to achieve a limited amount of fat and sugar typically used in traditional ice cream production (fat 7-15%, sugars 19-23%) (Clarke, 2012).

The main ingredients can be divided into the groups listed below; the ingredients will be listed from the most frequently used ingredient to the least.

Animal-based ingredients are the primary compounds of many snacks, providing essential proteins and fats necessary for a dog's health. Commonly used animal-based ingredients include meat (chicken, beef, lamb), which are a rich source of high-quality proteins and essential amino acids. Meat is often used in dried or freeze-dried form to maintain nutrient content and palatability (Di Cerbo et al., 2017). By-products (liver, heart) are nutrient-dense, offering vitamins such as A, D, and E, along with minerals like iron and zinc. They are highly palatable and often used in limited quantities due to their strong flavors (Larsen and Farcas, 2014). Fish, particularly salmon and tuna, is used for its high protein and omega-3 fatty acid content, which supports skin and coat health in dogs (Calancea et al., 2024).

Plant-based ingredients are increasingly popular in dog snacks (Kępińska-Pacelik et al., 2023). Grains (wheat, rice, oats, barley) provide carbohydrates, which are sources of energy for dogs. Whole grains also contribute fiber, aiding in digestion (Lema Almeida et al., 2022). Legumes (peas, lentils, chickpeas) are rich in proteins and fiber, making them valuable for nutrition. However, recent studies have raised concerns about the potential link between a grain-free diet (high in legumes and anti-nutrients such as saponins, tannins phytic acid and others) and dilated cardiomyopathy (DCM) in dogs, prompting further research (Kępińska-Pacelik et al., 2023). Vegetables (carrots, sweet potatoes) add vitamins, minerals, and fiber to dog snacks. They are often used in dried forms to maintain nutritional integrity while offering a crunchy texture (Di Cerbo et al., 2017).

Novel proteins and alternatives. With the rise in food sensitivities and allergies among dogs, novel protein sources are being explored. Insects like black soldier flies, larvae and mealworms are emerging as sustainable protein sources. They offer high protein content, and a lower environmental footprint compared to traditional livestock (Calancea et al., 2024). For dogs

10.3389/fanim.2025.1566858

TABLE 2 Characteristics of snacks for dogs available in the European market.

Snack	Characteristics				
	Weight, g	Main ingredients	Chemical composition, g per 100g	Functional properties	Producer
Noohide stick with rabbit	90	gelatin from skin and beef bones; rabbit meat, glycerin, tapioca, sorbic acid	fats 2.0 carbohydrates 0 proteins 60.0 fiber 2.0 ash 0	For chewing	Woolfsnakcs (UK)
Himalayan Dog chew churpi S	40	cottage cheese	fats 2.0 carbohydrates 0.5 proteins 84.0 fiber 2.0 ash 0	For chewing	Himalayan Dog chew churpi S (LV)
Freeze-dried snacks for dogs, chicken and banana	80	chicken, banana	fats 29.4 carbohydrates 0 proteins 24.3 fiber 4.2 ash 0 minerals 4.1 calcium 0.02 phosphorus 0.6g	No indicated	FARM pet food (EE)
PIG HOOF snacks for dogs	300	dried pig's feet	fats 18.9 carbohydrates 0 proteins 0 fiber 61.9 ash 0	For chewing	FARM pet food (EE)
Dr. Clauder's trainee snack	80	beef meat, fructooligosaccharides	fats 7.0 proteins 29.0 carbohydrates 0 fiber 0.4 ash 3.8	Prebiotic	Dr. Clauder's (DE)
More (deer antlers)	no	deer antlers	fats 0.2 proteins 36.0 carbohydrates 0 ash 62.0	For dental health; reducing stress	More Natural deer antlers (LV)
I'm different Freeze-dried sturgeon snack	40	sturgeon, chicory inulin – source of fructooligosaccharides, vegetable aromas, rosemary extracts, mixture of tocopherols, yeast, blend of dried fruits extract	fats 24.0 carbohydrates 0 proteins 46.0 fiber 2.2 ash 14.5 calcium 3.5 phosphorus 1.9	Prebiotic	Fancon food (IT)
Chewllagen, Collagen roll for dogs with beef flavor	105	collagen (type 1 and 3), water, cassava starch, glycerin, moisturizer, preservative: sorbic acid, beef meat	fats 4.5 carbohydrates 0 proteins 80.0 fiber 0.5 ash 0	Stimulates cartilage formation; cushions the joints, relieves joint pain; for intestinal health	Pets&friends (UK)
DigDog liver cubes	85	dried liver	fats 11.0 carbohydrates 0 proteins 60.0 fiber 0 ash 0	Improves feather and skin quality	DigDog (LV)
DigDog lung cubes	75	dried lung	fats 4.7 carbohydrates 0 proteins 15.2 fiber 0 ash 0	No indicated	DigDog (LV)
DigDog beef aorta	50	beef aorta	fats 10.0 carbohydrates 0	For metabolism promotion; for dental health	DigDog (LV)

(Continued)

