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The science of snacks: a review of dog treats

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The global growth in canine population has led to a thriving market for pet food, especially treats sector. This review explores the growing market for canine treats, revealing a deep emotional connection between pet owners and their pets, evident in feeding practices. With six distinct categories of treats, meat-based treats dominate due to perceptions of naturalness and health, highlighting an increased focus on dog nutrition and a preference for raw, locally sourced alternatives. However, labeling discrepancies and a lack of clear nutritional information present a challenge for owners looking for quality treats. Variations in nutritional values and sensory qualities of treats require informed choices to prevent excessive calorie consumption and potential health implications. Effective communication between the veterinarian and pet owners is crucial to adapting treats recommendations based on the individual needs of dogs, taking into account potential health risks and obesity. In conclusion, the use of treats provides several benefits such as positive reinforcement, promoting dental health and providing nutritional support for senior dogs. However, certain aspects that may limit their use should be considered, such as the risk of microbiological contamination, accidents related to incorrect administration, obesity and environmental impacts associated with treat production.

KEYWORDS

pet owners, feeding, nutrition, rewards, canine snacks, owners' behaviour

1 Introduction

The population of companion animals is increasing globally. According to information provided by the International Canine Federation (FCI) in 2021 there were around 147 million dogs worldwide, whether they are purebred or not (Kępińska-Pacelik and Biel, 2021). Another recent study published in 2023 shows that household animals amount to 703.3 million globally (Kępińska-Pacelik et al., 2023). About half of the population worldwide keeps companion animals, according to a recent study. There are more than 94 million cats and 89 million dogs in the United States of America (USA) only, where 47 million households have at least one cat and 60 million households have at least one dog (Dodd et al., 2020). The number of pets in Europe is gradually rising too, according to European Pet Food Industry Federation (FEDIAF), in 2020, at least 80 million European

families include at least one pet animal (Kazimierska et al., 2021). The same upward trend is also observed in New Zealand where, following a study, it was observed that the population of dog owners increased from 27% in 2015 to 37% in 2020 (Forrest et al., 2022).

Even if the world economy was severely damaged by the Covid-19 epidemic in the past years, the pet food industry's market sales exceeded \$100 billion dollars. The pet industry's market is progressively growing, according to the data presented in this article (Zhang et al., 2022). As technology advances continuously, the varieties of products accessible on the pet market will diversify even more in the future (Zhang et al., 2022). Dried dog and cat food constitutes 70% of the total US pet industry with extruded food being predominant (Stercova et al., 2022). Treats play a significant role in the economics of the pet products sector representing a significant share of about 15% of the pet food market (De Godoy et al., 2014). Almost any pet food company makes a variety of dog treats that vary in size, content, flavor and purpose because treats are a prominent component of the pet's diet (He et al., 2020; Morelli et al., 2020). There has been a noticeable shift in pet owners' nutritional preferences, which is reflected in the demand for dry dog food among dogs (White et al., 2016). The pet food market has continued to grow, with an impressive average annual expansion rate of 2.6% during the previous three years (Kepińska-Pacelik and Biel, 2021). Snacks and treats, in particular such as functional meals, those that promote dental hygiene or gourmet treats, typically provided as rewards, continue to register double-digit growth, +10.3% in value, the market's greatest growth rate (Assalco-Zoomark, 2017; Morelli et al., 2020; Stercova et al., 2022).

This growing trend of canine treats market over the past few years is partly a result of deep relationships that exist between people and their animals, notably around feeding behavior, where an owner's love or devotion for their dog is most obvious through the giving of food (White et al., 2016; Johnson et al., 2023). In another recent survey, 60% of participants think that their dogs are now more significant in their lives as compared to when they were children (Boya et al., 2015). Also, two out of three believe they are more compassionate and treat their animals better than their parents did and that's why dog owners in the US are often more likely to purchase proper diet for their pets than for themselves (Boya et al., 2015). Even more, owners believed that not feeding their dog treats was similar to not giving their children toys, regarded treat feeding to be necessary, and believed that feeding treats in such manner makes the dog happy. These remarks seem to support the idea that pet owners' care for their animals may be similar to parents' caring for their kids (White et al., 2016).

2 Types of treats

According to the most recent European Union (EU) Reg. 767/2009 rule, dog treats should be labeled as "complementary feed", which is legally defined as "compound feed with a high content of specific components but which, due to its composition, is sufficient for a daily ration only if used in combination with other feed" (Morelli et al., 2018). Pet treats are a small meal for domestic pets, dog owners around the world are rewarding their animals with

treats as a global trend while 92% of them buy treats regularly (Almeida, 2021). In a different study (Stercova et al., 2022), there were classified into six categories due to variations in the composition and size of the treats: biscuit, bone, chew, dental, meat product and rawhide (Stercova et al., 2022). Recent scientific research (He et al., 2020), shows that meat snacks continue to be the most popular treat type among pet owners, with natural-flavored twisted rawhide being the most popular chew product (He et al., 2020). In a previous study (Morgan et al., 2023), it was observed that pet owners who choose to feed their dogs with non-processed treats do so as they believe it to be a healthier and a more natural option for their dogs (Morgan et al., 2023).

2.1 Crunchy treats – biscuits

Biscuits are a type of dog treats that are typically produced from wheat flour and baked and slowly dried in an oven (Davidson, 2019). These treats are found in the United States under various names such as cookies or crackers, and they come in a variety of forms, sizes, and flavors (Almeida, 2021). According to a study on pet food and treats conducted by the American Pet Products Association (APPA), dog biscuits are the most popular treats given to dogs, accounting for 77% of all treats (White et al., 2016). The study surveyed dog owners across the USA and aimed to understand their preferences for pet food and treats (White et al., 2016). It is evident from the packaging of dog biscuits that cereals are the primary ingredient, with flour being the dominant component because its gluten contributes to the overall flavor and texture of the treat (Case et al., 2011). It is extremely important to consider the shelf life and quality maintenance of pet treats along with the structural and textural features of these treats as well as their shelf life and quality maintenance (Yarmolinsky et al., 2009). Low-moisture treats, characterized by their lower water activity, typically have an extended shelf life than their counterparts with greater moisture levels. Because of the low water activity, the treats stay fresh for a long time by preventing the formation of dangerous bacteria. However, despite the benefits of low-moisture treats, long-term storage might present some difficulties. Problems including lipid oxidation and loss of crispness may develop, which could compromise the product's sensory qualities and overall value (Almeida et al., 2022; Oba et al., 2022).

Research has shown that dogs are naturally drawn to sweet and umami flavors, making them highly desirable in dog food and treats (Yarmolinsky et al., 2009). As a result, many manufacturers of dog biscuits incorporate sucrose into their formulas to enhance the palatability and appeal of their products to dogs (Oba et al., 2022). However, it is important to note that the sugar content of these treats can be significant, with one item containing up to 51.7 g per 1000 kcal, which equals to more than 5% of the dry matter in the dog treat. That's why in the context of canine health, it is recommended that biscuits containing high levels of sucrose should be avoided for dogs with diabetes (Morelli et al., 2018).

Another study, investigated the potential benefits of baked biscuits containing propolis and pomegranates as natural ingredients for oral health. *In vitro* tests showed that these biscuits

had significant antimicrobial and antioxidant effects, suggesting their potential benefits for oral health in dogs (Santos et al., 2021).

A study conducted by Morelli G. et al. (2018) indicates that biscuits had a caloric density of approximately 329.2 ± 13.0 kcal ME/100g according to the label. Additionally, the weight of biscuits per treat ranged from 6.5 ± 3.5 grams to 11.8 grams, with an average of 21.7 ± 11.6 kcal per treat. This means that on average, per 100 grams, biscuits provided around 329.2 calories. The weight of each biscuit varied, contributing to a range of caloric content per individual biscuit.

2.2 Soft treats

From the variety of treats incorporated into the daily or occasional feeding routine, the preferred choices inclined heavily to soft treats (Nielson et al., 2023). These findings are reflected in the survey of Nielson et al. (2023), where 398 owners out of a total of 716, representing approximately 56%, show substantial preference for these specific type of treats. This preference suggests a strong inclination towards treats with a softer texture, likely attributed to ease of consumption and increased palatability potential, making them a preferred choice for pet training or occasional indulgence (Nielson et al., 2023).

Soft treats for dogs are also used as a therapy by introducing a compound that the dog needs at the particular time (Morris et al., 2022). For example, one recently released study (Greb and Puschner, 2018), described the administration of dog treats containing cannabidiol (CBD) as a alleviation for dogs with nausea, epilepsy, inflammation or arthritis pain (Cindy and Rupasinghe, 2021). Despite the fact that CBD treats have been surrounded by significant controversy, their popularity among pet owners continues to grow. A recent study conducted in Colorado (Greb and Puschner, 2018), investigated the public perception of the administration of CBD treats to pets, how it affects their health, and how it affects their pet's behavior. One particular study (Greb and Puschner, 2018) provided data regarding many aspects of the perception of CBD pet product perceptions, such as perceived efficacy and product safety. Out of the 632 dog owners who used CBD-based treats for their dogs, only 7% of the consumers sampled reported that the products were not effective as well as other standard care medications or therapies (Greb and Puschner, 2018). This research provided data regarding many aspects of the perception of CBD pet product perceptions, such as perceived efficacy and product safety (Greb and Puschner, 2018).

For soft treats, data collected from (Morelli et al., 2018) indicates a caloric density of approximately 294.0 ± 25.9 kcal ME/100g. The weight of treat ranged quite a bit, from 33.3 ± 63.8 grams to 97.7 ± 191.3 grams. On average, each chewable stick provided about 97.7 ± 191.3 kcal per treat. This implies that in a 100-gram portion, chewable sticks contained around 294.0 calories (Morelli et al., 2018).

