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Review paper

Ascophyllum nodosum as a nutrient supporting oral health in dogs and cats: a review

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Abstract

Home dental care is a key element of periodontal therapy in veterinary patients. Among many strategies of passive home dental care there is a supplementation of animal diet with seaweed *Ascophyllum nodosum* which have been shown to reduce both calculus and plaque accumulation after oral administration in both dogs and cats. *Ascophyllum nodosum* contains numerous biologically active ingredients, including micro-elements, vitamins, and several other compounds, however the exact mechanism of its beneficial action remains unclear. The very first metabolomic data suggest that it could change the composition of dog saliva. Several products containing *Ascophyllum nodosum* had been assessed clinically according to standards and requirements provided by the Veterinary Oral Health Council. The conducted clinical trials in dogs and cats revealed that *Ascophyllum nodosum* exerts the strongest preventive action as powder, followed by dental bites and dry pet food. The data concerning its curative action are limited to one study in cats in which no beneficial action has been observed. Based on available clinical data it is recommended to administer *Ascophyllum nodosum* to dogs and cats after oral cavity prophylactic procedure to reduce the recurrence of plaque and calculus formation.

Keywords: *Ascophyllum nodosum*, oral health, oral hygiene, nutrient, dogs, cats

Introduction

Veterinary cases are frequently dental in nature, and many oral cavity pathologies remain undiagnosed (Niemiec et al. 2020). Recent years brought, however, the significant advances in the diagnosis, management and prevention of periodontal disease, which seems to be a key oral pathology affecting dogs and cats. Periodontal disease is defined as plaque induced disease of any part of periodontium. It is agreed that we can separate this condition into gingivitis and periodontitis. The first one

is inflammation of the gingiva, which is presumed reversible when the cause is removed. Periodontitis is inflammation of periodontal ligament and alveolar bone compartments and is diagnosed when loss of attachment is recognized (Harvey 2005). It is ultimately leading to irreversible destruction of the periodontium. (Kwon et al. 2021). Advances in veterinary stomatology have significantly improved animal dental patient care, although owner involvement and proper home care remains a key element of the effective management (Hale 2003, Niemiec 2021). All oral patholo-

gies influence food intake, and nutrition plays a key role in the treatment of dental diseases, with food delivering both preventive and curative compounds to the animal. Thus, proper nutrition is a basic element of the home care (Jank 2021). Moreover, food alters the pH, oral cavity microbiome, immune status and saliva mineral content. Changes in even one of these elements can positively influence disease outcome and management. Saliva-content modification has recently become an attractive therapeutic approach, allowing alteration of the oral cavity microbiome and reduction of dental calculus formation risk (Borah et al. 2014, Bringel et al. 2020). Saliva is a good environment for growth of many microorganisms, also plays an important role in plaque deposition. Interestingly, supplements containing the seaweed *Ascophyllum nodosum* have been shown to reduce both calculus and plaque deposition after oral administration in both dogs and cats (Gawor et al. 2018). Here, we summarize the results of studies that were organized and performed by the authors and evaluated preventive and curative uses of *Ascophyllum nodosum* in dogs and cats.

Home dental care

Home dental care is a key element of effective periodontal disease prevention and management (Ray et al. 2009). It should be considered as a basis of prophylactic (preventive) oral health program as well as key element of patient management after performing of professional dental cleaning and comprehensive oral health assessment and treatment (Niemi 2003). Prophylactic oral health program requires both regular dental examinations and regular oral home care (Niemi 2021). Without it, bacterial plaque forms on tooth surfaces within 24 h after its removal (Boyce et al. 1995, Wiggs and Lobprise 1997) and starts to calcify into calculus as soon as the following day (Tibbitts and Kasiwa 1970). Without regular home dental care, gingival infection and inflammation quickly recurs (Payne et al. 1975, Corba et al. 1986, Fiorellini et al. 2006, Debowes 2010). A human study revealed that professional cleanings are of little value without proper home care (Needleman et al. 2005). The primary goal of home plaque control is to limit or reduce the amount of plaque on the teeth (Perry 2006). This in turn decreases gingival inflammation and ultimately reduces periodontal disease. The sooner the home care is implemented the better outcome of preventive action and the lower risk of periodontal diseases onset is observed (DuPont 1998). This approach follows the concept of prevention of periodontal diseases (Pihlstrom et al. 2005).