TABLE 2 Continued

Snack	Characteristics				
	Weight, g	Main ingredients	Chemical composition, g per 100g	Functional properties	Producer
			proteins 83.0 fiber 0 ash 0		
Billy + Margot coconut creme	139	fructose, coconut oil, dried coconut, sunflower oil, potato flavor; tapioca starch; lemon juice	fats 9.0 carbohydrates 0 proteins 0.2 fiber 0.7 ash 0	For overall health and vitality support	Billy +Margot (UK)
Essential tiny fish delight	90	dried sprats	fats 27.0 carbohydrates 0 proteins 47.0 fiber 0 ash 6.0	For overall health support	ESSENTIAL (UK)
Essential dental sticks without grains	200	meat and meat derivatives, E202; E262	fats 7.3 carbohydrates 0 proteins 42.6 fiber 0.4 ash 25.5	For dental health	Essential (UK)
Mark+ Chappell Intestinal Aid treat for puppies	50	wheat flour, rapeseed oil, corn starch, poultry protein, seaweed flour, natural spices, salt, inulin, ascorbic palmitate, rosemary extract oil, vitamin E, vitamin A, vitamin D3.	fats 30.2 carbohydrates 0 proteins 11.0 fiber 1.1 ash 5.0	For digestive tract hygiene and nutrients absorbance	Mark+ Chappell Limited (UK)
Fruitables treat for dogs with blueberries and pumpkin	200	pumpkin, oats, barley, potatoes, sunflower oil, molasses, cinnamon, blueberries, natural blueberry flavoring, natural vanilla flavoring, tocopherol blend (to preserve freshness), rosemary extract, green tea extract, mint.	fats 10.1 carbohydrates 0 proteins 10.0 fiber 4.7 ash 3.9	No indicated	Mannana products LLC (USA)
CHURU puree for dogs chicken/vegetables	56	chicken meat (30.0%), tapioca, carrots (1.8%), green beans (1.8%), chicken meat extract, yeast and its parts, collagen, green tea extract, additives: guar gum (E412)	fats 0.5 carbohydrates 0 proteins 8.5 fiber 0.1 ash 1.5 vitamin E 0.574	No indicated	Thai Inaba Foods Co. (TH)
BOXBY treat for dogs Chicken Wings	360	meat and animal derivatives (88% chicken), vegetable derivatives, minerals, oils and fats	fats 1.5 carbohydrates 0 proteins 60.0 fiber 1.0 ash 5.5	No indicated	Scholtus Special Products, (NL)

Data in the table were selected in the period from 10.09.2024. to 20.11.2024. The information given in the tables is taken from the sources, without modifying or correcting the text.

with specific dietary restrictions, plant-based proteins (soy, quinoa, pulses) offer as a hypoallergenic alternative. However, these proteins may require supplementation to ensure a complete amino acid profile and anti-nutrient presence (Wehrmaker et al., 2022).

Food additives. Various additives are used to ensure the product quality during shelf-life, appropriate structure and aroma of dog snacks, for example, antioxidants, stabilizers, colors, emulsifiers, etc. The formulation of dog snacks involves a careful selection of raw materials that balance nutritional value, safety, palatability, and cost-effectiveness. The growing demand for healthier, functional, and sustainable dog snacks is driving innovation in ingredient sourcing and processing methods. Continued research is essential to address emerging concerns, such as the potential application of different ingredients (traditional and non-traditional) for developing new types of snacks for dogs with functional properties. Research has shown that dogs are naturally drawn to sweet flavors, making them highly desirable in dog feed and snack production (Calancea et al., 2024), which underlines the potential for the development of ice cream for dogs.

Although there are many different snacks on the market, meat and meat by-products are the primary ingredients used in their manufacture, but in Morelli et al. study (2018) was mentioned that many treats are composed of ingredients that are not recommended for pet food, such as 'milk and milk derivatives', and 'sugars' and

sweeteners such as sorbitol, which were listed in the labels of many products reviewed (almost half of the products mentioned 'sugars' on the label's ingredient list) (Morelli et al., 2018). Prices and the weight for different snacks varied, accordingly from 28.75 to 162.5 EUR per kg, and from 40 to 360 g. Treats with higher protein (e.g. meat-based treats) or specific ingredients (like organic, novel proteins or single-source protein) tend to cost more due to the cost of sourcing these ingredients. For example, rawhides and chewable sticks vary widely in protein and fat content which can influence both calorie density and cost. Treats that require specific processing methods (e.g. freeze-drying for meat strips or semi-moist treats) or that contain added vitamins, minerals or palatability enhancers (e.g., glycerin in tender treats) can vary in price due to the complexity of processing and the used ingredients (Morelli et al., 2018).

3.2 The characteristics of ice cream composition for dogs available in the market

Ice cream is a multiphase system that contains ice crystals, air bubbles, fat globules, and partially coalesced fat networks that are distributed in an unfrozen serum phase (Goff, 2002); it can be made from dairy or plant-based ingredients. The serum phase is made up of dissolved soluble components, such as uncrystallized water, milk proteins, sweeteners, minerals and stabilizers (da Silva et al., 2020). Achieving this while accounting for the unique properties and interactions of each ingredient is referred to as the balancing process. High-fat diets are prone to elicit pancreatitis and in young and adult dogs, free access to a high-fat diet leads to additional body-weight gain and body fat content (Beynen, 2018). Most commercial adult dog foods typically contain 5%–15% fat (dry-matter basis) (MSD Manual, 2024). In ice cream formulation for dogs sugar and fat should be maximally decreased, respectively up to 5 g/100 g and 10g/100 g, to avoid consuming excess calories and to keep snacking healthy, where developing ice cream becomes extremely challenging, since fats play a crucial role in both the flavor and structure formation (Genovese et al., 2022). Low-fat content poses a challenge for producers significantly influencing the texture and aroma profile, leading to issues like coarseness, iciness, low overrun, and lack of rich flavor (Jardines et al., 2020). The composition of standard ice cream is fat 7–15%, protein 4–5%, sugars 19–23%, total solids 28–40%, and water 60–72% (Clarke, 2012). Second, the most important ingredient is sugar. Sugar enhances the structure of ice cream, plays a key role in providing the ice cream's sweetness and imparts a rich, creamy, and smooth texture. Additionally, sugar helps reduce coolness, ice crystal formation, melt rate, and overall hardness (Genovese et al., 2022). Dogs do not have a dietary requirement for carbohydrate, except during pregnancy and lactation. However, they have a metabolic requirement for glucose. Carbohydrates in pet foods provide a valuable and important source of glucose, but if carbohydrates are provided in insufficient amounts, protein can provide animals with glucose through gluconeogenic pathways. They play an important role in the development as well as the treatment of several conditions in dogs, one of which is obesity (Rankovic et al., 2019). Obesity is defined as an accumulation of excessive amounts of adipose tissue in the body and is the most common nutritional disorder in companion animals. Obesity is usually the result of either excessive dietary intake or inadequate energy utilization, which causes a state of positive energy balance. Numerous factors may predispose and individual to obesity including genetics, the amount of physical activity, and the energy content of the diet (German, 2006). When treats are fed to the dog, the daily amount should not exceed 10% of the daily calorie requirement, where 90% of the total calorie intake consists of a complete and balanced diet that meets the maintenance energy requirements (MER) mentioned by Cline et al. (2021), which align with the recommendations provided by the NRC Nutrient Requirements of Dogs and Cats (NRC, 2006).