2.3 Dried and jerky treats

Jerky is a dog treat with an intermediate moisture level that contains significant protein and minimal fat. The distribution of jerky

without refrigeration is made possible by its low water activity, which effectively inhibits microbial growth. This attribute allows jerky to maintain its stability and safety during storage, as the water activity can be reduced to 0.75 or lower to enhance its overall shelf life (Kim et al., 2020). Whole muscle was largely used as raw material in traditional jerky production. However, the restructuring approach has significantly increased in popularity due to food processing improvements. This process permits the use of a variety of raw materials and the integration of beneficial substances and non-meat resources into the jerky production process (Song et al., 2014). Manufacturers may explore a larger variety of ingredients and enhance the jerky products' composition by using the restructuring direction. This allows them to satisfy particular objectives like improving nutritional profiles or adding distinct flavors and sensations. In order to meet changing customer preferences, this strategy has given the jerky sector new opportunities and increased the variety of products it delivers (Song et al., 2014). There are currently different types of jerky available to consumers: beef, pork, and chicken, and only a few studies have been published on duck jerky (Triyannanto and Lee, 2016).

Caloric density of jerky treats is approximately 284.4 ± 19.2 kcal ME/100g. The weight of meat strips per treat was more consistent, ranging from 10.0 ± 0.6 grams to 28.6 ± 1.5 grams. On average, each meat strip provided around 28.6 ± 1.5 kcal per treat. This suggests that in a 100-gram portion, meat strips contained approximately 284.4 calories (Morelli et al., 2018).

2.4 Dental chews

The pet food industry has been trying for a long time to find options for dogs oral health and longevity (Pinto et al., 2020). Recently they have started to pay special attention to periodontal disease (PD) which is on the rise in dogs. It has been observed that one of the causes leading to the high incidence of PD in dogs is related to the consumption of foods and treats that are not as hard as they should be and come into very limited contact with the tooth surface (Pinto et al., 2020). PD is characterized by bacterial plaque accumulation on the periodontium and changes in the oral microbiota, which play a crucial role in the illness's pathogenesis. Periodontitis is the most frequent oral disease in dogs, affecting 44% to 64% of the population (Oba et al., 2021). After feeding the dog, bacterial plaque will colonize the clean tooth surfaces within 24 hours of cleaning (Quiryne et al., 2006). A recent study has shown that without proper home care, bacterial counts return to pre-scaling levels in just one week (Watanabe et al., 2016). Daily teeth brushing is regarded as the gold standard for preventing the development and progression of PD (Enlund et al., 2020a). Daily brushing of the teeth will not only increase the dog's oral health but also lower the owners' veterinary costs on the long term. However, in veterinary patients, compliance with the recommendation of daily dental cleaning is minimal because canine owners find this a difficult task to do and prefer to administer treats that can spare them from daily brushing of teeth (Enlund et al., 2020a, 2020b).

One study (Carroll et al., 2020) concludes that the dental treats assessed demonstrated the ability to decrease several factors

associated with PD. Plaque scores, calculus scores, and halitosis measurements were notably reduced after 27 days of daily administration of dental dog treats. The study suggests that longer durations of treatment might offer deeper insights into the differences in calculus thickness and gingivitis development among the various treatments (Carroll et al., 2020). Overall, the daily use of dental treats may prove beneficial in preventing or slowing the progression of PD in dogs (Oba et al., 2021; Tochio et al., 2022). Johnson et al. (2023) suggest that the effectiveness of a dental chew in maintaining dog's dental health is dependent on whether the dog is motivated to chew on it. Even if a dental chew is designed to help clean a dog's teeth and gums, if the dog doesn't show interest or is not motivated to engage with the chew, its dental benefits might not be fully realized. Therefore, whether the dental treat will be effective in promoting dental health will largely depend on whether the dog is willing to chew on it (Johnson et al., 2023).

Giving pets chewing material, such as hard dental treats, can have negative consequences on their oral health. Many pet owners have experienced dental fractures and oral injuries resulting from giving their pets dental chewing treats and bones (Arhant et al., 2021). Pet owners should carefully consider the type and amount of dental treats they provide to their pets to avoid potential risks to their pets' oral health (Arhant et al., 2021).

Dental sticks have a caloric density of approximately 267.7 ± 17.6 kcal ME/100g based on label data. The weight of dental sticks per treat varies between 20.4 ± 9.7 g to 55.4 ± 27.1 g. On average, each dental stick provides around 55.4 ± 27.1 kcal per treat. This suggests that in a 100g portion, dental sticks contained approximately 267.7 calories (Morelli et al., 2018).

2.5 Animal parts

According to UE Reg. 1069/2009, Category 3 animal by-products include a specific classification of dried, unprocessed dog chews. Within the context of this category, these dog treats consist of various materials derived from animals (Morgan et al., 2023). Such materials may include raw abattoir material that meets the requisite standards for human consumption but due to commercial considerations, it has been rejected for such purposes. Additionally, this category also encompasses materials obtained from animals that have undergone antemortem testing and are assessed as unsuitable for human consumption (Morgan et al., 2023). These pet treats frequently include such as ears, mouthparts, leg bones, intestines, oxtail, bull penises, and other residual body parts from animals sacrificed for human use. The items are dried until the water content is low enough for the snacks to remain stable at room temperature (Galvão et al., 2015).

Previous studies (Morelli et al., 2020; Morgan et al., 2023) have shown that owners who give to their dogs non-processed treats do so because they believe it is healthier and a more natural choice for their dog. They also believe that giving bones, for example, stimulates the dog's natural chewing behavior and provides mental stimulation by making the dog enjoy it (Arhant et al., 2021; Morgan et al., 2023). According to a research study (Arhant et al., 2021), 12% of participants reported that giving their dogs a

significant quantity of bones to eat could result in constipation. In addition, the consumption of raw animal products by dogs may lead to digestive issues such as vomiting or diarrhea (Arhant et al., 2021).

One study (Morelli et al., 2018) shows that treats that are made from animal parts have a caloric density of approximately 312.2 ± 70.6 kcal ME/100g as per the label information. The weight of this kind of treats per ranges from 3.5 ± 3.9 grams to 10.9 ± 12.6 grams. On average, each treat provides about 10.9 ± 12.6 kcal per serving. This implies that in a 100-gram portion, tenders contain approximately 312.2 calories. The variability in individual treat weights contributes to a wide range of caloric content per treat (Morelli et al., 2018).

2.6 Rawhide

Rawhide is a popular and affordable chew material derived from cow or horse hides. It is commonly used for dogs due to its durability and perceived dental benefits (Stern and Martin, 2021). However, caution should be exercised as swallowing large pieces of rawhide can pose a risk of gastrointestinal obstruction. As a result, alternatives to rawhide are gaining popularity as safer and healthier options for dogs (Stern and Martin, 2021). A recent study (Hooda et al., 2021) revealed that expanded pork skin exhibits higher digestibility compared to bovine or horse rawhide. This finding presents a significant advantage and makes it a preferable option for those seeking to minimize the risk of intestinal blockage. Therefore, choosing expanded pork skin as an alternative to rawhide can provide a safer and more suitable chewing option for dogs (Hooda et al., 2021).

Rawhide treats show a significant variability in terms of digestion, as observed during both the gastric and intestinal phases. Following the intestinal phase, the dry matter disappearance (DMD) of rawhide treats ranged widely, spanning from 35.10% to 95.70% (He et al., 2020). This notable range indicates that rawhide treats possess the largest variation in DMD when compared to other treat categories. The concern arises when rawhide treats exhibit a low DMD during the gastric phase, as this can potentially pose risks such as gastrointestinal blockage and intolerance, particularly for larger-sized treats that remain intact (He et al., 2020).

Rawhide, which contains dried bovine skin, are treats particularly rich in hydroxyproline. This is an amino acid that should be discouraged for dogs prone to calcium-oxalate urolith formation. Recent findings suggest that hydroxyproline containing protein sources may lead to the synthesis of endogenous oxalate, which is a potential substrate in the formation of calcium-oxalate uroliths in dogs and cats (Morelli et al., 2018).

This category of treats has a caloric density of approximately 309.5 ± 20.6 kcal ME/100g based on the label data (Morelli et al., 2018). The weight of rawhides per treat varied notably, ranging from 45.0 ± 16.0 grams to 132.5 ± 44.4 grams. On average, each rawhide provided around 132.5 ± 44.4 kcal per treat. This suggests that in a 100-gram portion, rawhides contain approximately 309.5 calories (Morelli et al., 2018).

3 Nutritional values

According to two studies (Sprinkle, 2019; Dodd et al., 2020), pet owners look for treats and foods for their companion animals that are raw, natural, organic, produced locally, and enhance positive benefits. Many pet food products are labeled in a confusing manner, making it difficult for pet owners to make comparisons between different brands of food (Heuberger and Wakshlag, 2011). Other dog owners may struggle to accurately interpret the information presented on the product label (Di DonFrancesco et al., 2014). They also are looking for products that have a short list of ingredients, use uncommon protein sources, and have clean labeling that nearly reflects that on human food (Morelli et al., 2020). Dog owners preferences are also influenced by sensory qualities like palatability, appearance and smell. In this case, color is the most important characteristic (Yam et al., 2017). These results may have an impact on the animal food sector and help engineers create more brand-new treats that meet consumer demand (Presume et al., 2022; Zhang et al., 2022). For instance, a recent study (Kępińska-Pacelik et al., 2023), demonstrated the potential use of insect products. Dog treats obtained from insects enable the branch of dog diets, including hypoallergenic diets and treats, to be explored. Due to their high nutritional content and potential health benefits, treats made with insect meal and spirulina can be utilized in dog nutrition (Kępińska-Pacelik et al., 2023). On the other hand, another study recommends caution, indicating that insect protein from yellow

mealworm larvae can be linked to allergies in dogs, particularly those sensitive to mites (Premrov Bajuk et al., 2021).

