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# Two Randomized Trials Demonstrate Lactic Acid Supplementation in Pet Food Inhibits Dental Plaque, Calculus, and Tooth Stain in Cats

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## Abstract

**Background:** Dental concerns are some of the most common health problems affecting companion animals. A variety of foods, treats, and chews comprising different mechanical and chemical technologies have been investigated as a means of promoting oral health. Here, we investigate the chemical technology, lactic acid added to a commercially available food, for its ability to inhibit dental plaque, calculus, and tooth stain accumulation in cats.

**Methods:** Two separate feeding trials assessed the utility of a nutritionally complete feline maintenance food supplemented with lactic acid to reduce oral substrate accumulation (dental plaque, calculus, and tooth stain) in cats. After a calibration study identified high and low dental plaque formers, 45 cats were randomized to 1 of 2 test groups (food with 1.2% lactic acid supplementation) or control (food without lactic acid supplementation) groups, stratified based on their calibration scores. Data were collected on a monthly basis for 3 months. The second study randomly assigned 24 cats to either the test or control groups for 1 year, with data collected at the 6- and 12-month time points.

**Results:** In the 3-month study, reductions in dental plaque, calculus, and tooth stain accumulations were observed at the 2-month assessment in both test groups compared with control ($P < .05$ for test group 2). The 1-year study showed that these reductions in oral substrate accumulation persisted through the 6- and 12-month time points ($P < .05$).

**Conclusions:** Taken together, these studies demonstrate that lactic acid supplemented at 1.2% in a feline maintenance food significantly inhibits oral substrate accumulation.


**Keywords**
feline, cat, lactic acid, teeth, dental plaque, dental calculus, gingivitis, tooth stain, periodontal disease, veterinary dentistry

## Introduction

Oral health concerns such as dental plaque accumulation and gingivitis are some of the most common diagnoses made by small animal veterinarians in the United States.[1-3] Dental plaque and calculus contribute to the evolution of gingivitis and, if left to accumulate and mature, may encourage periodontal disease progression, resulting in damage to the hard and soft tissues of the oral cavity, and the potential for systemic infection that may ultimately affect overall health.[4-11]

Dental foods, treats, and chews have been reported to attenuate dental plaque, calculus, and tooth stain accumulation in companion animals using a wide range of technologies, including both mechanical and chemical means.[12-17] Teethbrushing is one mechanical technology that has been extensively studied and shown to be effective.[18] However, adherence by pet owners to a regular schedule is often less than optimal[19] and may be particularly difficult with cats, which has prompted the development of specifically formulated dental diets that are easy for pet owners to use. These foods generally adjust the kibble size, shape, density, moisture levels, and fiber content to promote chewing and maximize contact with the tooth surface. Although these diets have been shown to be effective,[12,17] they limit food choice if the pet otherwise requires a specific diet (eg, weight control).

Chemical agents function by either reducing bacterial numbers (antimicrobials) or preventing the formation of calculus (calcium chelators) and can be used in conjunction with

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mechanical means. Toothpastes, rinsing solutions, and dental treats have been formulated with antimicrobials and antiseptics (eg, chlorhexidine). Pet foods and treats have included zinc salts, and grape, and green tea polyphenols, but published data on their effectiveness are lacking in companion animals. In addition, research has suggested that the mechanical properties of these products, rather than the antimicrobial properties, are responsible for the observed dental health benefits.[20,21] Calcium chelators, such as sodium hexametaphosphate, serve to reduce the amount of salivary calcium available to mineralize plaque into calculus and have been added to treats and foods. A study showed that the addition of sodium hexametaphosphate to a dry food or biscuits significantly reduced calculus formulation, but the addition of the crystal growth inhibitor, soluble pyrophosphate, resulted in only modest reductions in the formulation of calculus.[22]

Lactic acid is currently used as a preservative, not only for pet food but also cheeses, meats, dressings, and a variety of other human foodstuffs. It serves to reduce the risk of microcontamination, particularly *Salmonella*, *Pseudomonas fluorescens*, and *Yersinia enterocolitica*. Lactic acid is also known to be a good chelating agent that produces the soluble complex, calcium lactate, thereby sequestering the calcium that would otherwise be used to form calculus.[23] Thus, lactic acid supplementation in pet food may promote good oral health. The purpose of the present study was to investigate the effects of lactic acid for its ability to reduce oral substrate accumulation (dental plaque, calculus, and tooth stain) in cats.

## Materials and Methods

Two randomized feeding studies were conducted in which commercially available feline diets with (test) and without (control) 1.2% lactic acid supplementation were evaluated. The first study was run for 3 months, and data were collected on a monthly basis. The second study was run for 1 year, and data were collected at the 6- and 12-month time points.