Table 3 data showed that most ingredients used in dog ice cream can be divided into the following groups, the ingredients are listed from the most frequently used to the least.

Base Ingredients. The base of pet ice cream typically consists of ingredients that provide texture and volume, similar to traditional ice creams. Water is the ingredient in many ice creams, acting as a solvent and providing hydration. It is essential for the structure of the product and ensures that it remains soft enough for pets to consume (Fiol et al., 2017).

Dairy and its alternatives. Non-dairy analogous like coconut drink or soy milk are often preferred in ice cream formulations instead of cow's, goat's, and lactose-free milk. Soy products contain antinutritional factors such as trypsin inhibitors and oligosaccharides that can negatively affect digestion (Lee, 2017). The bioavailability of soy protein is well utilized by canines (Clapper et al., 2001) however, it is still discussible question about allergenicity of soy proteins. These alternatives are less likely to cause digestive issues, as many dogs are lactose intolerant (Kępińska-Pacelik et al., 2023). Despite this fact in the given ice cream examples (see Table 3) lactose free milk, yogurt and whey powder are often used as base ingredients. Whey proteins could be applied for canine ice cream formulation. The profile of whey proteins in cow's milk is similar to canine colostrum, in addition whey protein concentrate contain high amount of essential amino acids, but for canine whey protein isolate could be recommended as it doesn't contain lactose (Zhang et al., 2022). Lactose-free milk retains the creamy texture without the risk of gastrointestinal distress. In many subjects, intestinal brush border disaccharidase activity decreases after weaning to a fraction of the activity found in young animals. Osmotic diarrhea often occurs when excessive levels of lactose are consumed (Thatcher et al., 2010). Lactose intolerance refers to gastrointestinal symptoms resulting from incomplete lactose digestion. Approximately 1% of unhydrolyzed lactose in the small intestine is passively absorbed and excreted unmetabolized in urine. The remaining lactose exerts an osmotic effect in the jejunum, promoting water and sodium secretion and accelerating intestinal transit. Substantial amounts may reach the colon, where colonic bacteria ferment lactose, producing short-chain fatty acids (SCAFAs) and gasses, including hydrogen,

10.3389/fanim.2025.1566858

TABLE 3 Characteristics of ice cream for dogs available in the market.

Name of frozen dessert/ice cream	Characteristics	Raw Materials	Manufacturer
Dogsters Ice Cream Style Treats	Low-calorie, vet-approved; flavored with natural ingredients like mint and cheese aroma; no artificial flavors or colors	**Water, skim milk**, *maltodextrin, flavors (mint, cheese), guar gum, carrageenan*	Dogsters (by J&J Snack Foods) (USA)
Frosty Paws	Fortified with vitamins and minerals; dairy-free	**Soy flour, whey**, ***vitamins (vitamin D, vitamin A), minerals (calcium carbonate)***	Nestlé Purina Pet care (USA)
Yoghund (Yopup)	Frozen yogurt with live bacterial cultures (probiotics); contains easily digestible dairy	**Yogurt, pumpkin, banana**, ***prebiotic fiber***	The Barking Dog Ltd (USA)
Hoggin' Dogs	For sensitive stomachs; lactose-free	**Lactose-free milk**, *gelatin, salt, natural flavors (peanut, bacon, pumpkin, prime rib, cheese)*	Puppy Cake LLC (USA)
Ben & Jerry's Doggie Desserts	Responsibly sourced, non-GMO ingredients; available in flavors like pumpkin and peanut butter	**Sunflower butter, peanut butter, pumpkin,** *pretzel swirls, mini cookie.*	Ben & Jerry's (USA)
Scoop's ice cream for dogs	It is added joint care supplements from GWF Nutritionists to create a complementary dog feed designed as a treat for dogs.	**Lactose-free milk, Hemp oil, *Glucosamine, Vitamin C, curcumin***	Marshfield Farm, (UK)
Dolci Impronte	The ice cream contains inulin and apple powder which help digestion, all of which are always of high quality	**Rice flour, corn fructose, lactose-free skimmed milk powder, apple powder**, ***fiber vegetable, inulin***, *refined coconut fat, glucose syrup powder, emulsifiers: E471, E473, E472/b, E472/a, thickeners: E466, E410, E417, corn maltodextrins*, ***milk proteins (sodium caseinate), soy proteins***, *salt, yoghurt flavoring*	Pet bliss (IT)
Helado	Ice cream for dogs is made from high quality products and delivers the proteins and minerals our pets need in their daily lives	**Potato starch, poultry by-product, hydrolyzed meat, rice flour, wheat flour**, *maltodextrin, glycerin, chicken flavoring, coloring, propionic acid, potassium sorbate*	Dr Zoo (ESP)
Ice cream mix for dogs	The ice treats are 100% tailored for your awesome friend and are lactose, grain and fat free	**Fructose,** *maltodextrin, guar gum, topica starch, cellulose powder*, ***apple juice concentrate, carrot juice concentrate***, *natural colorants*	Smoofl (BE)
Maikai watermelon and berries ice cream for dogs	For dogs and cats can be used as a hydrating snack due to their refreshing function in summer. Lactose free, sugar free. contain prebiotics	**Lactose-free milk, cream, *chicory inulin, watermelon, raspberries, and blackberries***	Maikai (ESP)
Joy for tails Ice cream for dogs	The new ice cream is dog-friendly, made from high-quality, specially selected ingredients that have been tested for safety. It contains no added sugar or lactose, and includes inulin, which supports a healthy digestive system in dogs	**Water, lactose-free milk powder, pumpkin puree (12%) (100% pumpkin), refined coconut oil, *date powder, chicory root powder (inulin) (1.2%), linseed powder, vegetable fibers (peas, psyllium)***	Tervete food (LV)