The nutritional value of dog treats can vary depending on their ingredients and processing methods (Morelli et al., 2018). Some dog treats contain high levels of protein and fat, which benefit active dogs, but may lead to weight gain in less active dogs (Table 1). Additionally, some dog treats contain high levels of salt, which can be detrimental to a dog's health, particularly those with pre-existing heart conditions. Dog treats can also contain a variety of ingredients in addition to protein and fat (Morelli et al., 2018). According to most pet food reports, wheat flour is the most often utilized ingredient in dog treats since its starch and gluten help give biscuits their delicious texture and flavor (Almeida et al., 2022; Case et al., 2011). A study conducted by Kępińska-Pacelik et al. (2023) evaluated self-produced nutraceutical dog treats, both extruded and baked, focusing on dogs nutritional preferences and analyzing the treats proximate composition and mineral content. The study found that treats with higher buckwheat flour content were less favored by dogs, likely due to a bitter aftertaste. Baked snacks had twice the crude fat content of extruded ones, while extruded snacks contained more total carbohydrates. Magnesium levels and trace elements were significantly higher in baked treats (Kępińska-Pacelik et al., 2023).

Other ingredients may include carbohydrates, such as rice flour, or sweet potatoes, as well as vitamins and minerals, such as vitamin E and zinc. In some cases, dog treats may also contain additives or preservatives, such as tocopherols or citric acid, to extend their shelf

TABLE 1 Types of treats – advantages, disadvantages and risks.

Type of treats	Risks	Advantages	Disadvantages	Caloric density kcal/100g	Protein g/1000 kcal	Fat g/1000 kcal
Biscuits	Aggravates diabetes (Morelli et al., 2018)	Extended shelf life (Almeida et al., 2022)	High level of sugar – up to 51.7 g/1000 kcal (Morelli et al., 2018)	329.2 (Morelli et al., 2018)	47.0 ± 12.0 (88.6–91.6) (Morelli et al., 2018)	27.0 ± 9.5 (15.8–35.9) (Morelli et al., 2018)
Soft treats	1. Overweight (Morelli et al., 2018) 2. Involuntary ingestion (Castrica et al., 2021)	1. Decreases the dental calculus, dental plaque and gingivitis (Stokey, 2009) 2. Incorporate functional nutrients (He et al., 2020)	Easy to eat overfeeding (Larsen and Farcas, 2014)	294.0 (Morelli et al., 2018)	108.9 ± 54.1 (22.0–204.2) (Morelli et al., 2018)	19.7 ± 15.4 (4.8–53.9) (Morelli et al., 2018)
Jerky treats	Zoonosis (Nemser et al., 2014)	Stability and safety during storage (Kim et al., 2020)	1. Fanconi syndrome (Nybroe et al., 2022) 2. Microbiological contamination (Nemser et al., 2014)	284.4 (Morelli et al., 2018)	99.8 ± 14.2 (89.8–109.9) (Morelli et al., 2018)	24.8 ± 9.8 (17.9–31.8) (Morelli et al., 2018)
Dental chews	Esophageal blockage (Leib and Sartor, 2008)	Promote dental hygiene (De Godoy et al., 2014)	Oral injuries (Arhant et al., 2021)	267.7 (Morelli et al., 2018)	29.4 ± 15.6 (10.8–48.9) (Morelli et al., 2018)	11.5 ± 3.7 (6.5–14.6) (Morelli et al., 2018)
Animal parts	Dental fractures and oral injuries (Arhant et al., 2021)	1. Mental stimulation (Morgan et al., 2023) 2. Stable at room temperature (Davidson, 2019)	Constipation, vomiting or diarrhea (Arhant et al., 2021)	312.2 (Morelli et al., 2018)	–	–
Rawhide	Gastrointestinal blockage (Hooda et al., 2021)	1. Affordable (Stern and Martin, 2021) 2. Dental benefits (Stern and Martin, 2021)	Significant variability in terms of digestion (He et al., 2020) Formation of calcium-oxalate uroliths (Morelli et al., 2018)	309.5 (Morelli et al., 2018)	171.9 ± 67.5 (78.0–244.6) (Morelli et al., 2018)	10.7 ± 9.9 (1.2–23.7) (Morelli et al., 2018)

life. Some treats also contained unusual ingredients not commonly found in regular pet food, such as milk and milk derivatives, sugars, and sweeteners like glycerol, glycerin, and sorbitol (Morelli et al., 2018). However, it is important to note that not all dog treats are created equal, and some may include potentially harmful ingredients or additives like xylitol, ethoxyquin or sulphites (Craig, 2021).

4 Energy value

Dog' daily energy needs can change depending on a number of variables, including their age, breed, size, degree of exercise, and general health. A healthy adult dog needs roughly 30–70 calories per pound of body weight each day to maintain its weight. Puppies, pregnant or lactating dogs, and very active dogs may require extra calories to maintain their growth, development, and energy requirements. Pet owners can use a formula that accounts for the dog's weight, age, and activity level to establish daily energy needs. The Resting Energy Requirement (RER) calculation is frequently used to determine how many calories a dog needs while at rest: $RER = 70 \times (\text{body weight in kg})^{0.75}$ (NRC, 2006). According to one study on the nutritional evaluation of commercial diets for dogs, the energy content of treats can vary widely and in some cases exceed the recommended daily energy intake for dogs (Linder and Freeman, 2010).

It is recommended that treats be provided in small amounts and should not exceed 10% of the dog's daily caloric intake (Larsen and Farcas, 2014). In recent years, bull penis or "bully sticks" have become increasingly popular as dog treats (Freeman et al., 2013). However, it is important to note that one piece of bully stick per day can account for a significant proportion of a dog's daily calories intake. Specifically, for a medium-sized dog weighing 23 kg, one bully stick piece per day would provide approximately 9% of their daily caloric needs, while for a small-sized dog weighing 4.5 kg, one bully stick piece per day would provide approximately 30% of their daily caloric needs (Freeman et al., 2013). As a result, it is crucial to monitor the pet's intake of treats and other supplementary foods. Choosing treats that are appropriately balanced for their dietary requirements is also important. In order to ensure that supplementary foods are nutritionally complete and appropriately balanced, a feeding plan must be developed that meets each pet's unique dietary needs (Linder and Freeman, 2010).

5 Risk factors

5.1 Controversies

Recently, there has been a notable surge in the canine treats industry. However, it is imperative to consider that not all of these treats are universally appropriate for every dog, owing to variations in their specific requirements influenced by factors like size, associated pathologies, and age (Marchywka, 2022). Considering the current trend towards canine obesity and the fact that it has been shown that obese dogs receive more treats, the label of each treat should be more explicit (Nielson et al., 2023). This should

contain information about the caloric content, so that the veterinarian can offer advice on adding rewards to the dog's balanced diet (Morelli et al., 2018). In the study conducted by Morelli et al. (2018), it was showed that ingredients are not specifically described on the label of treats. This lack of standardization in the labeling of treats confuses both the veterinarian and pet owners to integrate rewards into the dog's diet based on their caloric and nutritional needs (Morelli et al., 2018). A recent study conducted by Stern and Martin (2021) investigated ten rawhide-free treat products. Histological analysis revealed discrepancies in two products, which did not align with their labeling claims. Contrary to being labeled as rawhide-free, these two products displayed characteristics consistent with rawhide composition (Stern and Martin, 2021). This discrepancy raises concerns regarding accurate product labeling, crucial for consumers making informed purchasing decisions. Notably, rawhide consumption is discouraged for dogs needing controlled protein intake or those prone to calcium oxalate stone formation (Stern and Martin, 2021).

The feeding regimens of dogs afflicted with chronic heart failure (CHF) and chronic kidney disease (CKD) require careful consideration of treats due to their potential high mineral content. Specifically, milk and milk derivatives found in certain treats should be considered when feeding dogs with known intolerances to these foods and their derivatives (Morelli et al., 2018).

Thyrototoxicosis in dogs can result from consuming dog treats that are contaminated with excessive levels of the thyroid hormone T4. In a research (Broome et al., 2015), with 14 dogs involved, it was shown that after ingesting commercially available meat-based dog diets or treats that were thought to have higher amounts of T4, all of the animals exhibited reversible thyrototoxicosis. The presence of thyroid gland tissue in the treats during the meat production phase is most likely what caused the contamination. The finding of elevated T4 concentrations in a variety of pet diets or treats marketed under different brands suggests that this problem of T4 contamination of treats may not be exclusive to certain products or manufacturers and that these problems are sporadic and occur as a result of processing errors. Laboratory analysis of the animal's diet is indicated if clinical signs of hyperthyroidism appear and the dog's diet should be changed immediately (Broome et al., 2015). Another study (Cridge et al., 2022), suggests that the dietary history of dogs that are fed large amounts of dog treats may result in elevated levels of canine-specific lipase, in some cases even developing an acute episode of pancreatitis (Cridge et al., 2022).

5.2 Pet owners' behavior

Pet treats are an excellent way to express affection. Pet owners use them to form emotional bonds with their pets or interact with them. In addition, treats may also be used as a positive reinforcement for good behavior or as a reward during training (Luño et al., 2021). One of the theories focuses on the idea that giving goodies to dogs without a clear aim can be seen as a sort of emotional expression and a way for owners and their dogs to communicate. In the special bond that dogs and their owners enjoy,

treats turn into symbols of love and connection (Luño et al., 2021). Studies (Boya et al., 2015; White et al., 2016; Luño et al., 2021) also underline the importance of treats as a fundamental element of the relationship between dogs and their human parents. Treats frequently represent more than simply a source of nutrients, they can stand for moments of happiness, friendly interaction, and reinforcement. Without intending to, owners may unintentionally promote their dogs' mental health and increase their emotional bond with their animals by giving them goodies (Luño et al., 2021). Dog food treats may also provide functional nutrients for managing specific conditions or improving pet health (He et al., 2020; Larsen and Farcas, 2014). While buying dog food instead of human food, pet owners are more inclined to stick with a certain brand and are less price sensitive. According to research (Boya et al., 2015), people's relationships with their dogs are systematically tied to how they shop for them (Boya et al., 2015). Based on a survey (White et al., 2016), a significant proportion of dog owners, 96%, provide treats for their dogs. Furthermore, 69% of dog owners reported giving their dogs store-bought treats on a daily basis. However, only a minority of owners adjust their dog's regular food intake to compensate for the number of treats given (White et al., 2016). In one study conducted by Morelli et al., 2020 in Italy, data were collected from the internet via Google Forms with the questionnaire provided in Italian. The frequency with which pet owners offer treats to their dogs varies, ranging from less than once a week to several times a day, according to the responses of 1,833 pet owners (Figure 1). In order to maintain a balanced and healthy diet for dogs, it is crucial to consider the size and frequency of treats given. It is recommended that treats be provided in small amounts and should not exceed 10% of the dog's daily caloric intake. Treat overfeeding may increase the risk of weight gain and other health problems, such as gastrointestinal disorders, dental problems, and pancreatitis (Larsen and Farcas, 2014).