### Animal Populations

Neutered male and spayed female adult (4-6 years old) cats were included in both the 3-month and 1-year studies. Cats were obtained from the colony maintained by Hill's Pet Nutrition. Cats had to be in overall good health, with all gradable teeth as determined by a veterinarian or veterinary technician. Exclusion criteria included the presence of severe periodontal disease or other oral abnormalities such as gingival hyperplasia or oral masses. Animals that would not eat the food, had been on antibiotics within the previous month, or had a systemic disease known to affect oral health or prevent an animal from participating on this study were also excluded. Criteria for removal from the study included excessive weight loss, food refusal, injury or illness, and resistance to participating in the required procedures.

Cats for each experiment were housed together in large, climate-controlled rooms with natural light and an opportunity for social interaction with their caretakers and other cats. All cats had access to water ad libitum and unlimited access to a nutritionally complete food, with the amount individualized to maintain body weight. All studies were conducted according to the guidelines of the Hill's animal welfare policy.[a] These protocols were accepted by the Hill's Institutional Animal Care and Use Committee.

### Three-Month Feeding Study

A calibration study was first conducted to identify high and low dental plaque formers within the group of 45 cats that would be participating in the 3-month dental efficacy study. This was done to ensure that high and low plaque formers were evenly distributed between the test and control groups. Each cat received a Comprehensive Oral Health Assessment and Treatment at baseline that comprised a professional dental prophylaxis under anesthesia to establish a baseline dental plaque score of 0. On day 28, all cats were anesthetized and dental plaque accumulation was quantified.

These 45 calibrated cats were then randomly assigned to 1 of 2 test (food with lactic acid supplementation at 1.2%) groups or the control (food without lactic acid supplementation) group, stratified equally among groups based on their calibration scores. The control food was a commercially available nutritionally complete cat food,[b] and the test food was that same food supplemented with 1.2% lactic acid. Each group contained 15 cats. Two test groups were included to provide more robust results. All cats were given a professional dental prophylaxis to establish a testing period baseline dental substrate score of 0. Over the testing period of 3 months, dental substrate accumulation was assessed every 28 days. A staggered start was used to accommodate the large numbers of cats.

### One-Year Feeding Study

Twenty-four cats (12 cats each) were randomly assigned to either the test (food with lactic acid supplementation at 1.2%) or control (food without lactic acid supplementation) groups. All cats received a professional dental prophylaxis under anesthesia at baseline to establish a testing period baseline dental substrate score of 0. At the 6- and 12-month time points, all cats were anesthetized and dental substrate accumulation was quantified. The control food was a commercially available nutritionally complete cat food,[c] but was different than that used in the 3-month study; the test food was that same food supplemented with 1.2% lactic acid.

## Dental Substrate Quantification

For both the 3-month and 1-year studies, the Logan/Boyce dental substrate quantification method[24] was used to assess oral substrate accumulation. This method has been cited numerous times, and the details will not be reproduced here. In short, dental plaque was disclosed with a 2% eosin solution, and the plaque coverage and dye intensity on the graded teeth were quantified and converted to a plaque score. Calculus coverage was assessed by drying the teeth with pressurized air to help visualize the calculus and then the tooth coverage is quantified and used as the calculus score. For tooth stain, separate coverage and intensity scores were quantified and then converted to a stain score. Tooth coverage was quantified using a 0 (none) to 4 (75%-100% coverage) scale, and where used, intensity used a 1 (light) to 3 (dark) scale. Dental plaque and tooth stain scores were the product of coverage and intensity. The teeth that were graded were the maxillary canine, third and fourth premolars, the mandibular canine, third and fourth premolars, and first molar. Whole mouth scores were used as the experimental unit and were calculated as the average of the individual tooth scores. Data were collected by a single expert grader.

## Statistics

Significance of the group differences was determined using a Student *t* test. *P* values of <.05 denoted a statistically significant difference between the test and control groups.

## Results

### Calibration and 3-Month Feeding Study

Table 1 presents the baseline calibration plaque scores for each of the 3 groups (2 test and 1 control group), documenting that the groups were well balanced with respect to plaque accumulation prior to study initiation.

Substrate accumulation scores are found in Table 2. At the first month assessment, test group 1 averaged 0.5% difference from the control group on plaque, 17.6% on calculus, and 20.6% on stain accumulations; none of these differences were statistically significant. Test group 2 averaged differences from the control group of 8.9% on plaque, 22.5% on calculus, and 26.5% on stain accumulation; these differences were also not statistically significant.

At the second month assessment, test group 1 demonstrated a 2.1% difference from the control group on plaque, 20.6% on calculus, and 19.7% on tooth stain accumulations, but these differences were not statistically significant. Test group 2 showed greater differences from the control group (19.4% on plaque, 35.3% on calculus, and 38.1% for tooth stain accumulation), and all 3 values were statistically significantly different.