The information given in the tables is taken from the sources, without modifying or correcting the text.
Data in the table were selected in the period from 10.09.2024. to 10.01.2025.
Raw materials description: bold - main ingredients, *italic* – additional raw materials, *italic bold* – functional additives.

methane, and carbon dioxide. SCAFAs are partially absorbed, while the remainder contribute to acidic stools. Fermentation by-products may cause abdominal discomfort, distention, nausea, flatulence, and diarrhea. Clinical response varies among lactase nonpersistent individuals. This is partly influenced by the colonic microbial load capable of fermenting lactose. (Miller et al., 2007). In study by Grandi et al. (2018) 57% of participant dogs exhibited a good tolerance up to a relatively high dietary dose of lactose (2g/kg $BW^{0,75}$/d).

In the process of ice cream making, whey proteins emulsify fat and air bubbles increase the ice-cream mix viscosity and raise the mixture's overrun, providing a desired interfacial behavior, and enhancing the functional properties of the finished product (Silantjeva et al., 2022). Yogurt is highly recommended for its nutritional value and positive health effects, mainly related to bioactive peptides, easily digested proteins and probiotics (Abdi-Moghadam et al., 2023).

Fruits, berries, vegetables. Although pumpkin is a desirable ingredient for many food products, it is not typically used in frozen desserts like ice cream, despite this fact, it was a fairly popular ingredient in the ice cream examples given in Table 3. Due to its high fiber especially pectin content, pumpkin puree may enhance ice cream's ability to increase water holding capacity, emulsify, and/or create gels, all of which may improve the texture of the product (Akbari et al., 2019). Additionally, pumpkin is a berry that is rich in violaxanthin, lutein, carotenoids, and phenols (Kampuse et al., 2019). Taking into account chemical composition and functional properties of pumpkin, the use of this berry in canine snack production is considered positive. Bananas are nutrient-dense fruits that serve as a primary source of numerous macronutrients, micronutrients, and

phytonutrients. Fruits are rich in vitamins and phenolic compounds and provide essential minerals such as sodium, potassium, iron, copper, phosphorus, manganese, and zinc. Afzal and co-authors have indicated that bananas contain varied levels of nutrients, including vitamin C (12.7 mg 100 g^{-1}), vitamin A (12.4 mg 100 g^{-1}), and total soluble solids (17.9 mg 100 g^{-1}). A medium-sized banana typically has about 6 grams of fiber and provides 450–467 mg of potassium (Afzal et al., 2022). Equally successful, but less common, ice cream for dogs can include pear, apple, and carrot purees.

Fats and oils are crucial in pet ice cream for texture (the size of the ice crystals and their growth), flavor, and energy density (Arbuckle and Marshall, 2000). Traditionally in ice cream production dairy fats are used, but vegetable oils and fats are more acceptable in dog ice-creams. Sunflower, peanut and coconut butter were commonly used in analyzed ice cream examples. Oils like coconut or sunflower are often used in pet ice creams for their mild flavor and smooth texture, they are also selected for their health benefits, including improved digestion and skin health (Moriano and Alamprese, 2017; Liu et al., 2018). One of the most often-used fat ingredients for dog's ice cream is peanut butter. Fiber, lipids, and protein are the main ingredients of peanut butter. Animal fats (e.g., chicken fat or fish oil) can be included to enhance flavor and provide essential fatty acids in a snack formulation (Ettinger et al., 2024).

Proteins in pet ice cream contribute to the nutritional value and help in creating a satisfying texture, stability and overrun. Ingredients like whey protein or casein hydrolysates are used in pet ice creams to increase the protein content and mimic the texture of traditional ice cream (Hossain et al., 2021). For pets with specific dietary restrictions or allergies, plant-based proteins such as pea or soy protein can be used. These proteins are hypoallergenic and provide a suitable texture while being easy to digest (Ettinger et al., 2024). Soy, rice and wheat flour were found in some ice cream examples (see Table 3).

Sugars and sweeteners might be used to enhance sweetness of ice-cream (Craig, 2021). Date is a rich and affordable source of several macro- and micronutrients as well as secondary metabolites, date fruits and products are gaining popularity. While carbohydrates (70%) make up the majority of the fruit's chemical composition (primarily glucose 35%, fructose 26%, and sucrose 0.5%), dates do not provide a substantial source of proteins or fats (Almuziree and Alhomaid, 2023). Additionally, dates provide a high amount of dietary fiber (6.5–11.0 g 100 g^{-1}) (Fernández-López et al., 2022). The polyphenols found in dates have potential antioxidant properties. The glycemic index (GI) of dates is low to moderate (from 43 to 75), despite their high sugar content. Honey can serve as a sweet compound in place of sugar to create low-sucrose frozen desserts. Since it is mainly composed of glucose and fructose, honey is an effective alternative to sucrose. Additionally, it has a moderate GI (Putradamni and Pramitasari, 2024). For low-calorie options sweeteners like steviol glycosides may be used. These do not contribute to obesity or dental issues and are safe for pets when used appropriately (Genovese et al., 2022).

Stabilizers and emulsifiers are used in ice cream production to maintain the texture of ice cream (Goff, 2002). Guar and xanthan gums are used as stabilizers to prevent ice crystallization and maintain a creamy texture in the ice cream. They are safe for pets and help to keep the ingredients evenly distributed (Genovese et al., 2022; Bahramparvar and Tehrani, 2011). Lecithin, a natural emulsifier, helps to mix fats and water uniformly, ensuring a smooth texture without separation of phases (Goff, 2002).