To ensure the safety of treats for dogs, it is important that they can be partially or completely digested during the gastric and intestinal phases of digestion (Stercova et al., 2022). This is crucial in preventing the risk of oral and gastrointestinal perforations or blockages, which can have serious health consequences for dogs (Hooda et al., 2021). A previous study indicated that the bone category was the least digestible of the treat categories, that is why most frequent gastrointestinal foreign bodies in dogs are bones. However, chew treats, rawhide, or other dental chew treats have also been documented to cause significant obstruction within dogs' esophagus (He et al., 2020; Stern and Martin, 2021). Small dogs are more likely to experience an esophageal blockage when given dental chew treats than bones. There is a possibility that this may be due to the ease with which a smooth tubular object can be swallowed as opposed to an irregular bone fragment (Leib and Sartor, 2008).

There are various types of owners when it comes to their relationship with their dog's and eating behavior. One type of dog owner is the one who often does not realize their dogs are overweight resulting in a clear discrepancy between the veterinarian's evaluation of the dog's weight and the owner's perception. This is because the owners often perceive their dogs as being healthy, regardless of their actual weight (Rohlf et al., 2010; White et al., 2011).

Another category are owners who do not perceive obesity as a disease and are more likely to have overweight or obese dogs. This could be due to a lack of knowledge about obesity's detrimental effects or a perception of obesity as a nutritional or metabolic disorder. It is suggested that increased awareness and educational strategies may play a vital role in preventing and reversing obesity spread in dogs. Therefore, it is essential to prioritize educational initiatives that promote awareness and disseminate knowledge about this condition and the methods to counter it (Muñoz-Prieto et al., 2018).

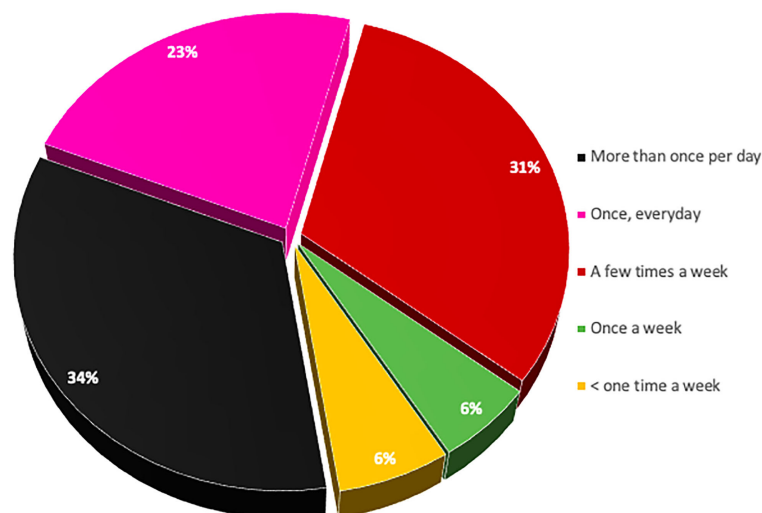


FIGURE 1
Frequency of treat administration in dogs (Morelli et al., 2020).

In order to help pet owners find the best option in terms of dog treats, it is important to be well established if they see the treats as part of the daily diet or as an additional component (Nielson et al., 2023). In one study carried out in Canada and the USA by Nielson et al. (2023), which included questionnaires given to 716 caregivers, 59% of the participants consider dog treat to be any food that the dog likes, 26% consider the reward whatever the dog likes and only 12% consider it to be the reward for dogs only those products specially designed for this purpose. According to this study (Nielson et al., 2023), most pet owners do not have a specific strategy to determine the amount of treats they offer to their dogs.

6 Advantages and disadvantages

6.1 Advantages of using treats

6.1.1 Positive reinforcement

Studies (Hiby et al., 2004; White et al., 2016; Nielson et al., 2023) found that positive reinforcement training techniques, which often involve treats, were the most commonly used and most effective methods of training dogs. Positive reinforcement involves rewarding desired behaviors with something the dog finds rewarding, such as treats or praise (Hiby et al., 2004). The use of treats in positive reinforcement training has been shown to be effective in several ways. The first benefit of treats is that they provide an immediate and tangible reward for the dog, which reinforces the desired behavior. Furthermore, treats provide clear motivation for the dog to perform good behavior, which makes it easier for him to learn new behaviors quicker (Hiby et al., 2004).

Furthermore, using treats as rewards help the dog and trainer build a strong connection. This type of positive reinforcement increases trust and improves the bond between the dog and its owner, creating a more harmonious and satisfied companionship (Beynen, 2011). This is also supported by the study of Nielson et al. (2023) in which it was noted that 434 owners out of a total of 716 interviewees (61%) are motivated to feed treats to their dogs because it makes them feel happy. Also 52% of the owners included in the study believe that offering treats to their dog will strengthen their relationship (Nielson et al., 2023).

During training sessions or intense sporting activities, many pet owners often exceed recommended feeding instructions (Morelli et al., 2020). There is a possibility that this pattern resulted from the realization that the higher amounts of treats they were offering their dogs were compensated by the higher energy expenditure they were consuming. Owners understood the correlation between the energy expended by their canine companions and the need for additional nutrition. As a result, they often tended to offer more treats to ensure that their pets' nutritional needs were adequately met during these physically demanding efforts (Morelli et al., 2020).

6.1.2 Promoting dental health

One of the advantages of using treats in dogs' diet is promoting dental health. Specialized treats for these conditions not only decreased plaque and calculus from the teeth, but also help in

episodes of gingivitis (Stookey, 2009). This results in increasing the dog's quality of life, promoting systemic health but also increases the dog's longevity. Furthermore, this prophylaxis is beneficial to the owner because the risk of a dental problem being expensive for the owner is lower (Nielson et al., 2023).

Several studies (Quiryren et al., 2006; Jeusette et al., 2016; Oba et al., 2021) investigated the effectiveness of dog treats at promoting canine oral health. One study (Jeusette et al., 2016) found that a specific dental treat containing vitamin C and zinc sulfate reduced oral bacterial growth and malodor in dogs for up to 12 and 24 hours, respectively. This is significant as PD, a common and widespread oral disease in dogs, has been associated with other health issues (Poppi et al., 2023). The results suggest that preventing PD through dental treats may improve overall canine health (Tochio et al., 2022).

6.1.3 Deliver necessary nutrients or supplements

Beynen (2011) demonstrates that it is possible to incorporate a targeted substance into a dog treat recipe and thereby increase its benefit. In this study, the authors introduced cellulose into a soft treat recipe for dogs and thus obtained an increase in elasticity and chewing time compared to those without cellulose (Beynen, 2011). These results suggest that the treat containing cellulose remains longer in contact with the tooth surface in the chewing process and thus mechanical cleaning occurs, which explains the decrease of clinical signs of periodontitis in the dogs that were included in the study (Beynen, 2011).

As dogs age, their nutritional needs change, impacting their overall health (Larsen and Farcas, 2014). When selecting treats for older dogs, it is important to consider their changing nutritional requirements. Senior dogs may experience reduced absorption of certain nutrients, such as protein, calcium, and phosphorus, due to age-related changes in their digestive system. In order to maintain their health, treats that are high in these nutrients may be beneficial for older dogs (Larsen and Farcas, 2014).

6.1.4 Food waste reduction

In a recent study, Poppi et al. (2023) highlight the benefit of integrating fish flour in the composition of dog treats. The Nile Tilapia fish species is recognized as the most consumed fillet in Brazil, thus all the residues resulting from filleting such as head, skin, viscera and backbone can lead to environmental pollution if not used in a sustainable manner (Poppi et al., 2023). The authors suggest that in order to minimize the environmental impact by reducing food waste but also to bring a healthier alternative into the dog treats market it might be relevant to produce fish flour from these residues to be incorporated into dog treat recipes (Poppi et al., 2023).

Another study exploring possibilities to reduce waste after industrial food processing was conducted by Chanioti (2019), where findings suggested the utilization of wet spent grain, a byproduct typically considered waste, in the creation of sustainable dog treats. This approach not only addresses environmental concerns by reducing food waste but also aligns with consumer preferences for sustainable products. The positive

reception from dog owners suggests a growing interest in eco-friendly options within the pet food industry (Chanioti, 2019).

6.2 Disadvantages of using treats

6.2.1 Microbiological contamination

Salmonella spp. are Gram-negative bacilli from the *Enterobacteriaceae* family that can colonize the intestines of most vertebrates. In humans and animals, *Salmonella non-typhoidalis* is an important food-borne pathogen that causes gastroenteritis, bacteremia, and generalized infection in humans and animals. Salmonellae are typically transmitted to humans through the consumption of contaminated meat, milk products, and other foods. Non-typhoidal *Salmonella* can also be transmitted zoonotically through direct contact with infected animals' feces (Galvão et al., 2015; Yukawa et al., 2019; Kępińska-Pacelik and Biel, 2021).