Home plaque control could be active and passive. The gold standard is active home care but correctly

and consistently performed also passive care could be rewarding (Hale 2003). The most important methods of active home care are teeth brushing and rinsing of oral cavity. Passive methods include chewing behaviors using treats or specially formulated diets and supplements as well as recently introduced water additives. Active home care was reported to be the most effective on rostral teeth (incisors and canines) (Capik 2007). In contrast, passive chew-based home care was reported to be more effective on distal teeth (i.e. premolars and molars) (Bjone et al. 2007). Although numerous passive home care products are available, fewer have been scientifically proven to have any benefits.

Calculus controlling diets

Regular dry dog food has long been considered beneficial for oral health, and one study appeared to support this (Gawor et al. 2006). However, other studies reported dry food not to be superior to moist foods (Harvey et al. 1996). There are several specially formulated diets available that have been shown to decrease plaque and tartar build-up (Jensen et al. 1995). These products simply employ abrasives to scrape teeth and the individual kibbles of such therapeutic diets tend to be larger than those of standard pet food (Vrieling et al. 2005, Hennet et al. 2007). As such, the amount of chewing is increased as is the efficacy of abrasive action (Larsen 2010). Specifically arranged fiber within kibble likewise enables tartar removal from the surface of teeth during chewing. Only the latter has been scientifically proven to decrease gingivitis (Logan et al. 1999, Logan et al. 2001, Logan et al. 2002). Also, calcium chelators are used to further reduce formation of dental calculus (Lage et al. 1990, White et al. 2002, Liu et al. 2002, Hennet et al. 2007).

Dental treats and chews

The effectiveness of passive home care is directly related with availability of different treats and chews, the commonest of which are biscuit-style treats. Plain biscuits have not been shown to support the reduction of periodontal disease (Roudebush et al. 2005). A better choice appears to be biscuits coated with hydroxymethylphosphate (HMP), although there are reports both supporting and contesting their efficacy (Stokey et al. 1996, Logan et al. 2000).

In recent years, new edible treats brought to market have been reported to possess varying efficacy. The most prevalent of such products, as well as those proven most effective, are rask-type and rawhide chews (Lage et al. 1990, Hennet et al. 2006). These products work similarly to calculus control diets, with abrasives cleaning tooth

surfaces, but additionally may contain calcium chelators or other substances to further increase anti-plaque efficacy (Warric et al. 2001). The addition of chlorhexidine to rawhide chews further decreased plaque accumulation, but not the level of gingivitis (Brown and McGenity 2005). The literature gives at least few examples of new treats (Rawlings et al. 1998) which has been shown to reduce plaque and calculus formation control as well as decrease halitosis. This product contains an antiplaque agent (chlorhexidine) which may exert some protective effect on canine incisor teeth. Having in mind the mechanism of chlorhexidine action it could be concluded that the effectiveness of the product relies on antibacterial action. Among the most effective products of this type are also the rask and rawhide chews (Lage et al. 1990, Hennem et al. 2006).

Water additives

This is a relatively new area of home dental care; several products containing water additives are available on the market. While human studies reported the active ingredients to have some efficacy (Hamp and Emilson 1973, Chapek et al. 1995), there are currently minimal peer reviewed data supporting their use in controlling periodontal disease in veterinary patients. One product with xylitol was shown to decrease plaque and calculus formation (Clarke 2006). Although there have been concerns about potential negative systemic effects of the product (e.g. hypoglycemia and hepatic derangement) (Dunayer 2004, Dunayer 2006, Xia et al. 2009), the product was demonstrated to be safe at the available concentration (Anthony et al. 2011).

Food additives with beneficial dental action

Probiotics

Nitric oxide (NO) is an important inflammatory mediator which was shown to be increased in human periodontitis (Matejka et al. 1998, Lappin et al. 2000) and reduction of its production or inactivation may help to manage periodontal disease (Paquette et al. 2000). *Lactobacillus brevis* (*L. brevis*), a probiotic bacterium with high levels of arginine deiminase, was reported to decrease levels of inflammatory mediators involved in human patient periodontitis when applied topically (Della Riccia et al. 2007).