Functional ingredients are added to ice cream for dogs to enhance its health benefits. Food components have been identified as "functional" if they provide health benefits beyond the provision of essential nutrients, such as vitamins, minerals, proteins, carbohydrates and fats (Di Cerbo et al., 2017). The functional ingredients are included in dog snacks for their health benefits beyond basic nutrition.

Prebiotics are a group of nutrients that can enhance probiotic growth and maintenance, and be able to degrade by gut microbiota (Davani-Davari et al., 2019). Substances that may have a prebiotic effect are mainly oligosaccharides (Thatcher et al., 2010). Inulin characterizes with several beneficial attributes. It is a natural component of several fruits and vegetables, whose ability is to stabilize the host's microbiome so that the organism benefits from it (Di Criscio et al., 2010; Gibson et al., 2017). As a supplement, inulin changes the intestinal microflora by increasing the desirable flora including bifidobacteria (Grieshop et al., 2004).

Although fiber is not considered an essential component of a dog's diet, it is often included in commercially produced foods. Dogs do not get energy by absorbing the end products of fiber bacterial fermentation; however, short-chain fatty acids are important for maintaining colon health. Therefore, it is recommended to add a small amount of fiber (<5%) to the feed, which contains both fast and slow fermentable fibers, to ensure the health of pets. Fiber also helps treat conditions such as obesity, diabetes, diarrhea, colitis, and constipation (Thatcher et al., 2010). In the digestive tract of dogs, millions of bacteria play a vital role in maintaining the health of the host. Bacteria stimulate the development of the immune system and intestinal structure, helping to defend against pathogenic invasions and providing the body with nutrients (i.e. producing short-chain fatty acids and vitamin B_{12}). In the gastrointestinal tract of healthy dogs and cats, not only bacteria are found, but also archaea, fungi, protozoa and viruses (Suchodolski, 2011; Montalban-Arques et al., 2015; Wernimont et al., 2020). Everyday diet leaves an impact on the canine bacterial population in the colon. The gut microbiome is a functional organ and is responsive to the nutrient composition of feed.

To ensure the ice cream that provides valuable nutrients, vitamins and minerals like E, D vitamins, calcium, and phosphorus may be added. These nutrients support overall health, including bone strength and immune function (Di Cerbo et al., 2017; Calancea et al., 2024; Kępińska-Pacelik et al., 2023). Vitamins A and D, and calcium were found in some ice cream examples (see Table 3).

Probiotics, such as *Lactobacillus acidophilus*, have modulated intestinal microbiota in dogs (Yang and Wu, 2023). Probiotics are still stable after freezing, but their bioavailability are different and depends on the bacteria strain *(Lactobacillus acidophilus* 40-72%, *Lactobacillus bulgaricus* 45%, *Bifidobacterium lactis* 66-89%) and storage conditions (temperature and period) (Tyutkov et al., 2022).

These are particularly beneficial for pets with sensitive digestive issues (Di Cerbo et al., 2017). The administration of probiotics can improve the intestinal microbiota, suppress inflammation, enhance immune functions, and alleviate intestinal disorders in dogs and cats (Yang and Wu, 2023; Molina et al., 2023; Xia et al., 2024). Combinations of probiotics (e.g., *Lactobacillus johnsonii* CRL1693, *Ligilactobacillus murinus* CRL1695, *Limosilactobacillus mucosae* CRL1696, and *Ligilactobacillus mucosae* CRL1696) accelerate the reduction of gastroenteritis symptoms, indicating a beneficial effect on the microbiota and gut functionality (Molina et al., 2023). Although the search for new, effective probiotic strains resilient to digestive tract conditions continues, the authors acknowledge the lack of a standardized probiotic evaluation system significantly hinders the assessment and use of new probiotics (Molina et al., 2023; Xia et al., 2024).

Glucosamine and chondroitin are commonly added to support health, particularly in older dogs or breeds prone to joint issues (Di Cerbo et al., 2017).

Herbs and botanicals (mint, turmeric, ginger) are included for their anti-inflammatory and antioxidant properties. They also contribute to the palatability and appeal of the snacks (Craig, 2021).

The anthropomorphization of pets goes beyond consumer behavior and impacts the emotional well-being of pet owners as well. Studies indicate that perceiving pets as family members can enhance owners' mental and physical health by providing companionship and emotional support, akin to human social connections (Astuti et al., 2024). This shift has led to an increase in pet services and products, as pet owners invest in high-quality food, healthcare, and even luxury items to reflect their pets' family status. For the pet care industry, this trend presents opportunities to cater to a customer base that values products fostering pet-human bonding and well-being.

Conclusions

Ice cream for dogs has been studied from a nutritional and functional perspective, indicating a growing trend toward pet wellness, reflecting owners' increasing interest in snacks that are not only enjoyable but also contribute to overall pet health.

The careful selection of ingredients ensures that these products meet the nutrition requirements for dogs. Ongoing research into new ingredients and formulations will likely continue to refine these products, making them even more appealing and beneficial for pets.

The study underscores the importance of further research to meet pet owners' demands for safe, innovative, and functional dog snacks, particularly with a focus on cooling treats and specialized dietary formulations.

Author contributions

AF: Writing – original draft, Writing – review & editing. AI: Writing – review & editing. ES: Funding acquisition, Project administration, Writing – review & editing. IC: Writing – review & editing. JZ: Project administration, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article.