Regulatory agencies such as the US Food and Drug Administration (FDA) and the EU (Kępińska-Pacelik and Biel, 2021), impose strict requirements for pathogens such as *Salmonella* in pet food, ensuring high food safety standards. Raw pet treats, which lack heat treatment, present a challenge in maintaining *Salmonella*-free products. The current microbiological requirements dictate that *Salmonella* is not permitted to be present in five samples of treats, each weighing 25 g. The EU mandates the absence of *Salmonella* in all pet treats, including those made from raw ingredients, reflecting their commitment to public health protection. In the USA, FDA requires labeling to inform consumers of the potential risks associated with feeding raw treats to their pets (Kępińska-Pacelik and Biel, 2021; Adley et al., 2011; Soffer et al., 2016).

In recent years, several studies (Finley et al., 2008; Galvão et al., 2015; Muñoz-Prieto et al., 2018; Yukawa et al., 2019) have documented occurrences of *Salmonella* infections that have been linked to the consumption of animal-derived pet treats. It has been demonstrated in studies conducted in countries such as Canada, Japan, Ireland, UK and the USA that dog treats contain an unacceptable amount of *Salmonella* (Clark et al., 2001; Finley et al., 2008; Adley et al., 2011; Soffer et al., 2016; Yukawa et al., 2019). More specifically, pig ears and other porcine and beef products may be a source of *Salmonella* infection in humans for several serotypes (Pitout et al., 2003; Adley et al., 2011).

One study (Nemser et al., 2014), shows that in many raw dog foods and jerky dog treats, in addition to *Salmonella*, severe samples were positive for *Listeria monocytogenes*. In this way the authors raise the concern about the handling of these types of treats by dog owners because of the risk of zoonosis. Veterinarians, public health professionals, and consumers must be aware of the potential infestation of *Listeria monocytogenes* in unprocessed pet foods because to the significant health effects of *Listeria monocytogenes* infections, particularly in pregnant women. If owners want to feed to their pets with this category of food, they should take serious precautions to prevent illness by washing their hands properly and sanitizing any surfaces or objects that come into touch with raw treats (Nemser et al., 2014).

Another microbiological concern reported in the raw category is the presence of beta-lactamase-producing bacteria of the *Enterobacteriaceae* family. Those were isolated in 77.8% of the raw treats taken in the study (Yabuki et al., 2017), while in the non-raw treats their percentage was 0%. Manufacturers of dog food consider *Enterobacteriaceae* as an indicator of hygiene, thus their presence may indicate poor sanitation in transport or manufacturing processes. According to the EU law No 142/2011, canine and other non-canned food products exceeding 3x10² cfu/g bacteria of the family *Enterobacteriaceae* are classified as unsatisfactory in terms of microbiological hygiene (Serhan et al., 2022).

6.2.2 Fanconi syndrome in dogs

Fanconi syndrome is characterized by kidney malfunction, a proximal renal tubular defect that impairs the resorption of glucose, amino acids, bicarbonate and other substances filtered by the glomeruli in the kidneys (Carmichael et al., 2014). Despite being described as a genetic disorder, the ingestion of pet jerky treats from China has recently been associated with renal Fanconi syndrome in North America, Australia, and Europe (Yabuki et al., 2017; Schaalo et al., 2021).

The occurrence of Fanconi syndrome has been reported as rare, with a genetic basis, as demonstrated in the Basenji breed through the identification of a FAN1 mutation (Littman, 2017). Furthermore, the syndrome has been observed in Labrador retrievers with copper-associated hepatitis (Langlois et al., 2013). Meanwhile, the prevalence of canine Fanconi syndrome has significantly increased in the last 15 years, with the FDA receiving over 360 cases of dogs diagnosed with acquired Fanconi syndrome between 2007 and 2015. The rising incidence of Fanconi syndrome appears to be associated with the excessive consumption of jerky treats, predominantly those made from chicken and imported from China. Despite thorough investigations, the underlying cause of jerky-induced Fanconi syndrome remains unclear (Nybroe et al., 2022).

Besides the previously discussed concerns, it has been well documented that chicken jerky dog treats have been linked to severe illnesses and fatalities in dogs across many nations (Bischoff and Rumbeiha, 2018). Research (Bischoff and Rumbeiha, 2018) indicates that Fanconi syndrome is more commonly seen in small breed dogs. A possible reason for this may be the dietary preferences of these dogs, and symptoms may be seen when dogs consume large amounts of jerky treats over the course of two to three months, resulting in approximately 50% of their diet containing these treats (Bischoff and Rumbeiha, 2018). Clinical signs are unspecific and may range from gastrointestinal symptoms such as vomiting, diarrhea, and loss of appetite to more severe symptoms such as kidney failure and even death (Sheridan et al., 2014).

6.2.3 Obesity

The obesity epidemic has been a major cause of concern for the global health system, impacting both human and domestic animals. As a result of the study (Flegal et al., 2010) conducted between 2007 and 2008, 32.2% of men and 35.5% of women in the USA were classified as obese, defined as having a Body Mass Index (BMI) of more than thirty (Flegal et al., 2010). Furthermore, as a result of the changes in dietary habits, obesity has become more prevalent in

Europe as well, with 22.8% of men and 35.6% of women now classified as obese (Branca et al., 2007). The same upward trend was also observed in dogs. A randomized study (Porsani et al., 2020) was conducted in the city of Sao Paulo in Brazil to determine the prevalence of obesity in dogs (Porsani et al., 2020). Thus, the authors concluded that 40.5% of all dogs included in the study suffered from obesity (Endenburg et al., 2018). Due to the fact that as time goes by more and more humans and animals suffer from obesity, it is recognized as one of the most pressing issues of the 21st century (Muñoz-Prieto et al., 2018).

Obesity is characterized by the excessive accumulation of adipose tissue in the body. Obesity is often caused by either excessive food intake or insufficient energy use, resulting in a condition of positive energy balance (Montoya-Alonso et al., 2017). Dog obesity is defined as being present when dogs are more than 15%–30% above their normal weight. Because of breed and body size differences, determining optimal body weight is difficult. As a result, body condition scores (BCS) are frequently used to provide an operational definition of obesity (Rohlf et al., 2010; Muñoz-Prieto et al., 2018).

A recent study (Kour et al., 2019), has shown that dogs fed ad libitum are 54% more likely to become obese than those fed a precise amount of food once or twice a day. This finding suggests a potential psychological influence in dogs, with origins in their ancestral memory of times when food wasn't always readily available, prompting them to consume as much as possible in a single meal (Kour et al., 2019). Numerous studies (Bland et al., 2009; White et al., 2016; Perry et al., 2020) have identified a correlation between obesity in dogs and the feeding behavior of owners regarding dog treats. It has been observed that owners who provide their dogs with daily treats, constituting more than 10% of the dog's daily caloric intake, are more likely to develop obesity compared to those who do not offer treats on a daily basis. Only a small proportion of canine obesity cases, approximately 3%, are attributed to dog-specific factors (Preet et al., 2021). This relationship between canine obesity and owner behavior suggests that monitoring treat consumption is crucial in maintaining a healthy weight for dogs (Bland et al., 2009; Perry et al., 2020). One study (Linder et al., 2021) outlines an association between obesity in dogs and obesity in owners, this is strictly due to the lifestyle of the owners which impacts on the dog (Linder et al., 2021). A recent published study (Pretlow and Corbee, 2016) reports the similarity of the upward trend in obesity pathology in dogs and in children. Thus, families houses with dogs and small children were studied and the tendency to obesity was observed in both cases (Pretlow and Corbee, 2016). From what was reported previously (Pretlow and Corbee, 2016), it appears that both dogs as well as the child, they cannot be responsible for their own food. Instead, the behavior of the dog owner and the child's parent is responsible for the overfeeding regime, low-quality and high-calorie food combined with a sedentary lifestyle (Pretlow and Corbee, 2016). Following a questionnaire conducted in Germany, a study (Banton et al., 2022) was carried out which observed that German dog owners place a higher value on exercise in terms of their dog's overall health, leading to longer exercise sessions and a decreased probability of being informed that their dog is overweight (Banton

et al., 2022). Exercise strategies should be included in weight loss programs for dogs and regular exercise should be promoted to prevent weight gain in dogs. The authors (Banton et al., 2022) highlight the importance that additional resources could assist veterinarians in developing exercise regimens for their patients to help them be more effective (Banton et al., 2022). This could help both owners and pets to have the most enjoyable life in terms of their health, but also veterinarians in managing the population of animals suffering from obesity along with all the pathologies that occur secondarily (Banton et al., 2022). Age was associated with the body condition of dogs, thus obesity was observed more frequently in dogs older than 10 years. This presumption is reinforced by the study of Endenburg et al. (2018), which observed that body BCS increases with dog age and correlates with the duration of dog ownership. This indicates that older dogs generally have higher BCS, aligning with the notion that overweight and obesity are more prevalent in middle-aged dogs. Also, dogs spending less than an hour exercising with owners, dogs with behavioral problems such as fear, aggression and hyperactivity have also been correlated with overweight more frequently (Julianna et al., 2020). Another risk factor that has been observed in the prevalence of obesity is sexual status. In a study published in Thailand (Endenburg et al., 2018), the sexual status of dogs had a big impact on their BCS. While intact dogs normally had a BCS of 3, spayed and neutered dogs typically had a BCS of 5. Strong evidence exists to support the idea that dogs tend to gain weight after neutering. In terms of breed, mixed breeds have a higher predisposition to overweight and only in a few pure breeds has a genetic predisposition been observed: Labrador Retriever, Cocker Spaniel and Rottweilers (Courcier et al., 2010; Preet et al., 2021).

There are many metabolic diseases that affect dogs today, and obesity is the most common, resulting in significant comorbidities and reducing the quality of life of these animals, thus reducing their quality of life and lifespan (Muñoz-Prieto et al., 2020). Excessive weight, for example, can predispose dogs to diseases like diabetes, osteoarthritis, urinary incontinence, cardiac-respiratory problem and oncologic disorders. The prevalence of canine obesity is estimated to range from 10% to 40% worldwide, according to studies (Marshall et al., 2009; White et al., 2011; Montoya-Alonso et al., 2017; Forrest et al., 2022). According to the Royal Society for the Prevention of Cruelty to Animals (RSPCA) of the United Kingdom, half of all dogs and cats are overweight, and this trend appears to be on the rise (Marshall et al., 2009).