Fatty acids

1-Tetradecanol complex (1-TDC) B, an esterified medium-chain unsaturated fatty acid (MUFA) mixture

of several fatty acids, was reported to stop the progression of periodontal disease in two *in vivo* studies on New Zealand Rabbits; 1-TDC treatment resulted in a significant reduction in macroscopic periodontal inflammation, attachment, and bone loss (Hastruk et al. 2007, Hastruk et al. 2009). There is no available information of these compound activity in dogs and cats.

Ascophyllum nodosum as a dental food additive

The seaweed *Ascophyllum nodosum* has garnered increasing interest as a food additive that supports passive oral veterinary care. Powder, dental bite chews and dry diets containing this additive have all garnered Veterinary Oral Health Council (VOHC) seal of acceptance as products with scientifically proven plaque control capabilities in dogs and cats. *Ascophyllum nodosum* has thus been suggested as vital to the stimulation of oral immunity and changes in saliva content (Gawor et al. 2018, Gawor et al. 2021).

The origin of *Ascophyllum nodosum*

Ascophyllum nodosum, commonly known as rockweed, is abundantly distributed throughout the northwest coast of Europe and the northeastern coast of North America (Moreire et al. 2017). It is the most widely researched brown, inter-tidal seaweed, used as a source of industrial and commercial plant biostimulants. Various commercial *Ascophyllum nodosum* extracts have been demonstrated to improve plant growth, mitigate abiotic and biotic stresses as well as improve plant immunity via regulation of biochemical processes (Shukla et al. 2019). The bioactivity and composition of *Ascophyllum nodosum*-containing biostimulants are not identical and are indeed dependent on extraction methods employed (Goni et al. 2018).

Processing of *Ascophyllum nodosum* includes the harvesting of fresh seaweed as well as its subsequent receiving, cutting, removal of stones and shells, milling, drying, repeat milling and sifting. After those steps, the product is packed, stored and shipped. Throughout the aforementioned process, numerous quality control measures are in place to reduce the impact of pollution, oil spills, microorganism contamination, metal and other foreign particles.

Chemical composition of *Ascophyllum nodosum*

The *Ascophyllum nodosum* studied by the authors of this review is available commercially and its production is a patented technology. According to the manufacturer, this *Ascophyllum nodosum* is a 100% organic kelp naturally harvested from select locations off the Scandinavian coastline. Being exposed to extreme environmen-

Table 1. The chemical composition of *Ascophyllum nodosum*.

Constituent	Level
Sulphated uronic acids (esterified form)	20–26%
Fucoidin	5-15%
Mannitol	5–8%
Laminaran	2-5%
Chloride	3-4%
Sodium	3-4%
Sulphur	2.5-3.5%
Potassium	2-3%
Calcium	1-3%
Magnesium	0.5-1%
Phosphorus	0.1-0.15%
Iodine	700-1200 mg/kg
Ascorbic acid	500-2000mg/kg
Iron	150-1000 mg/kg
Tocopherols	150-300 mg/kg
Zinc	20-200mg/kg
Bromide	40–100 mg/kg
Carotenes	30-60mg/kg
Barium	15-50 mg/kg
Manganese	10-50 mg/kg
Niacin	10-30 mg/kg
Vitamin K	10 mg/kg
Riboflavin	5-10 mg/kg
Copper	1-10 mg/kg
Cobalt	1-10 mg/kg
Nickel	2-5mg/kg
Thiamine	1-5 mg/kg
Vanadium	1.5-3 mg/kg
Molybdenum	0.3-1 mg/kg
Folic acid	0.2-1 mg/kg
Biotin	0.1-0.4 mg/kg
Vitamin B12	0.004 mg/kg

tal conditions and specially processed (Patent 2000), the seaweed naturally achieves maximum efficacy. This food additive contains water (8-14%), proteins (5-8%), fat (2-4%) and polysaccharides (45-60%) of which fucoidanes, mannitol and alginate are dominant, as well as vitamins and minerals. The chemical composition of *Ascophyllum nodosum* is presented in Table 1.