Conflict of interest

This study received funding contract No. 5.1.1.2.i.0/1/22/A/CFLA/003 between Latvian Food Sector Competence Centre Ltd. and the Central Finance and Contracting Agency; the study was conducted by Tervete Food Ltd. (Research No. 8) with support from the European Regional Development Fund (ERDF) within the framework of the project Latvian Food Sector Competence Centre. The funder had the following involvement in the study: recipe development; idea generation; testing and supply of raw materials; and preparation and review of the final article.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Abdi-Moghadam, Z., Darroudi, M., Mahmoudzadeh, M., Mohtashami, M., Jamal, A. M., Shamloo, E., et al. (2023). Functional yogurt, enriched and probiotic: A focus on human health. *Clin. Nutr. ESPEN* 57, 575–586. doi: 10.1016/j.clnesp.2023.08.005

Afzal, M. F., Khalid, W., Akram, S., Khalid, M. A., Zubair, M., Kauser, S., et al. (2022). Bioactive profile and functional food applications of banana in food sectors and health: a review. *Int. J. Food Properties* 25, 2286–2300. doi: 10.1080/10942912.2022.2130940

Akbari, M., Eskandari, M. H., and Davoudi, Z. (2019). Application and functions of fat replacers in low-fat ice cream: A review. *Trends Food Sci. Technol.* 86, 34–40. doi: 10.1016/j.tifs.2019.02.036

Almuziree, R. S. A., and Alhomaid, R. M. (2023). The effect of sugar replacement with different proportions of Khalas date powder and molasses on the nutritional and sensory properties of Kleicha. *Processes* 11, 1–16. doi: 10.3390/pr11113077

Arbuckle, W. S., and Marshall, R. T. (2000). *Ice cream* (New York: Springer US).

Astuti, Y., Orhan, B., Setyawan, H., Karacam, A., and Susanto, N. (2024). Explorando la Conexión entre la Salud Física y Mental en Mujeres y la Tenencia de un Perro. *Retos* 58, 190–204. Available at: https://recyt.fecyt.es/index.php/retos/index. (Accessed March 21, 2025)

Bahramparvar, M., and Tehrani, M. M. (2011). Application and functions of stabilizers in ice cream. *Food Rev. Int.* 27, 389–407. doi: 10.1080/87559129.2011.563399

Baritugo, K. A., Bakhsh, A., Kim, B., and Park, S. (2023). Perspectives on functional foods for improvement of canine health and treatment of diseases. *J. Funct. Foods* 109 (1-22). doi: 10.1016/j.jff.2023.105744

Beynen, A. (2018) 2015, 40–41. doi: 10.13140/RG.2.2.17708.05765. Anton C. Beynen.

Calancea, B.-A., Daina, S., and Macri, A. (2024). The science of snacks: a review of dog treats. *Front. Anim. Sci.* 5. doi: 10.3389/fanim.2024.1440644

Carroll, M. Q., Oba, P. M., Sieja, K. M., Alexander, C., Lye, L., De Godoy, M. R. C., et al. (2020). Effects of novel dental chews on oral health outcomes and halitosis in adult dogs. *J. Anim. Sci.* 98, 1–7. doi: 10.1093/JAS/SKAA274

Carter, A. J., and Hall, E. J. (2018). Investigating factors affecting the body temperature of dogs competing in cross country (canicross) races in the UK. *J. Therm. Biol.* 72, 33–38. doi: 10.1016/j.jtherbio.2017.12.006

Clapper, G. M., Grieshop, C. M., Merchen, N. R., Russet, J. C., Brent, J. L. Jr., and Fahey, G. C. Jr. (2001). Ileal and total tract nutrient digestibilities and fecal characteristics of dogs as affected by soybean protein inclusion in dry, extruded diets. *J. Anim. Sci.* 79, 1523–1532. doi: 10.2527/2001.7961523x

Clarke, C. (2012). *The Science of Ice Creame (second)* (Croydon, UK: CPJ Group).

Cline, M. G., Burns, K. M., Coe, J. B., Downing, R., Durzi, T., Murphy, M., et al. (2021). 2021 AAHA nutrition and weight management guidelines for dogs and cats. *J. Am. Anim. Hosp. Assoc.* 57, 157–178. doi: 10.5326/JAAHA-MS-7232

Craig, J. M. (2021). Additives in pet food: are they safe? *J. Small Anim. Pract.* 62, 624–635. doi: 10.1111/jsap.13375

da Silva, J. M., Klososki, S. J., Silva, R., Raices, R. S. L., Silva, M. C., Freitas, M. Q., et al. (2020). Passion fruit-flavored ice cream processed with water-soluble extract of rice by-product: What is the impact of the addition of different prebiotic components? *LWT* 128, 109472. doi: 10.1016/j.lwt.2020.109472

Davani-Davari, D., Negahdaripour, M., Karimzadeh, I., Seifan, M., Mohkam, M., Masoumi, S. J., et al. (2019). Prebiotics: Definition, types, sources, mechanisms, and clinical applications. *Foods* 8, 1–27. doi: 10.3390/foods8030092

de Castro, A. C. V., Araújo, Â., Fonseca, A., and Olsson, I. A. (2021). Improving dog training methods: Efficacy and efficiency of reward and mixed training methods. *PloS One* 16, 1–9. doi: 10.1371/journal.pone.0247321

Di Cerbo, A., Morales-Medina, J. C., Palmieri, B., Pezzuto, F., Cocco, R., Flores, G., et al. (2017). Functional foods in pet nutrition: Focus on dogs and cats. *Res. Veterinary Sci.* 112, 161–166. doi: 10.1016/j.rvsc.2017.03.020

Di Criscio, T., Fratianni, A., Mignogna, R., Cinquanta, L., Coppola, R., Sorrentino, E., et al. (2010). Production of functional probiotic, prebiotic, and synbiotic ice creams. *J. Dairy Sci.* 93, 4555–4564. doi: 10.3168/jds.2010-3355

Ettinger, L., Stright, A., Frampton, K., Baxter, L., Dabas, T., Gorman, M., et al. (2024). Sensory properties of thickened and protein-enriched plant-based frozen desserts. *J. Texture Stud.* 55, 1–9. doi: 10.1111/jtxs.12825

Fernández-López, J., Viuda-Martos, M., Sayas-Barberá, E., Navarro-Rodríguez de Vera, C., and Pérez-álvarez, J.Á. (2022). Biological, nutritive, functional and healthy potential of date palm fruit (Phoenix dactylifera L.): current research and future prospects. *Agronomy* 12, 1–30. doi: 10.3390/agronomy12040876