7 Conclusions

The global pet population, including dogs and cats, is growing, with a significant increase in the number of pet owners worldwide. This growth is accompanied by a thriving pet food industry, with dry dog food dominating the market and treats representing a substantial share. The growing market for canine treats reflects the deep emotional bond between pet owners and their pets, particularly through feeding behaviors. Dog treats are various, classified into six types, with meat treats being the most popular choice, determined by the belief in their natural and healthier

qualities. This trend suggests the growing importance of pets in people's lives and their desire to provide high quality food for their dogs.

Pet owners are looking for raw, natural and locally produced, clean label treats for their dogs. Labeling of treats has been reported as a concern because dog owners reported that this information is displayed in a confusing way. On top of this, nutritional information such as the calorie density of the treats should be included in all categories of treats with explanations on how these treats should be administered, so that pet owners do not exceed daily caloric needs by overusing them for their dogs. Sensory qualities, especially color, influence dog owners' preferences. The nutritional value of dog treats varies, impacting on dog health, and pet owners should be careful in their choice of ingredients. It is very important to be aware of the caloric energy of each treat, as some popular treats can contribute significantly to a dog's daily caloric intake. This review underlines the importance of communication between veterinarians and pet owners. Pet owners should talk to the veterinarian about the introduction of treats, so that the veterinarian can give them evidence-based advices depending on the dog's age, caloric needs and pathologies. At the same time, in the current study we emphasize the need for pet owners to see treats as part of the diet, not separately from it, in order to obtain a balance from a caloric and nutritional point of view. To ensure the well-being of pets, balanced feeding plans should be developed based on their individual dietary needs.

Feeding regimes for dogs with chronic conditions should consider the choice of treats because of potential health risks. Intrinsic and extrinsic factors contribute significantly to canine obesity, with owner behavior and environment playing a substantial role. Owners' treats choices have an impact on dogs' well-being and emotional bonding, requiring responsible treat selection and moderation to maintain canine health.

The environmental impact of this industry should also be taken into account when it comes to the production of dog treats. The production process of some types of dog treats can influence the environmental footprint by releasing substantial amounts of CO₂. On the other hand, the environmental footprint can be improved by introducing parts of the fish resulting from filleting into the composition of the treats. That would also help to decrease food waste and deliver a high quality protein alternative in the composition of treats.

In conclusion, the use of treats in dog training offers numerous advantages, including effective positive reinforcement and potential benefits for dog oral health and nutritional needs of senior dogs.

However, there are notable disadvantages associated with treats, such as the risk of microbiological contamination, particularly in the case of raw pet treats, leading to potential health hazards for both dogs and humans. In addition, involuntary consumption of dog treats, especially by children, poses health risks and there are concerns about the link between certain treats and conditions such as Fanconi syndrome. In addition, excessive use of treats may contribute to the growing problem of canine obesity, which is associated with various health problems and reduced quality of life for dogs. Considering the explosion of the treats market, further investigations are needed to clarify how the industry influences the environmental footprint, to develop healthier dog treats and the ideal way to integrate rewards into the diet of animals so that pet owners can offer their beloved animals a personalized diet based on individual needs.

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References

- Adley, C., Dillon, C., Morris, C. P., Delappe, N., and Cormican, M. (2011). Prevalence of Salmonella in pig ear pet treats. *Food Res. Int.* 44, 193–197. doi: 10.1016/j.foodres.2010.10.041
- Almeida, K. A. L. (2021). Alejandra k. Aldrich G. Supplementation of gluten-free sorghum flour-based dog treats with soluble animal proteins. *Electronic Theses Dissertations Rep.*
- Almeida, K. A. L., 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, skac191. doi: 10.1093/jas/skac191
- Arhant, C., Winkelmann, R., and Troxler, J. (2021). Chewing behaviour in dogs – A survey-based exploratory study. *Appl. Anim. Behav. Sci.* 241, 105372. doi: 10.1016/j.applanim.2021.105372
- Assalco-Zoomark (2017). *Report on the feeding and care of pets*. Available online at: <http://www.assalco.it/index.php?action=shownews&id=1&nid=6756>.
- Banton, S., Von Massow, M., Pezzali, J. G., Verbrugghe, A., and Shoveller, A. K. (2022). Jog with your dog: Dog owner exercise routines predict dog exercise routines and perception of ideal body weight. *PLoS One* 8, e0272299. doi: 10.1371/journal.pone.0272299