The protective mechanism of *Ascophyllum nodosum*

The beneficial effects of *Ascophyllum nodosum* in dental patients have been reported several years previously. In late 1990s the first data were published showing the ability of diet containing a brown alga (*Ascophyllum nodosum*) to reduce deposits formation in patients with heavy calculus. In 2014 *in vivo* human studies showed

that daily supplementation of *Ascophyllum nodosum*, combined with every day oral care highly significant reduced calculus formation. Moreover, the calculus was less well bonded to the tooth and showed reduced hardness. The reduction on plaque formation and gingival bleeding was also observed. Similar calculus-reducing effect was also observed in beagle dogs (van Dijken et al. 2015). Unfortunately, the exact mechanism of these effects remains unclear. Clues may be found in the influence of algal ingredients resulting in crystal growth inhibition, pellicle desorption, breakdown of plaque matrix or control of endogenous crystal growth inhibitors. Polysaccharides and proteins compose over 50% of *Ascophyllum nodosum* and are absorbed after gastrointestinal enzymatic breakdown or fermentation as monosaccharides, short chain fatty acids and bioactive

Table 2. The characteristics of clinical studies mentioned in the article conducted using *Ascophyllum nodosum*-containing products in dogs and cats in order to improve their oral health.

Number of study	Target species	Type of product used	Type of AN usage	Type of the study	Length of the study	Number of trials	Number of animals	Reference
1a	dogs	dental bites (Plaque Off Dental Bites, Sweden Care, Sweden)	preventive	double-blind, randomized, placebo-controlled uni-center	30 days	2	60	Gawor et al. 2018
1b	dogs	dental bites (Plaque Off Dental Bites, Sweden Care, Sweden)	preventive	double-blind, randomized, placebo-controlled uni-center	90 days	1	60	Gawor et al., 2018
2	dogs	powdered <i>Ascophyllum nodosum</i> (Plaque Off, Sweden Care, Sweden)	preventive	double-blind, randomized, placebo-controlled uni-center	30 days	2	60	VOHC report, 2018
3	cats	powdered <i>Ascophyllum nodosum</i> (Plaque Off, Sweden Care, Sweden)	preventive	double-blind, randomized, placebo-controlled uni-center	30 days	2	60	VOHC report, 2020a
4	cats	powdered <i>Ascophyllum nodosum</i> (Plaque Off, Sweden Care, Sweden)	curative	double-blind, randomized, placebo-controlled uni-center	30 days	1	30	Gawor and Jank, 2019
5	dogs	dry pet food containing <i>Ascophyllum nodosum</i> (Canagan, UK)	preventive	controlled, randomized, uni-center	30 days	2	60	VOHC Report 2020b

peptides to the teeth via saliva and crevicular fluid. These compounds have a high affinity to tooth surfaces and compete for the same adsorption sites (i.e. calcium ions) on hydroxyapatite as salivary acidic proteins and thus block nucleation and crystallization sites (van Dijken et al. 2015). In order to evaluate the potential systemic action of *Ascophyllum nodosum* and its ability to modify saliva composition, our team analyzed the salivary metabolome in dogs administered *Ascophyllum nodosum*. This study identified clear changes in the dog salivary metabolome after 30 days of supplementation; alterations were completely different as compared to dogs that were administered a placebo treatment during the same period. After 30 days of *A. nodosum* supplementation it was detected in dog saliva an ingredient derived from algae, known as isofucosterol, which is produced solely by algae. The supplementation of dogs' diets with *A. nodosum* also resulted in upregulation of the selenoamino acid metabolism pathway, which was probably associated with the observed significant change in selenomethionine Se-oxide level. The numbers of metabolites belonging to androgen and estrogen biosynthesis and metabolism pathways were also of interest, as was the disappearance of prostaglandin formation from the arachidonate pathway after 30 days of *A. nodosum* supplementation. The lack of dehydroepi-

androsterone and testosterone was of particular interest since in humans increased dehydroepiandrosterone is correlated with periodontitis level. The absence of some metabolites in the saliva of dogs on day 30 of supplementation suggests that *Ascophyllum nodosum* inhibits pathways that enhance plaque or calculus formation, although the exact mechanisms remain unclear and warrant further study (Gawor et al. 2021).