Fiol, C., Prado, D., Romero, C., Laburu, N., Mora, M., and Iñaki Alava, J. (2017). Introduction of a new family of ice creams. *Int. J. Gastronomy Food Sci.* 7, 5–10. doi: 10.1016/J.IJGFS.2016.12.001

Flint, H. E., Atkinson, M., Lush, J., Hunt, A. B. G., and King, T. (2023). Long-lasting chews elicit positive emotional states in dogs during short periods of social isolation. *Animals* 13, 1–21. doi: 10.3390/ani13040552

Genovese, A., Balivo, A., Salvati, A., and Sacchi, R. (2022). Functional ice cream health benefits and sensory implications. *Food Res. Int.* 161, 111858. doi: 10.1016/j.foodres.2022.111858

German, A. J. (2006). The growing problem of obesity in dogs and cats. *J. Nutr.* 136, 1940–1946. doi: 10.1093/jn/136.7.1940s

Gibson, G. R., Hutkins, R., Sanders, M. E., Prescott, S. L., Reimer, R. A., Salminen, S. J., et al. (2017). Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nat. Rev. Gastroenterol. Hepatol.* 14, 491–502. doi: 10.1038/nrgastro.2017.75

Goff, H. D. (2002). Formation and stabilisation of structure in ice-cream and related products. *Curr. Opin. Colloid Interface Sci.* 7, 432–437. doi: 10.1016/S1359-0294(02)00076-6

Grandi, M., Pinna, C., Bonaldo, A., Stefanelli, C., Vecchiato, C. G., Zaghini, G., et al. (2018). Effects of dietary supplementation with increasing doses of lactose on faecal bacterial populations and metabolites and apparent total tract digestibility in adult dogs. *Ital. J. Anim. Sci.* 17, 1021–1029. doi: 10.1080/1828051X.2018.1459210

Grieshop, C. M., Flickinger, E. A., Bruce, K. J., Patil, A. R., Czarnecki-Maulden, G. L., and Fahey, G. C. Jr. (2004). Gastrointestinal and immunological responses of senior dogs to chicory and mannan-oligosaccharides. *Arch. Anim. Nutr.* 58, 483–494. doi: 10.1080/00039420400019977

Hossain, M. K., Petrov, M., Hensel, O., and Diakité, M. (2021). Microstructure and physicochemical properties of light ice cream: Effects of extruded microparticulated whey proteins and process design. *Foods* 10, 1–14. doi: 10.3390/foods10061433

Jardines, A. P., Arjona-Román, J. L., Severiano-Pérez, P., Totosaus-Sánchez, A., Fiszman, S., and Escalona-Buendía, H. B. (2020). Agave fructans as fat and sugar replacers in ice cream: Sensory, thermal and texture properties. *Food Hydrocolloids* 108, 1–9. doi: 10.1016/j.foodhyd.2020.106032

Johnson, S. I., McMichael, M., and White, G. (2006). Heatstroke in small animal medicine: A clinical practice review. *J. Veterinary Emergency Crit. Care* 112–119. doi: 10.1111/j.1476-4431.2006.00191.x

Kępińska-Pacelik, J., Biel, W., Mizielińska, M., and Iwański, R. (2023). Chemical composition and palatability of nutraceutical dog snacks. *Appl. Sci. (Switzerland)* 13, 1–20. doi: 10.3390/app13052806

Kampuse, S., Tomsone, L., Klava, D., Ozola, L., and Galoburda, R. (2019). The influence of processing and storage conditions on quality parameters of pumpkin puree. *Food Balt* 2, 137–142. doi: 10.22616/foodbalt.2019.013

Khoo, C., Cunnick, J., Friesen, K., Gross, K. L., Wedekind, K., and Jewell, D. E. (2005). The role of supplementary dietary antioxidants on immune response in puppies. *Veterinary Ther.* 6, 43–56.

Larsen, J. A., and Farcas, A. (2014). Nutrition of aging dogs. *Veterinary Clinics North America: Small Anim. Pract.* 44, 741–759. doi: 10.1016/J.CVSM.2014.03.003

Lee, A. H. (2017). 229 Bioprocessed soy protein influences the fecal microbiota of healthy adult dogs. *J. Anim. Sci.* 95, 113. doi: 10.2527/asasann.2017.229

Lema Almeida, K. A., Koppel, K., and Aldrich, C. G. (2022). Sensory attributes, dog preference ranking, and oxidation rate evaluation of sorghum-based baked treats supplemented with soluble animal proteins. *J. Anim. Sci.* 100, 1–12. doi: 10.1093/jas/skac191

Lilja-Maula, L., Lappalainen, A. K., Hyytiäinen, H. K., Kuusela, E., Kaimio, M., Schildt, K., et al. (2017). Comparison of submaximal exercise test results and severity of brachycephalic obstructive airway syndrome in English bulldogs. *Veterinary J.* 219, 22–26. doi: 10.1016/j.tvjl.2016.11.019

Liu, R., Wang, L., Liu, Y., Wu, T., and Zhang, M. (2018). Fabricating soy protein hydrolysate/xanthan gum as fat replacer in ice cream by combined enzymatic and heat-shearing treatment. *Food Hydrocolloids* 81, 39–47. doi: 10.1016/j.foodhyd.2018.01.031

Miller, G. D., Jarvis, J. K., and McBean, L. D. (2007). *Handbook of dairy foods and nutrition. 3rd edition* (Boca Raton: CRC Press), 299–331. Taylor and Francis.

Molina, R. A., Villar, M. D. U., Miranda, M. H., Maldonado, N. C., Vignolo, G. M., and Nader-Macias, M. E. F. (2023). A multi-strain probiotic promoted recovery of puppies from gastroenteritis in a randomized, double-blind, placebo-controlled study. *Can. Veterinary J.* 64, 666–673.