- Beynen, A. C. (2011). Incorporation of cellulose into a chew treat for dogs increases elasticity and chewing time. *Am. J. Anim. Vet. Sci.* 6, 117–120. doi: 10.3844/ajavsp.2011.117.120
- Bischoff, K., and Rumblei, W. K. (2018). Pet food recalls and pet food contaminants in small animals. *Vet. Clin. North Am. Small Anim. Pract.* 48, 917–931. doi: 10.1016/j.cvsm.2018.07.005
- Bland, I. M., Guthrie-Jones, A., Taylor, R. D., and Hill, J. (2009). Dog obesity: owner attitudes and behaviour. *Prev. Vet. Med.* 92, 333–340. doi: 10.1016/j.prevetmed.2009.08.016
- Boya, U. O., Dotson, M. J., and Hyatt, E. M. A. (2015). Comparison of dog food choice criteria across dog owner segments: An exploratory study. *Int. J. Consum. Stud.* 39, 74–82. doi: 10.1111/ijcs.12145
- Branca, F., Nikogosian, H., Lobstein, T. NHT (2007). *The challenge of obesity in the WHO European Region and the strategies for response: summary 2007* (8DK-2100 Copenhagen Ø, Denmark: World Health Organization), ISBN 9789289014083.
- Broome, M. R., Peterson, M. E., Kemppainen, R. J., Parker, V. J., and Richter, K. P. (2015). Exogenous thyrotoxicosis in dogs attributable to consumption of all-meat commercial dog food or treats containing excessive thyroid hormone: 14 cases, (2008–2013). *J. Am. Vet. Med. Assoc.* 246, 105–111. doi: 10.2460/javma.246.1.105
- Carmichael, N., Lee, J., and Giger, U. (2014). Fanconi syndrome in dog in the UK. *Veter. Rec.* 174, 357–358. doi: 10.1136/vr.g2554
- 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.* 198, skaa274. doi: 10.1093/jas/skaa274
- Case, L., Daristotle, L., Hayek, M., and Raasch, M. (2011). *Canine and feline nutrition: a resource for companion animal professionals. 3rd ed.* (Mosby Elsevier, 3251 Riverport Lane, Maryland, Missouri: Elsevier), ISBN: .
- Castrica, M., Menchetti, L., Panseri, S., Cami, M., and Balzaretto, C. M. (2021). When pet snacks look like children's toys! The potential role of pet snacks in transmission of bacterial zoonotic pathogens in the household. *Foodborne Pathog. Dis.* 18, 56–62. doi: 10.1089/fpd.2020.2839
- Chanioti, K. (2019). Developing dog biscuits from industrial by-product. (Lund, Sweden: Division of Packaging Logistic. Lund University). ISBN 9789178952106.
- Cindy, H. J., and Rupasinghe, H. V. (2021). Cannabidiol-based natural health products for companion animals: Recent advances in the management of anxiety, pain, and inflammation. *Res. Vet. Sci.* 140, 38–46. doi: 10.1016/j.rvsc.2021.08.001
- Clark, C., Cunningham, J., Ahmed, R., Woodward, D., Fonseca, K., Isaacs, S., et al. (2001). Characterization of Salmonella associated with pig ear dog treats in Canada. *J. Clin. Microbiol.* 39, 3962–3968. doi: 10.1128/JCM.39.11.3962-3968.2001
- Courcier, E. A., Thomson, R. M., Mellor, D. J., and Yam, P. S. (2010). An epidemiological study of environmental factors associated with canine obesity. *J. Small Anim. Pract.* 51, 362–367. doi: 10.1111/j.1748-5827.2010.00933.x
- Craig, J. M. (2021). Additives in pet food: are they safe? *J. Small Anim. Pract.* 62, 624–635. doi: 10.1111/jsap.13375
- Cridge, H., Scott, N., and Steiner, J. M. (2022). Risk factors and clinical presentation in dogs with increased serum pancreatic lipase concentrations—A descriptive analysis. *Animals* 12, 1581. doi: 10.3390/ani12121581
- Davidson, I. (2019). Ingredients for biscuits: an introduction. *Ind. Biscuit Prod. Jan* 1, 165–172.
- De Godoy, C. M. R., Vermillion, R., Bauer, L. L., Yamka, R., Frantz, N., Jia, T., et al. (2014). *In vitro* disappearance characteristics of selected categories of commercially available dog treats. Cambridge. *J. Nutr. Sci.* 3, e47. doi: 10.1017/jns.2014.40
- Di DonFrancesco, B., Koppel, K., Swaney-Stueve, M., and Chambers, I. V. E. (2014). Consumer acceptance of dry dog food variations. *Animals* 4, 313–330. doi: 10.3390/ani4020313
- Dodd, S., Cave, N., Abood, S., Shoveller, A. K., Adolphe, J., and Verbrugge, A. (2020). An observational study of pet feeding practices and how these have changed between 2008 and 2018. *Vet. Rec.* 27, 186(19):643. doi: 10.1136/vr.105828
- Endenburg, N., Soontararak, S., Charoensuk, C., and van Lith, H. A. (2018). Quality of life and owner attitude to dog overweight and obesity in Thailand and the Netherlands. *BMC Vet. Res.* 14, 1–19. doi: 10.1186/s12917-018-1531-z
- Enlund, K. B., Brunius, C., Hanson, J., Hagman, R., Höglund, O. V., Gustås, P., et al. (2020a). Dog owners' Perspectives on canine dental health—A questionnaire study in Sweden. *Front. Vet. Sci.* 9. doi: 10.3389/fvets.2020.00298
- Enlund, K. B., Brunius, C., Hanson, J., Hagman, R., Höglund, O. V., Gustås, P., et al. (2020b). Dental home care in dogs- A questionnaire study among Swedish dog owners, veterinarians and veterinary nurses. *BMC Vet. Res.* 16, 1–13. doi: 10.1186/s12917-020-02281-y
- Finley, R., Reid-Smith, R., Ribble, C., Popa, M., Vandermeer, M., and Aramini, J. (2008). The occurrence and anti-microbial susceptibility of Salmonellae isolated from commercially available pig ear pet treats. *Zoonoses Public Health* 55, 455–461. doi: 10.1111/j.1863-2378.2008.01144.x
- Flegal, K. M., Carroll, M. D., Ogden, C. L., and Curtin, L. R. (2010). Prevalence and trends in obesity among US adults 1999–2008. *JAMA* 303, 235–241. doi: 10.1001/jama.2009.2014
- Forrest, R., Awawdeh, L., Esam, F., Pearson, M., and Waran, N. (2022). Potential owner-related risk factors that may contribute to obesity in companion dogs in Aotearoa New Zealand. *Animals* 12, 267. doi: 10.3390/ani12030267
- Freeman, L. M., Janecko, N., and Weese, S. J. (2013). Nutritional and microbial analysis of bully sticks and survey of opinions about pet treats. *Can. Vet. J.* 1, 50–54.
- Galvão, J. A., Yamatogi, R. S., Souza Junior, L. C. T., Joaquim, J. F., Rodrigues, M. V., Baldini, E. D., et al. (2015). Quality and safety of pet treats: assessment of the microbial safety and quality of pet treats. *J. Food Process Preserv.* 39, 1201–1205. doi: 10.1111/jfpp.12336
- Greb, A., and Puschner, B. (2018). Cannabinoid treats as adjunctive therapy for pets: gaps in our knowledge. *Toxicol. Commun.* 1, 10–14. doi: 10.1080/24734306.2018.1434470
- He, F., Holben, G., and De Godoy, M. R. C. (2020). Evaluation of selected categories of pet treats using *in vitro* assay and texture analysis. *Transl. Anim. Sci.* 4, txaa064. doi: 10.1093/tas/txaa064
- Heuberger, R., and Wakshlag, J. (2011). The relationship of feeding patterns and obesity in dogs. *J. Anim. Physiol. Anim. Nutr.* 95, 98–105. doi: 10.1111/jpn.2011.95.issue-1
- Hiby, E. F., Rooney, N. J., and Bradshaw, J. W. S. (2004). Dog training methods: their use, effectiveness and interaction with behaviour and welfare. *Anim. Welfare* 13, 63–69. doi: 10.1017/S0962728600026683
- Hooda, S., Ferreira, L. G., Latour, M. A., Bauer, L. L., Fahey, G. C., and Swanson, K. S. (2021). *In vitro* digestibility of expanded pork skin and rawhide chews, and digestion and metabolic characteristics of expanded pork skin chews in healthy adult dogs. *J. Anim. Sci.* 90, 4355–4361. doi: 10.2527/jas.2012-5333
- Jeusette, I. C., Mateo Román, A., Torre, C., Crusafont, J., Sánchez, N., Sánchez, M. C., et al. (2016). 24-hour evaluation of dental plaque bacteria and halitosis after consumption of a single placebo or dental treat by dogs. *Am. J. Vet. Res.* 77, 613–619. doi: 10.2460/ajvr.77.6.613
- Johnson, A. C., Miller, H. C., and Wynne, C. D. L. (2023). How dog behavior influences pet owner's perceptions of dog preference for dental chews. *Animals* 13, 1964. doi: 10.3390/ani13121964
- Julianna, T. O., Kata, V., Katalin, J. V., and Péter, P. (2020). Factors affecting canine obesity seem to be independent of the economic status of the country—A survey on Hungarian companion dogs. *Animals* 10, 1267. doi: 10.3390/ani10081267
- Keipińska-Pacelik, J., and Biel, W. (2021). Microbiological hazards in dry dog chews and feeds. *Animals* 11, 1–11. doi: 10.3390/ani11030631
- Keipińska-Pacelik, J., Biel, W., Mizielinska, M., and Iwański, R. (2023). Chemical composition and palatability of nutraceutical dog snacks. *Appl. Sci.* 13, 2806. doi: 10.3390/app13052806
- Kazimierska, K., Biel, W., Witkiewicz, R., Karakulska, J., and Stachurska, X. (2021). Evaluation of nutritional value and microbiological safety in commercial dog food. *Vet. Res. Commun.* 45, 111. doi: 10.1007/s11259-021-09791-6
- Kim, T. K., Kim, H. W., Lee, Y. Y., Jang, H. W., Kim, Y. B., and Choi, Y. S. (2020). Quality characteristics of duck jerky: combined effects of collagen and konjac. *Poult. Sci.* 99, 629–636. doi: 10.3382/ps/pez561
- Kour, H., Agrawal, R., Singh, R., and Pande, N. (2019). Prevalence and risk factors for obesity in dogs. *Pharma Innovation J.* 8, 709–713.
- Langlois, D. K., Smedley, R. C., Schall, W. D., and Kruger, J. M. (2013). Acquired proximal renal tubular dysfunction in 9 Labrador retrievers with copper-associated hepatitis, (2006–2012). *J. Vet. Intern. Med.* 27, 491–499. doi: 10.1111/jvim.12065
- Larsen, J. A., and Farcas, A. (2014). Nutrition of aging dogs. *Veterinary clinics of North America. Small Anim. Pract.* 44, 741–759. doi: 10.1016/j.cvsm.2014.03.003
- Leib, M. S., and Sartor, L. L. (2008). Esophageal foreign body obstruction caused by a dental chew treat in 31 dogs, (2000–2006). *J. Am. Vet. Med. Assoc.* 232, 1021–1025. doi: 10.2460/javma.232.7.1021
- Linder, D. E., and Freeman, L. M. (2010). Evaluation of calorie density and feeding directions for commercially available diets designed for weight loss in dogs and cats. *J. Am. Vet. Med. Assoc.* 236, 74. doi: 10.2460/javma.236.1.74
- Linder, D. E., Santiago, S., and Halbreich, E. D. (2021). Is there a correlation between dog obesity and human obesity? Preliminary findings of overweight status among dog owners and their dogs. *Front. Vet. Sci.* 8. doi: 10.3389/fvets.2021.654617
- Littman, M. P. (2017). Genetic basis for urinary tract diseases. *BSAVA Manual Canine Feline Nephrol. Urol.* 4, 172–184. doi: 10.22233/9781910443354.14
- Luño, I., Muniesa, A., Palacio, J., García-Belenguer, S., and Rosado, B. (2021). Detection of owner-perceived emotional eating in companion dogs: A regression modelling approach. *Vet. Rec.* 189, e63. doi: 10.1002/vetr.63
- Marchywka, M. J. (2022). *Experiences with a family of science based kitchen snacks for dogs. techreport MJM-2021-018, not institutional-ized, independent, 306 Charles Cox, Canton GA 30115.* Available online at: https://www.researchgate.net/publication/357517852_Experiences_with_a_Family_of_Science_Based_Kitchen_Snacks_for_Dogs.
- Marshall, W. G., Bockstahler, B. A., and Hulse, D. A. (2009). Carmichael, S. A review of osteoarthritis and obesity: Current understanding of the relationship and benefit of obesity treatment and prevention in the dog. *Vet. Comp. Orthop. Traumatol.* 22, 339–345. doi: 10.3415/Vcot-08-08-0069