Nutritional products used for evaluation of *Ascophyllum nodosum* efficacy

The *Ascophyllum nodosum* is an active nutritional agent available in several products and formulations including a powdered form (ProDen Plaque Off), as edible dental treats (Dental Bites), as an ingredient of a dietary prescription (Canagan, UK) or other treats. The authors conducted several clinical trials evaluating *Ascophyllum nodosum* in three different nutritional forms, namely: edible treats, powder and dry pet food. Edible treats consisted of veggie cereal mix (74.95%), *Ascophyllum nodosum* (25%) and natural tocopherols (0.05%). The product was compared to placebo treats which consisted of veggie cereal mix (99.95%) and natural tocopherols (0.05%). Dogs were administered *Ascophyllum nodosum* at a dose

Table 3. The percentage of improvement of the gingival bleeding index (GBI), plaque index (PI), calculus index (CI), oral health index (OHI) and volatile sulfur compound (VSC) concentration in dogs and cats administered *Ascophyllum nodosum* as a nutritional additive in various forms.

Study no	Study duration	Species	Product	Trial	GBI change [%]	PI change [%]	CI change [%]	Sum of GBI+PI+CI change	OHI change [%]	VSC change [%]
1a	30 days	dogs	Dental bites	1	58.8	37.2	30.8	126.8	24.6	55.7
				2	71.4	42.0	45.7	159.1	32.1	46.6
1b	90 days	dogs	Dental bites	1	46.7	22.1	38.4	107.2	21.9	46.4
2	30 days	dogs	Powder	1	59.6	32.5	28.7	120.8	3.4	
				2	74.8	31.8	42.6	149.2	20.4	
3	30 days	cats	Powder	1	73.2	34.0	57.9	165.1	16.2	
				2	48.1	39.3	56.4	143.8	9.6	
4	30 days	cats	Powder	1	20.6	3.1	8.9	32.6	12.9	
5	30 days	dogs	Dry diet	1	70.0	23.9	31.4	125.3	40.6	
				2	52.9	22.4	30.1	105.4	25.0	

of 33-62.5 mg/kg. A 100% powdered form of *Ascophyllum nodosum* was also compared to placebo which consisted of 100% microcrystalline cellulose. In these trials, 5 kg body weight cats were administered 33-66 mg/kg b.w. of *Ascophyllum nodosum* whereas 10 kg b.w. dogs were administered 33 mg/kg b.w.. The third form of *Ascophyllum nodosum* studied was that added to commercial dry dog food. One kg of this food contained 2500 mg of *Ascophyllum nodosum* which resulted in a daily *Ascophyllum nodosum* intake of 27-50 mg/kg b.w. depending on body weight and animal activity level.

The characteristics of the studies conducted by the authors on *Ascophyllum nodosum*-containing products is presented in Table 2. All studies were conducted by a clinical team under the supervision of a board-certified veterinary dentistry specialist. These studies were designed according to requirements stipulated by the Veterinary Oral Health Council (VOHC) (www.vohc.org). VOHC recognizes products that meet pre-set standards of plaque and calculus (tartar) retardation in dogs and cats. Any manufacturer can organize its dental products assessment according to evidence-based medicine (EBM) criteria to evaluate effectiveness of oral home care (Roudebush et al. 2005). One review article published in 2005 systematically analyzed oral care products from different categories and concluded the importance and need of high grades of evidence for the assessing efficacy of dental care products (Roudebush et al. 2005). Research performed by the authors are within quality grade I: evidence obtained from properly designed, randomized, controlled studies done in the target species.

The data coming from two trials conducted according to VOHC protocols are then reviewed by the American Veterinary Dental College and could be awarded the VOHC Seal of Acceptance. VOHC trial protocols

include detailed requirements concerning pre-trial screening, groups required, minimal trial period, number of group and randomization, required group differences, randomization and statistical analysis, population and source of animals, use the product during the trial, control diet and scoring. The scoring part is of special importance because VOHC gives detailed indications concerning training of scorers, teeth to be scored, order of presentation for scoring, timing of final scoring episode, division of crown into segments, scoring plaque, scoring tartar, gingivitis scores as well as all additional information. The minimum difference required between "mouth mean scores" (mean of all scored teeth for all animals in the group) comparing the test group with the negative control group is 15% reduction in the plaque or tartar score in each trial and 20% in the mean of the two required trials, with a statistically significant difference ($p < 0.05$) in each trial (www.vohc.org).