Montalban-Arques, A., De Schryver, P., Bossier, P., Gorkiewicz, G., Mulero, V., Gatlin, D. M., et al. (2015). Selective manipulation of the gut microbiota improves immune status in vertebrates. *Front. Immunol.* 6. doi: 10.3389/fimmu.2015.00512

Morelli, G., Fusi, E., Tenti, S., Serva, L., Marchesini, G., Diez, M., et al. (2018). Study of ingredients and nutrient composition of commercially available treats for dogs. *Veterinary Rec.* 182, 1–7. doi: 10.1136/vr.104489

Moriano, M. E., and Alamprese, C. (2017). Organogels as novel ingredients for low saturated fat ice creams. *LWT* 86, 371–376. doi: 10.1016/J.LWT.2017.07.034

MSD Manual (2024). Veterinary manual. Available online at: https://www.msdvetmanual.com/management-and-nutrition/nutrition-small-animals/nutritional-requirements-of-small-animalsFats_v3328622. (Accessed March 21, 2025)

National Research Council (2006). *Nutrient Requirements of Dogs and Cats. Animal nutrition series* (Washington, DC: National Academies Press).

Nielson, S. A., Khosa, D. K., Clow, K. M., and Verbrugghe, A. (2023). Dog caregivers' perceptions, motivations, and behaviours for feeding treats: A cross sectional study. *Prev. Veterinary Med.* 217, 105971. doi: 10.1016/J.PREVETMED.2023.105971

Putradamni, A. M., and Pramitasari, R. (2024). Formula optimization, physicochemical characterization, and sensory evaluation of beetroot-based blended frozen dessert. *Food Chem. Adv.* 4, 100672. doi: 10.1016/j.focha.2024.100672

Rankovic, A., Adolphe, J. L., and Verbrugghe, A. (2019). Role of carbohydrates in the health of dogs. *J. Am. Veterinary Med. Assoc.* 255, 546–554. doi: 10.2460/javma.255.5.546

Robbins, P. J., Ramos, M. T., Zanghi, B. M., and Otto, C. M. (2017). Environmental and physiological factors associated with stamina in dogs exercising in high ambient temperatures. *Front. Veterinary Sci.* 4. doi: 10.3389/fvets.2017.00144

Rutherfurd-Markwick, K. J., and Thomas, D. (2016). Effects of nutrient supplementation on immune function in cats and dogs: from the Purina Companion Animal Nutrition Summit-Beyond Essential. Available online at: https://www.vetcenter.purina.es/sites/default/files/article-pdf/Article562_EffectsofNutrientSupplementationonImmuneFunctioninCatsandDogs.pdf. (Accessed March 21, 2025)

Shahbandeh, M. (2024). Annual sales volume of pet food products in Europe from 2010 to 2023. Available online at: https://www.statista.com/statistics/515329/pet-food-sales-volume-europe/

Silantjeva, K., Zagorska, J., and Galoburda, R. (2022). Physicochemical and rheological properties of non-fat ice cream. *Proc. Latvian Acad. Sciences Section B: Natural Exact Appl. Sci.* 76, 138–144. doi: 10.2478/prolas-2022-0021

Stookey, G. K. (2009). Soft rawhide reduces calculus formation in dogs. *J. Veterinary Dentistry* 26, 82–85. doi: 10.1177/089875640902600202

Suchodolski, J. S. (2011). Intestinal microbiota of dogs and cats: A bigger world than we thought. *Veterinary Clinics North America - Small Anim. Pract.* 41, 261–272. doi: 10.1016/j.cvsm.2010.12.006

Thatcher, C., Hand, M., and Remillard, R. (2010). Small animal clinical nutrition: An iterative process. *Small Anim. Clin. Nutrition (January* 2010), 3–21.

Tyutkov, N., Zhernyakova, A., Birchenko, A., Eminova, E., Nadtochii, L., and Baranenko, D. (2022). Probiotics viability in frozen food products. *Food Bioscience* 50, 101996. doi: 10.1016/j.fbio.2022.101996

Wehrmaker, A. M., Draijer, N., Bosch, G., and van der Goot, A. J. (2022). Evaluation of plant-based recipes meeting nutritional requirements for dog food: The effect of fractionation and ingredient constraints. *Anim. Feed Sci. Technol.* 290, 115345. doi: 10.1016/j.anifeedsci.2022.115345

Wernimont, S. M., Radosevich, J., Jackson, M. I., Ephraim, E., Badri, D. V., MacLeay, J. M., et al. (2020). The effects of nutrition on the gastrointestinal microbiome of cats and dogs: impact on health and disease. *Front. Microbiol.* 11. doi: 10.3389/fmicb.2020.01266

White, G. A., Ward, L., Pink, C., Craigon, J., and Millar, K. M. (2016). Who's been a good dog?" – Owner perceptions and motivations for treat giving. *Prev. Veterinary Med.* 132, 14–19. doi: 10.1016/J.PREVETMED.2016.08.002

Xia, J., Cui, Y., Guo, Y., Liu, Y., Deng, B., and Han, S. (2024). The function of probiotics and prebiotics on canine intestinal health and their evaluation criteria. *Microorganisms* 12, 1–17. doi: 10.3390/microorganisms12061248

Yang, Q., and Wu, Z. (2023). Gut probiotics and health of dogs and cats: benefits, applications, and underlying mechanisms. *Microorganisms* 11, 1–14. doi: 10.3390/microorganisms11102452

Zanghi, B. M., Robbins, P. J., Ramos, M. T., and Otto, C. M. (2018). Working dogs drinking a nutrient-enriched water maintain cooler body temperature and improved pulse rate recovery after exercise. *Front. Veterinary Sci.* 5. doi: 10.3389/fvets.2018.00202

Zhang, M., Sun, X., Cheng, J., and Guo, M. (2022). Analysis and comparison of nutrition profiles of canine milk with bovine and caprine milk. *Foods* 11, 1–11. doi: 10.3390/foods11030472