For the third month of the study, differences from the control group for plaque, calculus, and tooth stain accumulation were 9.0%, 13.9%, and 18.8%, respectively, for test group 1, and 17.9%, 30.5%, and 31.4%, respectively, for test group 2. At this 3-month time point, the test group 1 differences were not statistically significant from the control group; however, for test group 2, the differences from the control group were statistically significant for calculus and stain, but not plaque.

**Table 1.** Baseline Calibration Study Dental Plaque Scores.

| Group | N | Mean Plaque Score | Standard Deviation |
|---|---|---|---|
| Control | 15 | 4.97 | 1.49 |
| Test group 1 | 15 | 4.91 | 1.50 |
| Test group 2 | 15 | 4.91 | 1.25 |

**Table 2.** Dental Substrate Accumulation for Each of the 3 Months of the 3-Month Study.

| | Mean (SD) | | |
|---|---|---|---|
| Substrate Accumulation Scores | Plaque | Calculus | Stain |
| 1 month | | | |
| Control group | 5.4 (1.9) | 2.3 (1.0) | 2.2 (1.0) |
| Test group 1 | 5.4 (1.5) | 1.9 (0.8) | 1.7 (0.8) |
| Difference,[a] % | 0.5 | 17.6 | 20.6 |
| *P* value[b] | 0.9633 | 0.2241 | 0.1980 |
| Lactic acid group 2 | 4.9 (2.0) | 1.8 (1.1) | 1.6 (1.1) |
| Difference,[a] % | 8.9 | 22.5 | 26.5 |
| *P* value[b] | 0.5022 | 0.1786 | 0.1478 |
| 2 months | | | |
| Control group | 8.0 (2.2) | 3.1 (1.3) | 3.0 (1.3) |
| Test group 1 | 7.8 (1.9) | 2.4 (1.2) | 2.5 (1.2) |
| Difference,[a] % | 2.1 | 20.6 | 19.7 |
| *P* value[b] | 0.8226 | 0.1695 | 0.1965 |
| Lactic acid group 2 | 6.4 (1.8) | 2.0 (1.0) | 1.9 (1.0) |
| Difference,[a] % | 19.4 | 35.3 | 38.1 |
| *P* value[b] | 0.0459 | 0.0169 | 0.0117 |
| 3 months | | | |
| Control group | 8.4 (2.9) | 3.4 (1.4) | 3.5 (1.5) |
| Test group 1 | 7.6 (1.9) | 2.9 (1.2) | 2.8 (1.3) |
| Difference,[a] % | 9.0 | 13.9 | 18.8 |
| *P* value[b] | 0.2049 | 0.1649 | 0.1126 |
| Lactic acid group 2 | 6.9 (2.7) | 2.3 (1.6) | 2.4 (1.7) |
| Difference,[a] % | 17.9 | 30.5 | 31.4 |
| *P* value[b] | 0.0787 | 0.0366 | 0.0388 |

Abbreviation: SD, standard deviation.
[a]Difference between control and test groups.
[b]*P* < .05 denotes significantly different from the control group.

### One-Year Feeding Study

Dental plaque, calculus, and tooth stain results at the 6- and 12-month time points are found in Table 3. At 6 months, a 30.9% difference between the test and control groups was observed in both the dental plague and calculus scores. Stain scores demonstrated a 36.6% difference between groups. All differences were statistically significant. At 12 months, dental plaque scores resulted in a 30.4% difference between the test and control groups. Calculus scores resulted in a 25.4% difference, and stain scores resulted in 33.1% difference between groups. All differences were statistically significant.

### Adverse Effects

For both the 3-month and 1-year studies, all cats completed all assessments without any apparent adverse effects. Cats readily

**Table 3.** Feline Logan/Boyce 6- and 12-Month Substrate Accumulation Data.

| | Mean (SD) | | |
|---|---|---|---|
| Substrate Accumulation Scores | Plaque | Calculus | Stain |
| 6 months | | | |
| Control group | 8.1 (1.8) | 3.7 (1.2) | 3.8 (1.5) |
| Test group | 5.6 (1.8) | 2.6 (1.2) | 2.4 (1.1) |
| Difference,[a] % | 30.9 | 30.9 | 36.6 |
| *P* value[b] | 0.0026 | 0.0271 | 0.0202 |
| 12 months | | | |
| Control group | 7.0 (2.2) | 4.5 (1.5) | 4.8 (2.0) |
| Test group | 4.9 (2.2) | 3.3 (1.1) | 3.2 (1.0) |
| Difference,[a] % | 30.4 | 25.4 | 33.1 |
| *P* value[b] | 0.0259 | 0.0455 | 0.0268 |

Abbreviation: SD, standard deviation.
[a]Difference between control and test groups.
[b]$P < .05$ denotes significantly different from the control group.

ate the foods, maintained weight, and were overall healthy throughout the studies.