In all conducted trials VOHC requirements were fulfilled in following way: dogs with mild to moderate gingivitis (< 2 GI, Gingivitis Index) (Logan and Boyce 1994) PD0 to maximum PD2 (www.adv.org); all teeth were required to be present with no signs of severe periodontal disease as defined by the VOHC. Non-gingival inflammation, oral ulceration and laceration on day zero and on final scoring were excluding criteria. Incomplete eruption, malocclusion, or missing teeth deemed strategic by the VOHC were also excluding criteria. Due to *Ascophyllum nodosum* containing high levels of iodine, hyperthyroidism was also an exclusion criterion. The VOHC model of assessing effectiveness was based on differential scoring of dental deposit accumulation on teeth professionally cleaned on day zero after a minimum of one month of daily product and standardized dry food administration. Oral health indices were

utilized and applied by an experienced scorer; the gingival bleeding (GBI) (Loe 1967), plaque (PI) (Hennet et al. 2006) and calculus (CI) indices were utilized (Logan and Boyce 1994). Additional assessment criteria included in all trials were the Oral Health Index (OHI) (Gawor et al. 2006) and in the first study the volatile sulphur compound (VSC) concentration (Milella 2015) (measured using Orastrip). The methodology of all conducted trials was not only in accordance with VOHC requirements but was also reviewed and accepted by reviewers of our paper published in 2018 (Gawor et al. 2018). The results of trials, expressed as % of improvement versus the control group, are presented in Table 3.

Summary of clinical data

As it was mentioned earlier, dental products are awarded the VOHC Seal of Acceptance following review of trials results when the mean difference in plaque and calculus reduction from two required trials compared with control group is greater than 20%. Duration of the VOHC trial is also defined and includes the wash out period to adapt to standardized dry diet to be fed. All trials evaluating products containing *Ascophyllum nodosum* resulted in receiving the VOHC seal of acceptance and the records are archived in the VOHC database. Despite there are differences in obtained results the protocols and conclusions remained the same.

All dogs and cats participated in the trials were client-owned and in every case they had to accept the same diet which was fed dry and receiving water 'ad libitum'. All of the observed patients did not receive any oral hygienic means at the time of study. In general, we recruited the dogs from these owners who for different reasons would not provide active homecare and who seek for easy affordable passive methods. Possibly the differences could come from the fact that there were different breeds and sizes participated in trials with differences in dentition and occlusion.

The results obtained allow for presentation of several observations concerning the following variables: research model, duration of observation, species, PI, CI, GBI, OHI, VSC concentration, and finally, different products. Due to differences among the studied populations the results were separately analyzed.

For clean teeth model research (preventive usage) and 30 days' trial duration, nutritional supplementation of *Ascophyllum nodosum* reduced plaque and calculus accumulation in observed populations. This reduction was significant when compared to control groups and within 34-39.3% (PI) and 56.4-57.9% (CI) in cats, respectively; as well as 22.4-42% (PI) and 28.7-45.7%

(CI) in dogs, respectively (Gawor et al. 2018, VOHC Report 2020a).

Nutritional supplementation of *Ascophyllum nodosum* for 90 days in dogs for clean teeth model research (preventive usage) reduced plaque and tartar accumulation in observed populations. This reduction was significant when compared to control groups and equaled 22.1% (PI) and 38.4 (CI), respectively (Gawor et al. 2018).

In dogs, the greatest reduction of plaque formation in 30-day trials was observed for edible treats (42%) and the lowest for dry food (22.4%). Interestingly, plaque reduction after 90 days of edible treat administration was only 22.1% (Gawor et al. 2018, VOHC report 2020b). Cats were only evaluated with powder formulation; we were thus unable to compare different product forms.