- Montoya-Alonso, J. A., Bautista-Castaño, I., Peña, C., Suárez, L., Juste, M. C., and Tvarijonavičiute, A. (2017). Prevalence of canine obesity, obesity-related metabolic dysfunction, and relationship with owner obesity in an obesogenic region of Spain. *Front. Vet. Sci.* 25. doi: 10.3389/fvets.2017.00059
- 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. *Vet. Rec.* 24, 182(12):351. doi: 10.1136/vr.104489.16
- Morelli, G., Marchesini, G., Contiero, B., Fusi, E., Diez, M., and Ricci, R. (2020). A survey of dog owners' Attitudes toward treats. *J. Appl. Anim. Welf. Sci.* 23, 1–9. doi: 10.1080/10888705.2019.1579095
- Morgan, G., Saal, M., Corr, A., Jenkins, C., Chattaway, M. A., Pinchbeck, G., et al. (2023). Isolation of *Salmonella* species of public health concern from commonly fed dried meat dog treats. *Vet. Rec.* 192, e2642. doi: 10.1002/vetr.2642
- Morris, E. M., Kitts-Morgan, S. E., Spangler, D. M., McLeod, K. R., Suckow, M. A., and Harmon, D. L. (2022). Feeding treats containing can-nabidiol (CBD) did not alter canine immune response to immunization with a novel antigen. *Res. Vet. Sci.* 1, 143:13–143:19. doi: 10.1016/j.rvsc.2021.12.012
- Muñoz-Prieto, A., Cerón, J. J., Martínez-Subiela, S., Mrljak, V., and Tvarijonavičiute, A. (2020). Systematic review and meta-analysis of serum adiponectin measurements in the framework of dog obesity. *Animals* 10, 1650. doi: 10.3390/ani10091650
- Muñoz-Prieto, A., Rosenbaum Nielsen, L., Dąbrowski, R., Bjørnvad, C. R., Söder, J., Lamy, E., et al. (2018). European dog owner perceptions of obesity and factors associated with human and canine obesity. *Sci. Rep.* 8, 13353. doi: 10.1038/s41598-018-31532-0
- National Research Council (2006). *Nutrient Requirements of Dogs and Cats* (Washington, DC: The National Academies Press). doi: 10.17226/10668
- Nemser, S. M., Doran, T., Grabenstein, M., McConnell, T., McGrath, T., Pamboukian, R., et al. (2014). Investigation of listeria, salmonella, and toxigenic *Escherichia coli* in various pet foods. *Foodborne Pathog. Dis.* 11, 706–709. doi: 10.1089/fpd.2014.1748
- Nielson, S. A., Khosa, D. K., Clow, K. M., and Verbrugge, A. (2023). Dog caregivers' perceptions, motivations, and behaviours for feeding treats: A cross sectional study. *Prev. Vet. Med.* 217, 105971. doi: 10.1016/j.prevetmed.2023.105971
- Nybroe, S., Bjørnvad, C. R., Hansen, C. F. H., Andersen, T. S. L., and Kieler, I. N. (2022). Outcome of acquired fanconi syndrome associated with ingestion of jerky treats in 30 dogs. *Animals* 12, 3192. doi: 10.3390/ani12223192
- Oba, P. M., Carroll, M. Q., Alexander, C., Somrak, A. J., Keating, S. C. J., Sage, A. M., et al. (2021). Dental chews positively shift the oral microbiota of adult dogs. *J. Anim. Sci.* 99, 1–14. doi: 10.1093/jas/skab1100
- Oba, P. M., Hwisa, N., Huang, X., Cadwallader, K. R., and Swanson, K. S. (2022). Nutrient and Maillard reaction product concentrations of commercially available pet foods and treats. *J. Anim. Sci.* 100, skac305. doi: 10.1093/jas/skac305
- Perry, L. M., Shmalberg, J., Tanprasertsuk, J., Massey, D., Honaker, R. W., and Jha, A. R. (2020). Risk factors associated with canine over-weightness and obesity in an owner-reported survey. *BioRxiv*. doi: 10.1101/2020.01.06.896399
- Pinto, C. F. D., Lehr, W., Pignone, V. N., Chain, C. P., and Trevizan, L. (2020). Evaluation of teeth injuries in Beagle dogs caused by auto-claved beef bones used as a chewing item to remove dental calculus. *PLoS One* 15, e0228146. doi: 10.1371/journal.pone.022814
- Pitout, J. D. D., Reisbig, M. D., Mulvey, M., Chui, L., Louie, M., Crowe, L., et al. (2003). Association between handling of pet treats and infection with *Salmonella enterica* serotype newport expressing the AmpC beta-lactamase, CMY-. *J. Clin. Microbiol.* 10, 4578–4582. doi: 10.1128/JCM.41.10.4578-4582.2003
- Poppi, A. C. D. O., Oliveira, G. G., Cassetta, J., Goes, E. S. D. R., Gasparino, E., Marques, D. D. O., et al. (2023). Nutritional evaluation and palatability of pet biscuits for dogs. *Braz. J. Food Technol.* 26, e2022132. doi: 10.1590/1981-6723.13222
- Porsani, M. Y. H., Teixeira, F. A., Oliveira, V. V., Pedrinelli, V., Dias, R. A., German, A. J., et al. (2020). Prevalence of canine obesity in the city of São Paulo, Brazil. *Sci. Rep.* 10, 1–15. doi: 10.1038/s41598-020-70937-8
- Preet, G. S., Turkar, S., Gupta, S., and Kumar, S. (2021). Dog obesity: Epidemiology, risk factors, diagnosis and management: A review paper. *Pharma Innovation J.* SP-10, 698–705.
- Premrov Bajuk, B., Zrimšek, P., Kotnik, T., Leonardi, A., Krizaj, I., and Jakovac Strajn, B. (2021). Insect protein-based diet as potential risk of allergy in dogs. *Animals* 11, 1942. doi: 10.3390/ani11071942
- Presume, M. R., Soler, R. F., Chilenje, M. E., Sandoval, J. L., Avila, L. P., Garner, L. J., et al. (2022). Physicochemical parameters of raw pet food and dehydrated pet treats developed from beef processing co-products. *Animals* 12, 278. doi: 10.3390/ani12030278
- Pretlow, R. A., and Corbee, R. J. (2016). Similarities between obesity in pets and children: the addiction model. *Br. J. Nutr.* 116, 944–949. doi: 10.1017/S0007114516002774
- Quirynen, M., Teughels, W., Kinder Haake, S., and Newman, M. G. (2006). "Microbiology of periodontal diseases," in *Carranza's Clinical Periodontology, 10th ed.* Eds. M. G. Newman, H. H. Takei and P. R. Klokkevold (Saunders, St. Louis), 134–169.
- Rohlf, V. I., Toukhsati, S., Coleman, G. J., and Bennett, P. C. (2010). Dog obesity: can dog caregivers' (Owners') feeding and exercise in-tentions and behaviors be predicted from attitudes? *J. Appl. Anim. Welf. Sci.* 13, 213–236. doi: 10.1080/10888705.2010.483871
- Santos, M. K. R., Baptista, L. M. S., Hauptli, L., Lima, A. L. F., Netto, D. P., Dahlke, F., et al. (2021). Development of baked biscuits containing propolis and pomegranate for oral health in dogs. *Anim. Feed Sci. Technol.* 2080, 115056. doi: 10.1016/j.anifeeds.2021.115056
- Schaalo, S., Miklis, A., Schlüter, C., and Neiger, R. (2021). Acquired transient Fanconi syndrome after feeding jerky treats in dogs - A case series. *Tierarztl. Prax. Ausg. K. Kleintiere Heimtiere* 49, 300–308. doi: 10.1055/a-1514-6014
- Serhan, M., Hadid, M., Dimassi, H., Deghel, M., and Hassan, H. F. (2022). Microbiological safety of commercial canned and dry pet food products in Lebanon. *Front. Vet. Sci.* 9. doi: 10.3389/fvets.2022.995184
- Sheridan, R., Mirabile, J., and Hafler, K. (2014). Determination of six illegal antibiotics in chicken jerky dog treats. *J. Agric. Food Chem.* 62, 3690–3696. doi: 10.1021/jf405458m
- Soffer, N., Abuladze, T., Woolston, J., Li, M., Hanna, L. F., Heyse, S., et al. (2016). Bacteriophages safely reduce *Salmonella* contamination in pet food and raw pet food ingredients. *Bacteriophage* 6, e1220347. doi: 10.1080/21597081.2016.1220347
- Song, D. H., Choi, J. H., Choi, Y. S., Kim, H. W., Hwang, K. E., Kim, Y. J., et al. (2014). Effects of mechanically deboned chicken meat (MDCM) and collagen on the quality characteristics of semi-dried chicken jerky. *Korean J. Food Sci. Anim. Resour.* 34, 727. doi: 10.5851/kosfa.2014.34.6.727
- Sprinkle, D. (2019). *Current top trends in pet treats and chews*. Available online at: <https://www.petfoodindustry.com/articles/8573-current-top-trends-in-pet-treats-and-chews>.
- Stercova, E., Strakova, E., Tsponova, J., Grmelova, M., Janacova, K., and Muchova, K. (2022). Nutritional evaluation of commercial dry dog foods available on the Czech market. *J. Anim. Physiol. Anim. Nutr.* 106, 614–621. doi: 10.1111/jpn.13573
- Stern, A. W., and Martin, L. A. (2021). Microscopic examination of dog chews: correlation of histological findings to product labeling. *J. Histotechnol.* 44, 12–19. doi: 10.1080/01478885.2020.1775003
- Stokey, G. K. (2007). Soft rawhide reduces calculus formation in dogs. *J. Vet. Dent.* 26, 82–85. doi: 10.1177/089875640902600202
- Tochio, T., Makida, R., Fujii, T., Kadota, Y., Takahashi, M., Watanabe, A., et al. (2022). The bacteriostatic effect of erythritol on canine periodontal disease-related bacteria. *Polish J. Vet. Sci.* 25, 75–82. doi: 10.24425/pjvs.2022.140843
- Triyannanto, E., and Lee, K. T. (2016). Evaluation of honey and rice syrup as replacements for sorbitol in the production of restructured duck jerky. *Asian-Australas. J. Anim. Sci.* 29, 271–279. doi: 10.5713/ajas.15.0431
- Watanabe, K., Kijima, S., Nonaka, C., Matsukawa, Y., and Yamazoe, K. (2016). Inhibitory effect for proliferation of oral bacteria in dogs by tooth brushing and application of toothpaste. *J. Vet. Med. Sci.* 78, 1205–1208. doi: 10.1292/jvms.15-0277
- White, G. A., Hobson-West, P., Cobb, K., Craigon, J., Hammond, R., and Millar, K. M. (2011). Canine obesity: is there a difference between veterinarian and owner perception? *J. Small Anim. Pract.* 52, 622–626. doi: 10.1111/j.1748-5827.2011.01138.x
- 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. Vet. Med.* 132, 14–19. doi: 10.1016/j.prevetmed.2016.08.002
- Yabuki, A., Iwanaga, T., Giger, U., Sawa, M., Kohyama, M., and Yamato, O. (2017). Acquired Fanconi syndrome in two dogs following long-term consumption of pet jerky treats in Japan: case report. *J. Vet. Med. Sci.* 79, 818–821. doi: 10.1292/jvms.17-0043
- Yam, P. S., Naughton, G., Butowski, C. F., and Root, A. L. (2017). Inaccurate assessment of canine body condition score, bodyweight, and pet food labels: a potential cause of inaccurate feeding. *Vet. Sci.* 4, 30. doi: 10.3390/vetsci4020030
- Yarmolinsky, D. A., Zuker, C. S., and Ryba, N. J. P. (2009). Common sense about taste: from mammals to insects. *Cell* 139, 234–244. doi: 10.1016/j.cell.2009.10.001
- Yukawa, S., Uchida, I., Tamura, Y., Ohshima, S., and Hasegawa, T. (2019). Characterisation of antibiotic resistance of *Salmonella* isolated from dog treats in Japan. *Epidemiol. Infect.* 147, 1–6. doi: 10.1017/S0950268819000153
- Zhang, W., Cao, H., and Lin, L. (2022). "Analysis of the future development trend of the pet industry," in *Proceedings of the 2022 7th Inter-national Conference on Financial Innovation and Economic Development (ICFIED 2022)*, Advance in Economics, Business and Management Research, Vol. 648. 1682–1689.