## Discussion

These results show that lactic acid supplementation (1.2%) to a standard feline diet inhibits the formation of dental plaque, calculus, and tooth stain. Results were seen as early as 2 months and were sustained for 1 year. The cats readily ate the foods, without overt adverse effects.

Dental disease has been shown to affect almost 70% of domestic cats and about 75% of domestic dogs, making it the most common disease in pets.[3] In addition, there has been an increase in dental disease of about 23% over the past 10 years.[3] Preventing dental problems is of paramount concern because it can lead to tooth loss, bacterial infections and abscesses, and significant oral pain. Dental disease has also been shown to have systemic consequences. An increased risk of developing chronic kidney disease in both cats[25] and humans[26] has been shown to be associated with dental disease. Dental disease has also been shown to negatively affect markers of systemic inflammation (albumin, hemoglobin, hematocrit, and aspartate aminotransferase) in cats, and treatment of dental disease improves these indicators.[27] A large historical cohort (N = 118 592) observation study of dogs with periodontal disease found a significant correlation between severity of periodontal disease and subsequent risk of cardiovascular-related conditions, such as endocarditis and cardiomyopathy, as compared to age-matched controls.[28]

Thus, substantial efforts have been directed at reducing the risk of periodontal disease and its related sequelae. Researchers in the human domain have sought to discover and implement technologies that reduce oral substrate accumulation. A non-comprehensive list of plaque and calculus inhibitors include chlorhexidine,[29,30] polyphosphates,[31] mechanical cleansing,[32] triclosan,[33] cetylpyridinium chloride,[34] essential oils,[35] zinc,[36] and others. Several of these technologies have been successfully used in the veterinary oral health domain. Polyphosphates, such as hexametaphosphate, are being used to control tartar in pet foods and treats.[22] Mechanical cleansing to reduce oral substrate accumulation has been translated from tooth-brushing to pet foods and treats.[12] A zinc-containing gel was shown to decrease dental plaque growth and gingivitis in cats.[37] Small carboxylic acids have been shown to inhibit dental calculus formation in dogs and cats when fed a commercial pet food coated with fumaric acid, malic acid, or citric acid.[38] Topical application of calcium lactate was shown to significantly reduce calculus formation in humans.[39] Additionally, a rinse containing calcium lactate was shown to increase the concentration of calcium and phosphate found in plaque without increasing calculus formation.[40] However, the mechanism by which calcium lactate provides these benefits remains unclear, and to our knowledge, the present study is the first trial to examine whether these results are transferable to companion animals.

Lactic acid is a particularly attractive target of study as a chemical means of preventing oral substrate accumulation (dental plaque, calculus, and tooth stain) because of its intrinsic properties. It has been reported that the tooth surface pH of a healthy cat is 8.65,[41] and since the $pK_a$ of lactic acid is 3.86,[42] essentially all of the lactic acid is expected to be present in its ionized lactate form. Since lactic acid is known to be a good chelating agent,[23] we hypothesize that in the oral cavity, it forms a soluble complex (calcium lactate) with the free calcium found in food and saliva. Thereby, as the results of the present study suggest, the lactic acid in the pet food sequesters the calcium that would otherwise be used to form calculus. This is supported by studies in humans that have shown that the addition of calcium lactate to toothpastes and mouthwashes reduces calculus formation.[39,40]

One limitation of the study may have been the number of cats included. In the 3-month study, the test population was divided into 2 smaller groups. This may have contributed to the lack of statistical significance seen in test group 1 at the 2- and 3-month time points despite the large numerical differences from control. Also, 2 different foods were used in each of the studies: Hill's Science Diet Adult feline diet in the 3-month study and Hill's Science Diet Mature Adult feline diet in the 1-year study. Although this may have affected the results, the efficacy observed in both studies suggests that the effects of lactic acid are applicable over a range of foods, which should facilitate incorporation into commercial diets.

In conclusion, this is the first study to demonstrate that a standard feline diet supplemented with 1.2% lactic acid mixed into the food inhibits dental substrate accumulation (plaque, calculus, and stain) compared with a non–lactic acid-supplemented control food. Since lactic acid is currently a commonplace ingredient of some commercially available pet foods, serving as a preservative, supplementing at therapeutic levels should be readily achievable. This will assist in maintaining dental and overall health in a large population of pets.

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## Declaration of Conflicting Interests

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## Supplemental Material

Supplemental material for this article is available online.

## Materials

a. Hill's Commitment to Animal Welfare can be found at the following website: http://www.hillspet.com/our-company/commitment-to-animal-welfare.html#.
b. Hill's Science Diet Adult feline with and without 1.2% lactic acid supplementation.
c. Hill's Science Diet Mature Adult feline with and without 1.2% lactic acid supplementation.

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