The group of cats with the uncleaned teeth model (curative usage) showed reduction of plaque and calculus formation after 30 days of observation at 3.1 and 8.8%, respectively (Gawor and Jank 2019). These findings suggest that the curative effects of *Ascophyllum nodosum* supplementation are not remarkable, and this product should be rather a part of home care strategy following professional dental cleaning (preventive usage) than an exclusive treatment modality. Some improvement was observed, however in the authors' opinion changes were not sufficient to recommend *Ascophyllum nodosum* as the only solution for reduction of dental deposit accumulation.

The authors were able to perform a limited number of tests for the VSC concentration only in Study 1, however after both 30- and 90-day observation periods the reduction was significant at 46.6-55.7% and 46.4%, respectively (Gawor et al. 2018). As VSC concentrations play an important role in the development of periodontal tissue destruction associated with periodontal diseases, *Ascophyllum nodosum* appears particularly beneficial in long-term reduction of concentrations.

Trials were conducted in the same manner and over the same timeframe in both dogs and cats so they allowed for characterization of the preventive action of powdered *Ascophyllum nodosum* formulation in both species. Results were more marked in cats than in dogs in terms of PI (34-39.3% versus 31.8-32.5%) and CI (56.4-57.9% versus 28.7-42.6%) (VOHC Report 2018, VOHC Report 2020a).

The GBI characterizes safety of the trials and expected situation is when the GBI does not increase with time. Differences between treated and control groups revealed significantly lower GBI values in treated animals; this value was within 48.1-73.2% in cats and 46.7-74.8% in dogs regardless of trial duration and form of *Ascophyllum nodosum* administered, but only for the clean tooth model (preventive usage) (Gawor et al. 2018, VOHC

Report 2020a). Reduction of GBI in the non-cleaned teeth model (curative usage) was less significant and in cats reached 20.6%.

To compare product efficacies the authors summarized changes in GBI, PI and CI and calculated the mean of the two trials. The greatest result (greater sum) was noted in the 30-day trial in cats administered *Ascophyllum nodosum* powder (154.45) followed by dogs administered *Ascophyllum nodosum*-containing edible treats (142.95), dogs administered powdered *Ascophyllum nodosum* (135) and dogs administered dry food (115.35). For the 90-day trial with edible treat administration this value was 107.2. The lowest obtained value was in cats in the non-cleaned teeth model (curative usage): 32.6 (VOHC Report 2018, Gawor et al. 2018, VOHC Report 2020a, VOHC Report 2020b.).

The OHI was designed to assess large populations of animals. This parameter is very easy to apply, however it is not very precise. Differences between days zero and 30 or 90 revealed a remarkable improvement in animals receiving *Ascophyllum nodosum* supplementation.

Conclusions

Ascophyllum nodosum is used as a nutritional additive and plays a positive role in the dental home care strategy in dogs and cats. All studied products were found to significantly reduce plaque formation and calculus deposition, and were awarded the VOHC seal of acceptance. The association between plaque formation and calculus reduction and the improvement of oral health was the highest during the first 30 days of the treatment and less remarkable thereafter. Although the exact mechanism of its action is still unclear the results of our studies suggest that brown algae change the composition of saliva in supplemented dogs by inhibition or turning off some pathways that could enhance plaque or calculus development (Gawor et al. 2021). While the preventive action of *Ascophyllum nodosum* on dental deposit accumulation is significant, the curative action of the kelp on existing plaque and calculus is insufficient. *Ascophyllum nodosum* supplementation has been found to exert beneficial effects on oral health as measured by GBI and OHI; however, none of the studies assessed oral health parameters such as periodontal probing or radiographic alveolar bone appearance accurately. Finally, the form in which *Ascophyllum nodosum* is administered greatly influences its efficacy; greatest efficacy values were found in animals treated with powder followed by those treated with edible treats and dry diets. *Ascophyllum nodosum*, a compound representing passive homecare that plays a role complementa-

ry to active metabolites, appears to be a valuable addition to the management of animal dental care. As an additional argument supporting recommendation of the mentioned products is the fact that all of them received the VOHC seal of acceptance. Daily use of products that have been awarded the VOHC seal will help to keep the pet's teeth clean and the gum tissues as well as alveolar bone healthier.

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